# 2019 Illinois Statewide Technical Reference Manual for Energy Efficiency

# Version 7.0

## Volume 1: Overview and User Guide

**FINAL**

**September 28, 2018**

**Effective:**

**January 1, 2019**

# Table of Contents

**Tables and Figures**

# 1 Purpose of the TRM

The purpose of the Illinois Statewide Technical Reference Manual (TRM) is to provide a transparent and consistent basis for calculating energy (electric kilowatt-hours (kWh) and natural gas therms) and capacity (electric kilowatts (kW)) savings generated by the State of Illinois' energy efficiency programs[1] which are administered by the state's largest electric and gas Utilities[2] (collectively, Program Administrators or the Utilities).

The TRM is a technical document that is filed with the Illinois Commerce Commission (Commission or ICC) and is intended to fulfill a series of objectives, including:

- "Serve as a common reference document for all… stakeholders, [Program Administrators], and the Commission, so as to provide transparency to all parties regarding savings assumptions and calculations and the underlying sources of those assumptions and calculations.
- Support the calculation of the Illinois Total Resource Cost test[3] ("TRC"), as well as other cost-benefit tests in support of program design, evaluation and regulatory compliance. Actual cost-benefit calculations and the calculation of avoided costs will not be part of this TRM.
- Identify gaps in robust, primary data for Illinois, that can be addressed via evaluation efforts and/or other targeted end-use studies.
- [Provide] a process for periodically updating and maintaining records, and preserve a clear record of what deemed parameters are/were in effect at what times to facilitate evaluation and data accuracy reviews.
- …[S]upport coincident peak capacity (for electric) savings estimates and calculations for electric utilities in a manner consistent with the methodologies employed by the utility's Regional Transmission Organization ("RTO"), as well as those necessary for statewide Illinois tracking of coincident peak capacity impacts."[4]

## 1.1 Acknowledgments

This document was created through collaboration amongst the members of the Illinois Energy Efficiency Stakeholder Advisory Group (SAG). The SAG is an open forum where interested parties may participate in the evolution of Illinois' energy efficiency programs. Parties wishing to participate in the SAG process may do so by visiting http://www.ilsag.info/questions.html and contacting the Independent Facilitator at Annette.Beitel@FutEE.biz. Parties wishing to participate in the Technical Advisory Committee (TAC), a subcommittee of the SAG, may do so by contacting the TRM Administrator at iltrmadministrator@veic.org.

| SAG Stakeholders[5] |
|---|
| Ameren Illinois Company (Ameren) |
| Citizen's Utility Board (CUB) |
| City of Chicago |
| Commonwealth Edison Company (ComEd) |
| Elevate Energy |
| Energy Resources Center at the University of Illinois, Chicago (ERC) |
| Environment IL |
| Environmental Law and Policy Center (ELPC) |
| Future Energy Enterprises LLC |
| Illinois Attorney General's Office (AG) |
| Illinois Commerce Commission Staff (ICC Staff) |

[1] 220 ILCS 5/8-103B and 220 ILCS 5/8-104.

[2] The Program Administrators include: Ameren Illinois, ComEd, Peoples Gas, North Shore Gas, and Nicor Gas (collectively, the Utilities).

[3] The Illinois TRC test is defined in 220 ILCS 5/8-104(b) and 20 ILCS 3855/1-10.

[4] Illinois Statewide Technical Reference Manual Request for Proposals, August 22, 2011, pages 3-4, http://ilsag.org/yahoo_site_admin/assets/docs/TRM_RFP_Final_part_1.230214520.pdf

[5] Being an open forum, this list of SAG stakeholders and participants may change at any time.

| SAG Stakeholders[5] |
|---|
| Illinois Department of Commerce and Economic Opportunity (DCEO) |
| Independent Evaluators (ADM, Cadmus, Itron, Navigant) |
| Metropolitan Mayor's Caucus (MMC) |
| Midwest Energy Efficiency Association (MEEA) |
| Natural Resources Defense Council (NRDC) |
| Nicor Gas |
| Peoples Gas and North Shore Gas |

**Table 1.1: Document Revision History**

| Document Title | Applicable to PY Beginning |
|---|---|
| Illinois_Statewide_TRM_Effective_060112_Version_1.0_091412_Clean.doc | 6/1/12 |
| Illinois_Statewide_TRM_Effective_060113_Version_2.0_060713_Clean.docx | 6/1/13 |
| Illinois_Statewide_TRM_Effective_060114_Version_3.0_022414_Clean.docx | 6/1/14 |
| Illinois_Statewide_TRM_Effective_060115_Final_022415_Clean.docx | 6/1/15 |
| IL-TRM_Effective_060116_v5.0_Vol_1_Overview_021116_Final<br>IL-TRM_Effective_060116_v5.0_Vol_2_C_and_I_021116_Final<br>IL-TRM_Effective_060116_v5.0_Vol_3_Res_021116_Final<br>IL-TRM_Effective_060116_v5.0_Vol_4_X-Cutting_Measures_and_Attach._021116_Final | 6/1/16 |
| IL-TRM_Effective_010118_v6.0_Vol_1_Overview_020817_Final<br>IL-TRM_Effective_010118_v6.0_Vol_2_C_and_I_020817_Final<br>IL-TRM_Effective_010118_v6.0_Vol_3_Res_020817_Final<br>IL-TRM_Effective_010118_v6.0_Vol_4_X-Cutting_Measures_and_Attach_020817_Final | 1/1/18 |
| IL-TRM_Effective_010119_v7.0_Vol_1_Overview_092818_Final<br>IL-TRM_Effective_010119_v7.0_Vol_2_C_and_I_092818_Final<br>IL-TRM_Effective_010119_v7.0_Vol_3_Res_092818_Final<br>IL-TRM_Effective_010119_v7.0_Vol_4_X-Cutting_Measures_and_Attach_092818_Final | 1/1/19 |

## 1.2 Summary of Measure Revisions

The following tables summarize the evolution of measures that are new, revised or errata. This version of the TRM contains 143 measure-level changes as described in the following table.

**Table 1.2: Summary of Measure Level Changes**

| Change Type | # Changes |
|---|---|
| Errata | 13 |
| Revision | 113 |
| New Measure | 17 |
| Total Changes | 143 |

The 'Change Type' column indicates what kind of change each measure has gone through. Specifically, when a measure error was identified and the TAC process resulted in a consensus, the measure is identified here as an 'Errata'. In these instances the measure code indicates that a new version of the measure has been published, and that the effective date of the measure dates back to January 1$^{st}$, 2018. Measures that are identified as 'Revised' were included in the sixth edition of the TRM, and have been updated for this edition of the TRM. Both 'Revised' and 'New Measure(s)' have an effective date of January 1$^{st}$, 2019.

The following table provides an overview of the 143 measure-level changes that are included in this version of the TRM.

**Table 1.3: Summary of Measure Revisions**

| Volume | End Use | Measure Name | Measure Code | Change Type | Explanation | Impact on Savings |
|---|---|---|---|---|---|---|
| Volume 1: Overview | N/A | N/A | N/A | Revision | Edits to 1.4 Development Process – docket information<br>Section 3.4 – Addition of mobile home<br>Section 3.5 – Addition of loadshapes from primary research studies. Edits or additions of the following loadshape values:<br>Residential Indoor Lighting<br>Residential Holiday String Lighting<br>Commercial Indoor Lighting<br>Grocery/Conv. Store Indoor Lighting<br>Health Indoor Lighting<br>Office Indoor Lighting<br>Retail Indoor Lighting<br>Warehouse Indoor Lighting<br>Education Indoor Lighting<br>Commercial Outdoor Lighting<br>Commercial Clothes Washer<br><br>Reference to new Excel file mapping Illinois zip codes to Heating and Cooling Degree-day zones. | N/A |
| Volume 2: C&I | 4,1 Agricultural | 4.1.1 Engine Block Timer for Agricultural Equipment | CI-AGE-EBLT-V02-190101 | Revision | Assumptions adjusted from Vermont basis to Illinois climate.<br>Variables defined. | N/A |
| | | 4.1.2 High Volume Low Speed Fans | CI-AGE-HVSF-V02-190101 | Revision | Minor typo fixes | N/A |
| | | 4.1.3 High Speed Fans | CI-AGE-HSF_-V02-190101 | Revision | Minor typo fixes | N/A |
| | | 4.1.4 Livestock Waterer | CI-AGE-LSW1-V02-190101 | Revision | Minor typo fixes.<br>Additions to measure and coincidence factor description. | N/A |
| | 4.2 Food Service Equipment | 4.2.2 Commercial Solid and Glass Door Refrigerators and Freezers | CI-FSE-CSDO-V02-190101 | Revision | Updated based on new ENERGY STAR and Federal Standard<br>Updated measure cost. | Dependent on inputs |
| | | 4.2.3 Commercial Steam Cooker | CI-FSE-STMC-V05-190101 | Revision | Addition of secondary kWh savings for water supply | Increase |
| | | 4.2.6 ENERGY STAR Dishwasher | CI-FSE-ESDW-V04-190101 | Revision | Addition of secondary kWh savings for water supply and waste water treatment<br>Update to conversion factor | Increase |
| | | 4.2.7 ENERGY STAR | CI-FSE-ESFR-V02-190101 | Revision | Updated based on new ENERGY STAR spec. | Dependent |

| Volume | End Use | Measure Name | Measure Code | Change Type | Explanation | Impact on Savings |
|---|---|---|---|---|---|---|
| | | Fryer | | | Updated Measure Life | on inputs |
| | | 4.2.8 ENERGY STAR Griddle | CI-FSE-ESGR-V03-190101 | Revision | Coincident factor fix | kW Increase dependent on inputs |
| | | 4.2.9 ENERGY STAR Hot Food Holding Cabinets | CI-FSE-ESHH-V03-190101 | Revision | Coincident factor fix | kW Increase dependent on inputs |
| | | 4.2.10 ENERGY STAR Ice Maker | CI-FSE-ESIM-V02-190101 | Revision | Measure Life Update.<br>Update to Federal Standard and ENERGY STAR specifications effective January 2018. | Dependent on inputs |
| | | 4.2.11 High Efficiency Pre-Rinse Spray Valve | CI-FSE-SPRY-V05-190101 | Revision | Addition of secondary kWh savings for water supply and waste water treatment | Increase |
| | | 4.2.19 ENERGY STAR Electric Convection Oven | CI-FSE-ECON-V02-190101 | Revision | Coincident factor fix | kW Increase dependent on inputs |
| | 4.3 Hot Water | 4.3.1 Storage Water Heater | CI-HWE-STWH-V03-190101 | Revision | Standard change to Uniform Energy Factor.<br>Reference to upcoming IECC 2018 code for New Construction. | Dependent on inputs |
| | | 4.3.2 Low Flow Faucet Aerators | CI-HWE-LFFA-V08-190101 | Revision | Measure Life Update.<br>Addition of secondary kWh savings for water supply and waste water treatment | Increases |
| | | 4.3.3 Low Flow Showerheads | CI-HWE-LFSH-V05-190101 | Revision | Addition of secondary kWh savings for water supply and waste water treatment | Increases |
| | | 4.3.4 Commercial Pool Covers | CI-HWE-PLCV-V02-190101 | Revision | Addition of secondary kWh savings for water supply | Increases |
| | | 4.3.5 Tankless Water Heater | CI-HWE-TKWH-V04-190101 | Revision | Gas storage baseline definition made consistent with Storage Water Heater.<br>Added IECC 2018 new construction code baseline assumptions. | Unknown |
| | | 4.3.6 Ozone Laundry | CI-HWE-OZLD-V02-190101 | Revision | Addition of secondary kWh savings for water supply and waste water treatment | Increases |
| | | 4.3.7 Multifamily Central Domestic Hot Water Plants | CI-HWE-MDHW-V03-190101 | Revision | Reference to upcoming IECC 2018 code for New Construction. | N/A |
| | 4.4 HVAC | 4.4 HVAC End Use | N/A | Revision | Update to select building type heating and cooling EFLH assumptions that have been transitioned and | Dependent on inputs |

| Volume | End Use | Measure Name | Measure Code | Change Type | Explanation | Impact on Savings |
|---|---|---|---|---|---|---|
| | | | | | calibrated to OpenStudio by the Modeling Subcommittee.<br>Model Source provided in table | |
| | | 4.4.1 Air Conditioner Tune-Up | CI-HVC-ACTU-V05-180101 | Errata | Correction of error in algorithm for deemed approach. | Decrease |
| | | 4.4.6 Electric Chiller | CI-HVC-CHIL-V06-190101 | Revision | Measure Life Update.<br>Added IECC 2018 new construction code baseline assumptions. | Increase lifetime savings |
| | | 4.4.7 ENERGY STAR and CEE Super-Efficient Room Conditioner | CI-HVC-ESRA-V02-190101 | Revision | Update to Federal Standard and Efficient specifications. | Dependent on inputs |
| | | 4.4.9 Heat Pump Systems | CI-HVC-HPSY-V06-190101 | Revision | Update to Federal Standard.<br>Added IECC 2018 new construction code baseline assumptions. | Dependent on Inputs |
| | | 4.4.10 High Efficiency Boiler | CI-HVC-BOIL-V06-190101 | Revision | Addition of new federal standard notice | N/A |
| | | 4.4.11 High Efficiency Furnace | CI-HVC-FRNC-V08-190101 | Revision | Update to select building type cooling run hours assumptions that have been transitioned and calibrated to OpenStudio by the Modeling Subcommittee.<br>Model Source provided in table | N/A |
| | | 4.4.13 Package Terminal Air Conditioner (PTAC) and Package Terminal Heat Pump (PTHP) | CI-HVC-PTAC-V09-190101 | Revision | Measure Life Update.<br>Update to Federal Standard | Decrease |
| | | 4.4.14 Pipe Insulation | CI-HVC-PINS-V05-190101 | Revision | Assumptions for larger pipe sizes added. | N/A |
| | | 4.4.15 Single-Package and Split System Unitary Air Conditioners | CI-HVC-SPUA-V06-190101 | Revision | Update to Federal Standard.<br>Added IECC 2018 new construction code baseline assumptions.<br>Clarification of use of EER for older units. | Dependent on Inputs |
| | | 4.4.17 Variable Speed Drives for HVAC Pumps and Cooling Tower Fans | CI-HVC-VSDHP-V05-190101 | Revision | Update to measure life.<br>Reference to upcoming IECC 2018 code for New Construction.<br>Update to select building type heating and cooling run hours assumptions that have been transitioned and calibrated to OpenStudio by the Modeling Subcommittee. | Increase in lifetime savings |

| Volume | End Use | Measure Name | Measure Code | Change Type | Explanation | Impact on Savings |
|---|---|---|---|---|---|---|
| | | | | | Model Source provided in table | |
| | | 4.4.18 Small Commercial Programmable Thermostats | CI-HVC-PROG-V02-190101 | Revision | Update to measure life. | Increase in lifetime savings |
| | | 4.4.19 Demand Controlled Ventilation | CI-HVC-DCV-V05-190101 | Revision | Addition of assumptions for adding DCV controls to exhaust fans in enclosed parking garages.<br>Adjustments to analysis resulting in new savings factors. | Dependent on Inputs |
| | | 4.4.25 Small Commercial Programmable Thermostat Adjustments | CI-HVC-PRGA-V02-180101 | Errata | Correction of error in the Natural Gas Climate Zone Coefficients for Assembly building type. | Dependent on Inputs |
| | | | CI-HVC-PRGA-V03-190101 | Revision | Measure Life update | N/A |
| | | 4.4.26 Variable Speed Drives for HVAC Supply and Return Fans | CI-HVC-VSDF-V03-190101 | Revision | Measure cost update.<br>Reference to upcoming IECC 2018 code for New Construction.<br>Update to select building type fan run hours assumptions that have been transitioned and calibrated to OpenStudio by the Modeling Subcommittee.<br>Model Source provided in table | N/A |
| | | 4.4.27 Energy Recovery Ventilator | CI-HVC-ERVE-V03-190101 | Revision | Addition of cooling savings.<br>Reference to upcoming IECC 2018 code for New Construction. | Increase |
| | | 4.4.30 Notched V Belts for HVAC Systems | CI-HVC-NVBE-V04-190101 | Revision | Update to select building type fan run hours assumptions that have been transitioned and calibrated to OpenStudio by the Modeling Subcommittee.<br>Model Source provided in table | N/A |
| | | 4.4.32 Combined Heat and Power | CI-HVC-CHAP-V03-190101 | Revision | Update to Heat Rate base on eGrid 2016 | Dependent on Inputs |
| | | 4.4.33 Industrial air Curtain | CI-HVC-AIRC-V02-190601 | Revision | Reference to upcoming IECC 2018 code for New Construction. | N/A |
| | | 4.4.34 Destratification Fan | CI-HVC-DSFN-V03-190101 | Revision | Change to assumptions in thermal resistance through roof | Decrease |
| | | 4.4.35 Economizer Repair and Optimization | CI-HVC-ECRP-V03-180101 | Errata | Correction of error in Integrated Economizer Operation (EL) variable and example calculation. | Dependent on Inputs |

| Volume | End Use | Measure Name | Measure Code | Change Type | Explanation | Impact on Savings |
|---|---|---|---|---|---|---|
| | | 4.4.36 Multi-Family Space Heating Steam Boiler Averaging Controls | CI-HVC-SBAC-V02-190101 | Revision | Change to qualification criteria.<br>Measure cost update.<br>Change to Savings Factor | Increase |
| | | 4.4.40 Gas High Efficiency Single Package Vertical Air Conditioner | CI-HVC -SPVA-V01-190101 | New | New Measure | N/A |
| | | 4.4.41 Advanced Rooftop Controls | CI-HVC-ARTC-V01-190101 | New | New Measure | N/A |
| | | 4.4.42 Advanced Thermostats for Small Commercial | CI-HVC-ADTH-V01-190101 | New | New Measure | N/A |
| | | 4.4.43 Packaged RTU Sealing | CI-HVC-PRTU-V01-190101 | New | New Measure | N/A |
| | | 4.4.44 Commercial Ground Source Heat Pump | CI-HVC-GSHP-V01-190101 | New | New Measures | N/A |
| | | 4.4.45 Adsorbant Air Cleaning | CI-HVC-ADAC-V01-190101 | New | New Measures | N/A |
| | 4.5 Lighting | 4.5 Lighting End Use Table | N/A | Revision | Update to select building type assumptions that have been transitioned and calibrated to OpenStudio by the Modeling Subcommittee.<br>Change to Exterior dusk to dawn hours assumption.<br>Change to Refrigerator and Freezer Coincidence Factor. | Dependent on Inputs |
| | | 4.5.1 Commercial Compact Fluorescent Lamp | CI-LTG-CCFL-V08-190101 | Revision | Addition of language that measure is effective until 12/31/2018. | N/A |
| | | 4.5.3 High Performance and Reduced Wattage T8 Fixtures and Lamps | CI-LTG-T8FX-V07-190101 | Revision | Measure Life Update.<br>Update to C&I v RES split and ISR.<br>Additional year of T12 as viable retrofit baseline. | Decrease |
| | | 4.5.4 LED Bulbs and Fixtures | CI-LTG-LEDB-V07-180101 | Errata | Correction of year that the mid-life adjustment applies to account for T12 replacement, from 2018 to 2019.<br>Addition of mid-life adjustment assumptions for omnidirectional screw based lamps. | N/A |
| | | | CI-LTG-LEDB-V08-190101 | Revision | Update to Lamp lumen bins.<br>Decorative and Directional Lamp EISA backstop | Dependent on Inputs |

| Volume | End Use | Measure Name | Measure Code | Change Type | Explanation | Impact on Savings |
|---|---|---|---|---|---|---|
| | | | | | adjustments added.<br>Update to C&I v RES split and ISR.<br>Clarification on calculation of 3-way lamps. | |
| | | 4.5.5 Commercial LED Exit Signs | CI-LTG-LEDE-V03-190101 | Revision | Update to lifetime.<br>Update to measure cost.<br>Update to WattsBase and WattsEE assumptions | Dependent on Inputs |
| | | 4.5.7 Lighting Power Density | CI-LTG-LPDE-V04-190101 | Revision | Added IECC 2018 new construction code baseline assumptions. | Dependent on Inputs |
| | | 4.5.8 Miscellaneous Commercial/ Industrial Lighting | CI-LTG-MSCI-V03-190101 | Revision | Measure Life Update. | N/A |
| | | 4.5.9 Multi-Level Lighting Switch | CI-LTG-MLLC-V04-190101 | Revision | Reference to upcoming IECC 2018 code for New Construction. | N/A |
| | | 4.5.10 Lighting Controls | CI-LTG-OSLC-V05-190101 | Revision | Combining occupancy, daylighting and integrated controls in to one measure.<br>Updating watts controlled and % savings factors.<br>Updated costs. | Decrease |
| | | 4.5.12 T5 Fixtures and Lamps | CI-LTG-T5FX-V06-190101 | Revision | Measure Life Update.<br>Additional year of T12 as viable retrofit baseline. | N/A |
| | | 4.5.13 Occupancy Controlled Bi-Level Lighting Fixtures | CI-LTG-OCBL-V03-190101 | Revision | Reference to upcoming IECC 2018 code for New Construction. | N/A |
| | | 4.5.14 Commercial Specialty Compact Fluorescent Lamp | CI-LTG-SCFL-V04-190101 | Revision | Addition of language that measure is effective until 12/31/2018. | N/A |
| | | 4.5.16 LED Streetlighting | CI-LTG-STRT-V01-190101 | New | New Measure | N/A |
| | 4.6 Refrigeration | 4.6.1 Automatic Door Closer for Walk-In Coolers and Freezers | CI-RFG-ATDC-V02-190101 | Revision | Reference update | N/A |
| | | 4.6.3 Door Heater Controls for Cooler or Freezer | CI-RFG-DHCT-V02-190101 | Revision | Measure Life Update. | Decrease in lifetime savings |
| | | 4.6.6 Evaporator Fan Control for Electrically Commutated Motors | CI-RFG-EVPF-V04-190101 | Revision | Measure Life Update. | Decrease in lifetime savings |
| | | 4.6.10 High Speed Roll Up Doors | CI-RFG-HSRD-V02-190101 | Revision | Measure Life Update. | Increase in lifetime savings |

| Volume | End Use | Measure Name | Measure Code | Change Type | Explanation | Impact on Savings |
|---|---|---|---|---|---|---|
| | | 4.6.11 Q-Sync Motors for Reach-in Coolers/Freezers | CI-RFG-QMF-V01-190101 | New | New measure | N/A |
| | | 4.6.12 Variable Frequency Drive for Condenser Fans | CI-RFG-VSC-V01-190101 | New | New measure | N/A |
| | 4.7 Compressed Air | 4.7.1 VSD Air Compressor | CI-CPA-VSDA-V02-190101 | Revision | Clarification on measure eligibility.<br>Additional baseline characterized.<br>CF for varying shift lengths.<br>Measure Life Update. | Dependent on Inputs |
| | | 4.7.2 Compressed Air Low Pressure Drop Filters | CI-CPA-LPDF-V02-190101 | Revision | Measure Life Update.<br>CF and hours for varying shift lengths. | Dependent on Inputs |
| | | 4.7.3 Compressed Air No-Loss Condensate Drains | CI-CPA-NCLD-V02-190101 | Revision | Added CF assumption. | N/A |
| | | 4.7.4 Efficient Compressed Air Nozzles | CI-CPA-CNOZ-V02-190101 | Revision | CF for varying shift lengths. | N/A |
| | | 4.7.5 Efficient Refrigerated Compressed Air Dryer | CI-CPA-CADR-V02-190101 | Revision | Measure Life Update.<br>CF for varying shift lengths.<br>Removal of default 50% CFM factor. | Increases |
| | 4.8 Miscellaneous | 4.8.1 Pump Optimization | CI-MSC-PMPO-V02-190101 | Revision | Measure Life Update. | Decrease in lifetime savings |
| | | 4.8.2 Roof Insulation for C&I Facilities | CI-MSC-RINS-V03-190101 | Revision | Reference to upcoming IECC 2018 code for New Construction. | N/A |
| | | 4.8.7 Advanced Power Strip – Tier 1 Commercial | CI-MSC-APSC-V02-190101 | Revision | Algorithm typo fixed | N/A |
| | | 4.8.10 Commercial Clothes Dryer Moisture Sensor | CI-MSC-CDMS-V01-190101 | New | New Measure | N/A |
| | | 4.8.11 Efficient Thermal Oxidizers | CI-MSC-ETOX-V01-190101 | New | New Measure | N/A |
| | | | | | | |
| Volume 3: Residential | 5.1 Appliances | 5.1.2 ENERGY STAR Clothes Washer | RS-APL-ESCL-V05-180101 | Errata | Update to Federal Standard. | Decrease |
| | | | RS-APL-ESCL-V06-190101 | Revision | Addition of CEE Tier 3.<br>Measure cost update. | Dependent on Inputs |

| Volume | End Use | Measure Name | Measure Code | Change Type | Explanation | Impact on Savings |
|---|---|---|---|---|---|---|
| | | | | | Update to assumptions based on current available product and updated RECS information.<br>Addition of secondary kWh savings for water supply and waste water treatment | |
| | | 5.1.3 ENERGY STAR Dehumidifier | RS-APL-ESDH-V04-180101 | Errata | Update to ENERGY STAR specification. | Increase |
| | | | RS-APL-ESDH-V05-190101 | Revision | Notes for upcoming Federal Standard change.<br>Update to measure cost. | N/A |
| | | 5.1.4 ENERGY STAR Dishwasher | RS-APL-ESDI-V04-190101 | Revision | Update to measure cost.<br>Update to measure life.<br>Update to operating hours assumption.<br>Addition of secondary kWh savings for water supply and waste water treatment | Increase in kWh. Decrease in kW savings |
| | | 5.1.5 ENERGY STAR Freezer | RS-APL-ESFR-V03-190101 | Revision | Measure Life Update. | Increase in lifetime savings |
| | | 5.1.6 ENERGY STAR and CEE Tier 2 Refrigerator | RS-APL-ESRE-V06-190101 | Revision | Measure Life Update. | Increase in lifetime savings |
| | | 5.1.7 ENERGY STAR Room Air Conditioner | RS-APL-ESRA-V07-190101 | Revision | Removal of Connected Allowance from ENERGY STAR specification. | Increase |
| | | 5.1.8 Refrigerator and Freezer Recycling | RS-APL-RFRC-V07-190101 | Revision | Removal of NTG discussion and reference to section 4.2.<br>Measure Life Update. | Decrease in lifetime savings |
| | | 5.1.9 Room Air Conditioner Recycling | RS-APL-RARC-V02-190101 | Revision | Update to assumption of retired unit efficiency. | Decrease |
| | | 5.1.10 ENERGY STAR Clothes Dryer | RS-APL-ESDR-V02-190101 | Revision | Measure Life Update. | Increase in lifetime savings |
| | | 5.1.12 Ozone Laundry | RS-APL-OZNE-V01-190101 | New | New Measure. | N/A |
| | 5.2 Consumer Electronics | 5.2.1 Advanced Power Strip – Tier 1 | RS-CEL-SSTR-V04-190101 | Revision | Clarification of ISR definitions | N/A |
| | | 5.2.2 Advanced Power Strip – Residential Audio Visual | RS-CEL-APS2-V03-190101 | Revision | Clarification of ERP | N/A |
| | 5.3 HVAC | 5.3.1 Air Source Heat Pump | RS-HVC-ASHP-V08-190101 | Revision | Note added that it is not appropriate to claim additional ECM savings.<br>Addition of Quality Install assumptions.<br>Measure Life Update.<br>Updates to existing and in-situ efficient ratings. | Dependent on Inputs |

| Volume | End Use | Measure Name | Measure Code | Change Type | Explanation | Impact on Savings |
|---|---|---|---|---|---|---|
| | | 5.3.2 Boiler Pipe Insulation | RS-HVC-PINS-V03-190101 | Revision | Addition of midlife adjustment to account for HVAC replacement during lifetime of measure | Decrease in lifetime savings |
| | | 5.3.3 Central Air Conditioning | RS-HVC-CAC1-V08-190101 | Revision | Note added that it is not appropriate to claim additional ECM savings.<br>Addition of Quality Install assumptions.<br>Update efficient condition specifications.<br>Updates to existing and in-situ efficient ratings. | Dependent on Inputs |
| | | 5.3.4 Duct Insulation and Sealing | RS-HVC-DINS-V07-190101 | Revision | Addition of midlife adjustment to account for HVAC replacement during lifetime of measure | Decrease in lifetime savings |
| | | 5.3.5 Furnace Blower Motor | RS-HVC-FBMT-V04-190101 | Revision | Updates to description.<br>Change to savings methodology based on Opinion Dynamics and Cadmus metering study.<br>Measure Life Update. | Dependent on Inputs |
| | | 5.3.6 Gas High Efficiency Boiler | RS-HVC-GHEB-V07-190101 | Revision | Change to 'EFLH * Capacity' methodology. | Dependent on Inputs |
| | | 5.3.7 Gas High Efficiency Furnace | RS-HVC-GHEF-V08-190101 | Revision | Change to 'EFLH * Capacity' methodology. | Dependent on Inputs |
| | | 5.3.8 Ground Source Heat Pump | RS-HVC-GSHP-V08-190101 | Revision | Update to gas water heater Federal standard.<br>Addition of GSHP as an existing option for early replacement.<br>Updates to existing efficient ratings.<br>Update to Heat Rate base on eGrid 2016. | Dependent on Inputs |
| | | 5.3.9 High Efficiency Bathroom Exhaust Fan | RS-HVC-BAFA-V02-190101 | Revision | Update to include both standard and continuous usage.<br>Addition of ENERGY STAR specifications. | Dependent on Inputs |
| | | 5.3.10 HVAC Tune Up (Central Air Conditioning or Air Source Heat Pump) | RS-HVC-TUNE-V04-190101 | Revision | Clarification of multifamily definitions | N/A |
| | | 5.3.11 Programmable Thermostats | RS-HVC-PROG-V05-190101 | Revision | Measure Life Update.<br>Addition of mobile home and unknown household factors | Increase in lifetime savings |
| | | 5.3.12 Ductless Heat Pumps | RS-HVC-DHP-V06-190101 | Revision | Measure Life Update.<br>Addition of incremental cost from baseline DMSHP.<br>Updates to existing efficient ratings.<br>Update to Heat Rate base on eGrid 2016. | Dependent on Inputs |
| | | 5.3.13 Residential | RS-HVC-FTUN-V04- | Revision | Clarification of measure life. | Dependent |

| Volume | End Use | Measure Name | Measure Code | Change Type | Explanation | Impact on Savings |
|---|---|---|---|---|---|---|
| | | Furnace Tune-Up | 190101 | | Methodology added to use HVAC SAVE outputs directly.<br>Change to 'EFLH * Capacity' methodology. | on Inputs |
| | | 5.3.14 Boiler Reset Controls | RS-HVC-BREC-V02-190101 | Revision | Addition of midlife adjustment to account for HVAC replacement during lifetime of measure | Decrease in lifetime savings |
| | | 5.3.16 Advanced Thermostats | RS-HVC-ADTH-V03-190101 | Revision | Measure Life Update.<br>Addition of mobile home and unknown household factors and capacities.<br>Updates to existing efficient ratings.<br>Updates to assumptions based on Navigant program participant evaluation<br>Update to cooling % reduction assumption. | Dependent on Inputs |
| | | 5.3.17 Gas High Efficiency Combination Boiler | RS-HVC-COMB-V01-190101 | New | New Measure | N/A |
| | 5.4 Hot Water | 5.4.1 Domestic Hot Water Pipe Insulation | RS-HWE-PINS-V03-190101 | Revision | Addition of circumference factor pre- and post-insulation. | Dependent on Inputs |
| | | 5.4.2 Gas Water Heater | RS-HWE-GWHT-V08-190101 | Revision | Addition of Uniform Energy Factor.<br>Update to gas water heater Federal standard. | Dependent on Inputs |
| | | 5.4.3 Heat Pump Water Heaters | RS-HWE-HPWH-V07-190101 | Revision | Addition of Uniform Energy Factor<br>Update to electric water heater Federal Standard.<br>Update to measure costs.<br>Update to COP of cooling estimate.<br>Measure Life Update.<br>Addition of midlife adjustment to account for HVAC replacement during lifetime of measure | Dependent on Inputs |
| | | 5.4.4 Low Flow Faucet Aerators | RS-HWE-LFFA-V07-190101 | Revision | Measure Life Update.<br>Updates to eligibility and existing GPM assumptions.<br>Updates to ISR assumptions.<br>Addition of unknown household type size.<br>Addition of secondary kWh savings for water supply and waste water treatment.<br>Update to Gallons per Hour calculation. | Dependent on Inputs |
| | | 5.4.5 Low Flow Showerheads | RS-HWE-LFSH-V06-190101 | Revision | Updates to eligibility and existing GPM assumptions.<br>Updates to ISR assumptions.<br>Addition of unknown household type size.<br>Addition of secondary kWh savings for water supply and waste water treatment. | Dependent on Inputs |

| Volume | End Use | Measure Name | Measure Code | Change Type | Explanation | Impact on Savings |
|---|---|---|---|---|---|---|
| | | | | | Update to Gallons per Hour calculation. | |
| | | 5.4.6 Water Heater temperature Setback | RS-HWE-TMPS-V06-190101 | Revision | Clarification of multifamily definitions | N/A |
| | | 5.4.8 Thermostatic Restrictor Shower Valve | RS-HWE-TRVA-V04-190101 | Revision | Addition of unknown household type size.<br>Addition of secondary kWh savings for water supply and waste water treatment | Increase |
| | | 5.4.9 Shower Timer | RS-DHW-SHTM-V02-190101 | Revision | Addition of unknown household type size.<br>Addition of secondary kWh savings for water supply and waste water treatment | Increase |
| | 5.5 Lighting | 5.5.1 Compact Fluorescent Lamp | RS-LTG-ESCF-V07-180101 | Errata | Addition of leakage assumption to kW and waste heat algorithms. | Decrease in kW savings |
| | | | RS-LTG-ESCF-V08-190101 | Revision | Addition of language that measure is effective until 12/31/2018. | N/A |
| | | 5.5.2 Specialty Compact Fluorescent Lamp | RS-LTG-ESCC-V06-180101 | Errata | Addition of leakage assumption to kW and waste heat algorithms. | Decrease in kW savings |
| | | | RS-LTG-ESCC-V07-190101 | Revision | Addition of language that measure is effective until 12/31/2018. | N/A |
| | | 5.5.3 ENERGY STAR Torchiere | RS-LTG-ESTO-V05-180101 | Errata | Addition of leakage assumption to kW and waste heat algorithms. | Decrease in kW savings |
| | | | RS-LTG-ESTO-V06-190101 | Revision | Addition of language that measure is effective until 12/31/2018. | N/A |
| | | 5.5.4 Exterior Hardwired Compact Fluorescent Lamp Fixture | RS-LRG-EFOX-V07-180101 | Errata | Addition of leakage assumption to kW and waste heat algorithms. | Decrease in kW savings |
| | | | RS-LRG-EFOX-V08-190101 | Revision | Addition of language that measure is effective until 12/31/2018. | N/A |
| | | 5.5.5 Interior Hardwired Compact Fluorescent Lamp Fixture | RS-LTG-IFIX-V07-180101 | Errata | Addition of leakage assumption to kW and waste heat algorithms. | Decrease in kW savings |
| | | | RS-LTG-IFIX-V08-190101 | Revision | Addition of language that measure is effective until 12/31/2018. | N/A |
| | | 5.5.6 LED Specialty Lamps | RS-LTG-LEDD-V08-180101 | Errata | Addition of leakage assumption to kW and waste heat algorithms. | Decrease in kW savings |
| | | | RS-LTG-LEDD-V09-190101 | Revision | Updates to Res v C&I split, ISR, leakage, CF and HOU.<br>Decorative and Directional Lamp EISA backstop adjustments added.<br>Format of watts tables updated.<br>Clarification on deferred install methodology. | Decrease in Savings |
| | | 5.5.7 LED Exit Signs | RS-LTG-LEDE-V03-190101 | Revision | Clarity of application within multifamily unit.<br>Measure made RF only.<br>Measure life adjusted accordingly. | Dependent on Inputs |

| Volume | End Use | Measure Name | Measure Code | Change Type | Explanation | Impact on Savings |
|---|---|---|---|---|---|---|
| | | | | | Measure cost updated.<br>Base and Efficient wattage adjusted. | |
| | | 5.5.8 LED Screw Based Omnidirectional Bulbs | RS-LTG-LEDA-V06-180101 | Errata | Addition of leakage assumption to kW and waste heat algorithms. | Decrease in kW savings |
| | | | RS-LTG-LEDA-V07-190101 | Revision | Updates to Res v C&I split, ISR, leakage, CF and HOU. Clarification on deferred install methodology. | Dependent on Inputs |
| | | 5.5.9 LED Fixtures | RS-LTG-LDFX-V01-190101 | New | New Measure | N/A |
| | | 5.5.10 Holiday String Lighting | RS-LTG-LEDH-V01-190101 | New | New Measure | N/A |
| | | 5.5.11 LED Nightlights | RS-LTG-NITL-V01-190101 | New | New Measure | N/A |
| | 5.6 Shell | 5.6.1 Airsealing | RS-SHL-AIRS-V07-190101 | Revision | Update to measure life.<br>Addition of midlife adjustment to account for HVAC replacement during lifetime of measure<br>Addition of cooling, heating fan and gas heating adjustment factors, with distinction made between measures combined with attic insulation or not. | Dependent on Inputs |
| | | 5.6.2 Basement Sidewall Insulation | RS-SHL-BINS-V09-190101 | Revision | Update to measure life.<br>Addition of midlife adjustment to account for HVAC replacement during lifetime of measure | Decrease in lifetime savings |
| | | 5.6.3 Floor Insulation Above Crawlspace | RS-SHL-FINS-V09-190101 | Revision | Update to measure life.<br>Addition of midlife adjustment to account for HVAC replacement during lifetime of measure. | Decrease in lifetime savings |
| | | 5.6.4 Wall Insulation | RS-SHL-WINS-V08-190101 | Revision | Separation of Wall and Ceiling/Attic Insulation measures<br>Update to measure life.<br>Addition of midlife adjustment to account for HVAC replacement during lifetime of measure | Decrease in lifetime savings |
| | | 5.6.5 Ceiling/Attic Insulation | RS-SHL-AINS-V01-190101 | Revision | Separation of Wall and Ceiling/Attic Insulation measures<br>Update to measure life.<br>Addition of midlife adjustment to account for HVAC replacement during lifetime of measure<br>Updates to cooling, gas heating adjustment factors plus addition of heating fan adjustment factor, with distinction made between measures combined with airsealing measure or not. | Dependent on Inputs |
| | | 5.6.6 Rim/Band Joist Insulation | RS-SHL-RINS-V01-190101 | New | New Measure | |
| | 5.7 | 5.7.1 High Efficiency | RS-MSC-RPLP-V02-190101 | Revision | Update to ENERGY STAR specifications. | Dependent |

| Volume | End Use | Measure Name | Measure Code | Change Type | Explanation | Impact on Savings |
|---|---|---|---|---|---|---|
| | Miscellaneous | Pool Pumps | | | Addition of above ground pools.<br>Update to measure cost. | on Inputs |
| | | | | | | |
| Volume 4: Cross Cutting Measures and Attachments | 6.1 Behavior | 6.1.1 Adjustments to Behavior Savings to Account for Persistence | CC-BEH-BEHP-V03-190101 | Revision | Footnote added to Retention Rate variable to acknowledge uncertainty related to the current assumption, and a recommendation to update should better evaluation information become available. | N/A |
| | Attachment B: Effective Useful Life for Custom Measure Guidelines | N/A | N/A | New | New section providing guidelines and default assumptions for custom measure effective useful lives. | N/A |

**Table 1.4: Summary of Attachment A: IL-NTG Methods Revisions**

| IL-TRM Volume | Sectors | Protocol Name | Change Type | Explanation |
|---|---|---|---|---|
| Vol. 4 | All Sectors | Programs Currently Covered in this Document | Revision | Added language to allow SAG-approved updates to go into effect before the effective date of the updated TRM. |
| Vol. 4 | All Sectors | Spillover Specific Issues | Revision | Added language and table for estimating spillover from trade allies for all sectors (not only for residential). |
| Vol. 4 | All Sectors | Commercial, Industrial and Public Sector Programs | Revision | Updated table with 2018-21 programs. |
| Vol. 4 | All Sectors | Core Free Ridership Scoring Algorithm: Algorithm 1 and Algorithm 2 | Revision | Added language to aid evaluators in selecting the appropriate algorithm to use. |
| Vol. 4 | Residential and Low Income | Residential and Low Income Programs | Revision | Updated table with 2018-21 programs.<br>Added footnote regarding NTG value for Income Eligible programs. |
| Vol. 4 | Residential and Low Income | Residential and Low Income Programs | Revision | Changed language from program influence on *decision* to program influence on *making* energy efficiency improvements. |
| Vol. 4 | All Sectors | Non-Participant Spillover Measured Through Trade Allies | Revision | Moved and revised language from section 4.1.3 to section 5.1 to allow for combining trade ally free ridership with customer free ridership for all sectors. |
| Vol. 4 | Residential and Low Income | Appliance Recycling | Revision | Deleted language in section 4.2 regarding Induced Replacement to reflect current industry practiced described in the latest version of the Uniform Methods Protocol. |
| Vol. 4 | Residential and Low Income | Nonparticipant Spillover Measured Through Trade Allies | Revision | Deleted section 4.1.3 to allow estimating nonparticipant spillover through trade allies for all sectors. |
| Vol. 4 | Residential and Low Income | Multifamily Protocol | Revision | Added language clarifying CFL, non-CFL, LED and non-LED measures. |
| Vol. 4 | Residential and Low Income | Builder Nonparticipant Spillover | Revision | Updated Table 4-6 to IECC 2015 Building Energy Code. |
| Vol. 4 | Cross- Sectors | Combining Participant and Trade-Ally Free Ridership Scores | Revision | Added section 5.1 for combining trade ally free ridership with customer free ridership for all sectors. |
| Vol. 4 | Cross- Sectors | Combining Participant and Trade-Ally Free Ridership Scores | Revision | Added section 5.2 for estimating spillover through trade allies for all sectors. |
| Vol. 4 | Cross-Sectors | Consumption Data Analysis Protocol | Revision | Revised to address when consumption data analysis yields net savings, gross savings, or something in between. |
| Vol. 4 | Cross-Sectors | Survey-Based Approaches | Revision | Added language to consider survey mode effects, especially online vs. telephone. |

## 1.3 Enabling ICC Policy

This Illinois Statewide Technical Reference Manual (TRM) was developed to comply with the Illinois Commerce Commission (ICC or Commission) Final Orders from the electric and gas Utilities'[6] Energy Efficiency Plan dockets. In the Final Orders, the ICC required the utilities to work with the Illinois Department of Commerce and Economic Opportunity (DCEO) and the Illinois Energy Efficiency Stakeholder Advisory Group (SAG) to develop a statewide TRM. *See, e.g.,* ComEd's Final Order *(Docket No. 10-0570, Final Order[7] at 59-60, December 21, 2010);* Ameren's Final Order *(Docket No. 10-0568, Order on Rehearing[8] at 19, May 24, 2011);* Peoples Gas/North Shore Gas' Final Order *(Docket No. 10-0564, Final Order[9] at 76, May 24, 2011),* and Nicor's Final Order *(Docket No. 10-0562, Final Order[10] at 30, May 24, 2011).*

As directed in the Utilities' Efficiency Plan Orders, the SAG had the opportunity to, and also participated in, every aspect of the development of the TRM. Interested members of the SAG participated in weekly teleconferences to review, comment, and participate in the development of the TRM. The active participants in the TRM were designated as the "Technical Advisory Committee" (TAC). The TAC participants include representatives from the following organizations:

- the Utilities (ComEd, Ameren IL, Nicor Gas, Peoples Gas/North Shore Gas),
- Implementation contractors (CLEAResult, Conservation Services Group, Elevate Energy, Franklin Energy, GDS Associates, PECI, 360 Energy Group),
- Illinois Department of Commerce and Economic Opportunity (DCEO),
- the independent evaluators (ADM Associates, The Cadmus Group, Itron, Navigant Consulting, Michael's Engineering, Opinion Dynamics Corporation),
- ICC Staff,
- the Illinois Attorney General's Office (AG),
- Natural Resources Defense Council (NRDC),
- the Environmental Law and Policy Center (ELPC),
- the Citizen's Utility Board (CUB),
- The University of Illinois at Chicago,
- Future Energy Enterprises,
- Issue-specific invited participants including; Geothermal Alliance of Illinois, the Geothermal Exchange Organization, Embertec, TrickleStar, Google Nest, Ecobee, and US EPA ENERGY STAR.

## 1.4 Development Process

The first edition of the IL-TRM was approved by the Commission in ICC Docket No. 12-0528[11]. The second edition of the IL-TRM was approved by the Commission in ICC Docket No. 13-0437[12]. The policies surrounding the applicability and use of the IL-TRM in planning, implementation, and evaluation were originally established by the

[6] The Illinois Utilities subject to this TRM include: Ameren Illinois Company d/b/a Ameren Illinois (Ameren), Commonwealth Edison Company (ComEd), The Peoples Gas Light and Coke Company and North Shore Gas Company, and Northern Illinois Gas Company d/b/a Nicor Gas.
[7] http://www.icc.illinois.gov/docket/files.aspx?no=10-0570&docId=159809
[8] http://www.icc.illinois.gov/docket/files.aspx?no=10-0568&docId=167031
[9] http://www.icc.illinois.gov/docket/files.aspx?no=10-0564&docId=167023
[10] http://www.icc.illinois.gov/docket/files.aspx?no=10-0562&docId=167027
[11] http://www.icc.illinois.gov/docket/files.aspx?no=12-0528&docId=187554
[12] http://www.icc.illinois.gov/docket/files.aspx?no=13-0437&docId=200492

Commission in ICC Docket No. 13-0077[13], and most recently in ICC Docket No. 17-0270[14]. The third edition of the IL-TRM was approved by the Commission in ICC Docket No. 14-0189[15]. The fourth edition of the IL-TRM was approved by the Commission in ICC Docket No. 15-0187[16]. The fifth edition of the IL-TRM was approved by the Commission in ICC Docket No. 16-0171[17]. The sixth edition of the IL-TRM was approved by the Commission in ICC Docket No. 17-0106[18].

This document represents the seventh edition of the IL-TRM and it applies to Section 8-103B and Section 8-104 energy efficiency programs. It contains a series of new measures, as well as a series of errata items[19] and updates to existing measures that were already present in the first six editions. Like the previous editions, it is a result of an ongoing review process involving the Illinois Commerce Commission (ICC) Staff (Staff or ICC Staff), the Utilities, the Evaluators, the SAG TAC, and the SAG. VEIC meets with the SAG and/or the TRM TAC at least once each month to create a high level of transparency and vetting in the development of this TRM.

Measure requests that are submitted by interested parties are ranked based on the following criteria to determine the approximate priority level for order of inclusion in the TRM:

1. High Priority
   a. For those existing measures that make up a significant portion of a utilities' portfolio and/or where the impact of the requested change is high
   b. For new measures where plans are in place to implement in the next program year
2. Medium Priority
   a. For existing measures that are a less significant percent of a utilities' portfolio and value change will not have a significant impact
   b. For new measures where a savings value is estimated but implementation plans not yet developed
3. Low Priority
   a. For existing measures that represent a very small percent of a utilities' portfolio
   b. For new measures that are just beginning to be explored and will not be implemented in the next program year

These rankings are used to align budget and schedule constraints with desired updates from the TRM.

As measure requests are finalized leading up to the next update of the TRM, weekly TAC meetings are often scheduled to maximize the level of collaboration and visibility into the measure characterization process. Where consensus does not emerge on specific measures or issues, those items are identified in a memo. As a result, this TRM represents a broad consensus amongst the SAG and TAC participants. In keeping with the goal of transparency, all of the comments and their status to-date are available through the TAC SharePoint web site, https://portal.veic.org.

For each measure characterization, this TRM includes engineering algorithm(s) and a value(s) for each parameter in the equation(s). These parameters have values that fall into one of three categories: a single deemed value, a lookup

[13] http://www.icc.illinois.gov/docket/files.aspx?no=13-0077&docId=203903; http://www.icc.illinois.gov/docket/files.aspx?no=13-0077&docId=195913; http://www.icc.illinois.gov/downloads/public/edocket/339744.pdf

[14] https://www.icc.illinois.gov/docket/files.aspx?no=17-0270&docId=257523 Please see IL-TRM Policy Document Version 2.0 available at https://www.icc.illinois.gov/downloads/public/edocket/447989.pdf

[15] http://www.icc.illinois.gov/docket/files.aspx?no=14-0189&docId=210478 http://www.icc.illinois.gov/downloads/public/Illinois_Statewide_TRM_Effective_060114_Version_3.0_022414_Clean.pdf

[16] http://www.icc.illinois.gov/docket/files.aspx?no=15-0187&docId=226161 http://www.icc.illinois.gov/downloads/public/Illinois_Statewide_TRM_Effective_060115_Final_022415_Clean.pdf

[17] https://www.icc.illinois.gov/docket/files.aspx?no=16-0171&docId=239985 https://www.icc.illinois.gov/downloads/public/IL-TRM%20Version%205.0%20dated%20February%2011,%202016%20Final%20-%20Compiled%20Volumes%201-4.pdf

[18] https://www.icc.illinois.gov/docket/files.aspx?no=17-0106&docId=250827 https://www.icc.illinois.gov/downloads/public/edocket/442527.pdf

[19] Errata as well as links to the official IL-TRM documents, dockets, and policy documents are available on the following ICC webpage: http://www.icc.illinois.gov/Electricity/programs/TRM.aspx

table of deemed values or an actual value such as the capacity of the equipment. The TRM makes extensive use of lookup tables because they allow for an appropriate level of measure streamlining and customization within the context of an otherwise prescriptive measure.

Accuracy is the overarching principle that governs what value to use for each parameter. When it is explicitly allowed within the text of the measure characterization, the preferred value is the actual or on-site value for the individual measure being implemented. The *deemed values*[20] in the lookup tables are the next most accurate choice, and in the absence of either an actual value or an appropriate value in a lookup table, the single, *deemed value* should be used. As a result, this single, *deemed value* can be thought of as a default value for that particular input to the algorithm.

A single *deemed savings estimate* is produced by any given combination of an algorithm and the allowable input values for each of its parameters. In cases where lookup tables are provided, there is a range of deemed savings estimates that are possible, depending on site-specific factors such as equipment capacity, location and building type.

Algorithms and their parameter values are included for calculating estimated:

- Gross annual electric energy savings (kWh)
- Gross annual natural gas energy savings (therms)
- Gross electric summer coincident peak demand savings (kW)

To support cost-effectiveness calculations, parameter values are also included for:

- Incremental costs ($)
- Measure life (years)
- Operation and maintenance costs ($)
- Water (gal) and other resource savings where appropriate.

### 1.4.1 Reliability Review

The process of incorporating new and better information into the TRM occurs annually as new measures and errors are identified, program designs change, old measures are dropped from programs, or other external events (such as code and standard changes or new evaluations and other data) warrant a review of assumptions. However, not all measures have updates triggered by such events, and some measures continue to appear in the TRM without ongoing review. Short of proactively identified issues that would trigger an update to a TRM characterization, a regular reliability review should be undertaken to assess that the information in older measures is still relevant and reliable. This review will include a general appraisal of reasonableness and continued program relevancy and an update of any assumptions to reflect new information.

To ensure that measures initially developed in the past and not recently revisited are updated and retired as needed, each measure is given a Review Deadline – a date that triggers a reliability review. This Review Deadline is established for each measure based on factors such as expected revisions to energy codes or federal standards; knowledge of upcoming evaluation or research efforts; knowledge of rapidly changing technology, cost, baselines, or other factors; or expected shifts in current customer practices. No Review Deadline is longer than six years from the date of the initial characterization or last update of a measure. The TRM Administrator will propose Review Deadlines for each measure, and they are reviewed and approved by the TAC. The Review Deadline for each measure is indicated in the measure characterization within the TRM. For example, a Review Deadline specified as 1/1/2019 means that the measure will be reviewed no later than the annual IL-TRM update process that occurs in 2018, in advance of the 1/1/2019 Review Deadline. Following a review and/or update, a new Review Deadline will be assigned to that measure.

[20] Emphasis has been added to denote the difference between a “deemed value” and a “deemed savings estimate”. A deemed value refers to a single input value to an algorithm, while a deemed savings estimate is the result of calculating the end result of all of the values in the savings algorithm.

# 2 Organizational Structure

The organization of this document follows a three-level format. These levels are designed to define and clarify what the measure is and where it is applied.

1. **Market Sectors Volumes**[21]
   - This level of organization specifies the type of customer the measures apply to, either Commercial and Industrial (provided in Volume 2), Residential (provided in Volume 3), or cross-cutting measures, such as Behavior Persistence (provided in Volume 4, together with Attachments including the documentation of Illinois Statewide Net-to-Gross methodologies).
   - Answers the question, "What category best describes the customer?"
2. **End-use Category**
   - This level of organization represents most of the major end-use categories for which an efficient alternative exists. The following table lists all of the end-use categories in this version of the TRM.
   - Answers the question, "To what end-use category does the measure apply?"

**Table 2.1: End-Use Categories in the TRM**[22]

| Volume 2: Commercial and Industrial Market Sector | Volume 3: Residential Market Sector | Volume 4: Cross-Cutting Measures and Attachments |
|---|---|---|
| Agricultural Equipment | Appliances | Behavior |
| Food Service Equipment | Consumer Electronics | |
| Hot Water | Hot Water | |
| HVAC | HVAC | |
| Lighting | Lighting | |
| Refrigeration | Shell | |
| Compressed Air | Miscellaneous | |
| Miscellaneous | | |

3. **Measure & Technology**
   - This level of organization represents individual efficient measures such as CFL lighting and LED lighting, both of which are individual technologies within the Lighting end-use category.
   - Answers the question, "What technology defines the measure?"

This organizational structure is silent on which fuel the measure is designed to save; electricity or natural gas. By organizing the TRM this way, measures that save on both fuels do not need to be repeated. As a result, the TRM will be easier to use and to maintain.

## 2.1 Measure Code Specification

In order to uniquely identify each measure in the TRM, abbreviations for the major organizational elements of the TRM have been established. When these abbreviations are combined and delimited by a dash ('-') a unique, 18-character alphanumeric code is formed that can be used for tracking the measures and their associated savings estimates. Measure codes appear at the end of each measure and are structured using five parts.

**Code Structure = Market + End-use Category + Measure + Version # + Effective Date**

[21] Note that the Public sector buildings and low income measures are not listed as a separate Market Sector. The Public building type is one of a series of building types that are included in the appropriate measures in the Commercial and Industrial Sector.
[22] Please note that this is not an exhaustive list of end-uses and that others may be included in future versions of the TRM.

For example, the commercial boiler measure is coded: "CI-HVC-BLR_-V01-120601"

**Table 2.2: Measure Code Specification Key**

| Market (@@) | End-use (@@@) | Measure (@@@@) | Version (V##) | Effective Date |
|---|---|---|---|---|
| CI (C&I) | AGE (Agricultural Equipment) | BLR_ | V01 | YYMMDD |
| RS (Residential) | APL (Appliances) | T5FX | V02 | YYMMDD |
| CC (Cross-Cutting) | BEH (Behavior) | T8FX | V03 | YYMMDD |
| | CEL (Consumer Electronics) | … | … | … |
| | CPA (Compressed Air) | | | |
| | FSE (Food Service Equipment) | | | |
| | HVC (HVAC) | | | |
| | HWE (Hot Water) | | | |
| | LTG (Lighting) | | | |
| | MSC (Miscellaneous) | | | |
| | RFG (Refrigeration) | | | |
| | SHL (Shell) | | | |

## 2.2 Components of TRM Measure Characterizations

Each measure characterization uses a standardized format that includes at least the following components. Measures that have a higher level of complexity may have additional components, but also follow the same format, flow and function.

#### DESCRIPTION

Brief description of measure stating how it saves energy, the markets it serves and any limitations to its applicability.

#### DEFINITION OF EFFICIENT EQUIPMENT

Clear definition of the criteria for the efficient equipment used to determine delta savings. Including any standards or ratings if appropriate.

#### DEFINITION OF BASELINE EQUIPMENT

Clear definition of the efficiency level of the baseline equipment used to determine delta savings including any standards or ratings if appropriate. If a Time of Sale measure the baseline will be new base level equipment (to replace existing equipment at the end of its useful life or for a new building). For Early Replacement or Early Retirement measures the baseline is the existing working piece of equipment that is being removed.

#### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected duration in years (or hours) of the savings. If an early replacement measure, the assumed life of the existing unit is also provided.

#### DEEMED MEASURE COST

For time of sale measures, incremental cost from baseline to efficient is provided. Installation costs should only be included if there is a difference between each efficiency level. For Early Replacement the full equipment and install cost of the efficient installation is provided in addition to the full deferred hypothetical baseline replacement cost.

#### LOADSHAPE

The appropriate loadshape to apply to electric savings is provided.

**COINCIDENCE FACTOR**

The summer coincidence factor is provided to estimate the impact of the measure on the utility's system peak – defined as 1PM to hour ending 5PM on non-holiday weekdays, June through August.

**Algorithm**

**CALCULATION OF ENERGY SAVINGS**

Algorithms are provided followed by list of assumptions with their definition.

If there are no Input Variables, there will be a finite number of Output values. These will be identified and listed in a table. Where there are custom inputs, an example calculation is often provided to illustrate the algorithm and provide context.

**ELECTRIC ENERGY SAVINGS**

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

**NATURAL GAS SAVINGS**

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

**DEEMED O&M COST ADJUSTMENT CALCULATION**

Only required if the operation and maintenance cost for the efficient case is different to the baseline.

**MEASURE CODE**

**REVIEW DEADLINE**

If not otherwise updated as part of an identified new TRM issue request before this Review Deadline, the measure will undergo a reliability review for reasonableness, continued program relevancy, and update of material assumptions during the update cycle prior to this deadline.

## 2.3 Variable Input Tables

Many of the measures in this TRM require the user to select the appropriate input value from a list of inputs for a given parameter in the savings algorithm. Where the TRM asks the user to select the input, look-up tables of allowable values are provided. For example, a set of input parameters may depend on building type; while a range of values may be given for each parameter, only one value is appropriate for any specific building type. If no table of alternative inputs is provided for a particular parameter, then the single deemed value will be used, unless the measure has a custom allowable input.

### 2.3.1 C&I Custom Value Use in Measure Implementation

This section defines the requirements for capturing Custom variables that can be used in place of defaults for select assumptions within the prescriptive measures defined in this statewide TRM. This approach is to be used when a variable in a measure formula can be replaced by a verifiable and documented value that is not presented in the TRM. This approach assumes that the algorithms presented in the measure are used as stated and only allows changes to certain variable values and is not a replacement algorithm for the measure. A custom variable is when customer input is provided to define the number or the value is measured at the site. Custom values can also be supplied from product data of the measure installed. In certain cases the custom data can be provided from a documented study or report that is applicable to the measure. Custom variables and potential sources are clearly defined in the specific measures where "Actual" or "Custom" is noted.

In exceptional cases where the participant, program administrator, and independent evaluator all agree that the TRM algorithm for a particular energy efficiency measure does not accurately characterize the energy efficiency measure within a project due to the complexity in the design and configuration of the particular energy efficiency project, a more comprehensive custom engineering and financial analysis may be used that more accurately incorporates the attributes of the measure in the complex energy efficiency project. In such cases and consistent with Commission policy adopted in ICC Docket No. 17-0270, Program Administrators are subject to retrospective evaluation risk (retroactive adjustments to savings based on ex post evaluation findings) for such projects using customized savings calculations.

## 2.4 Program Delivery & Baseline Definitions

The measure characterizations in this TRM are not grouped by program delivery type. As a result, the measure characterizations provided include information and assumptions to support savings calculations for the range of program delivery options commonly used for the measure. The organizational significance of this approach is that multiple baselines, incremental costs, O&M costs, measure lives and in-service rates are included in the measure characterization(s) that are delivered under two or more different program designs. Values appropriate for each given program delivery type are clearly specified in the algorithms or in look-up tables within the characterization.

Care has been taken to clearly define in the measure's description the types of program delivery that the measure characterization is designed to support. However, there are no universally accepted definitions for a particular program type, and the description of the program type(s) may differ by measure. Nevertheless, program delivery types can be generally defined according to the following table. These are the definitions used in the measure descriptions, and, when necessary, individual measure descriptions may further refine and clarify these definitions of program delivery type.

**Table 2.3: Program Delivery Types**

| Program | Attributes |
|---|---|
| Time of Sale (TOS) | Definition: A program in which the customer is incented to purchase or install higher efficiency equipment than if the program had not existed. This may include retail rebate (coupon) programs, upstream buydown programs, online store programs or contractor based programs as examples.<br>Baseline = New equipment.<br>Efficient Case = New, premium efficiency equipment above federal and state codes and standard industry practice.<br>Example: CFL rebate |
| New Construction (NC) | Definition: A program that intervenes during building design to support the use of more-efficient equipment and construction practices.<br>Baseline = Building code or federal standards.<br>Efficient Case = The program's level of building specification<br>Example: Building shell and mechanical measures |
| Retrofit (RF) | Definition: A program that upgrades existing equipment before the end of its useful life.<br>Baseline = Existing equipment or the existing condition of the building or equipment. A single baseline applies over the measure's life.<br>Efficient Case = New, premium efficiency equipment above federal and state codes and standard industry practice.<br>Example: Air sealing and insulation |
| Early Replacement (EREP) | Definition: A program that replaces existing equipment before the end of its expected life.<br>Baseline = Dual; it begins as the existing equipment and shifts to new baseline equipment after the expected life of the existing equipment is over.<br>Efficient Case = New, premium efficiency equipment above federal and state codes and standard industry practice.<br>Example: Refrigerators, freezers |
| Early | Definition: A program that retires duplicative equipment before its expected life is over. |

| Program | Attributes |
| --- | --- |
| Retirement (ERET) | Baseline = The existing equipment, which is retired and not replaced.<br>Efficient Case = Zero because the unit is retired.<br>Example: Appliance recycling |
| Direct Install (DI) | Definition: A program where measures are installed during a site visit.<br>Baseline = Existing equipment.<br>Efficient Case = New, premium efficiency equipment above federal and state codes and standard industry practice.<br>Example: Lighting and low-flow hot water measures |
| Efficiency Kits (KITS) | Definition: A program where measures are provided free of charge to a customer in an Efficiency Kit.<br>Baseline = Existing equipment.<br>Efficient Case = New, premium efficiency equipment above federal and state codes and standard industry practice.<br>Example: Lighting and low-flow hot water measures |

The concept and definition of the baseline is a key element of every measure characterization and is directly related to the program delivery type. Without a clear definition of the baseline, the savings algorithms cannot be adequately specified and subsequent evaluation efforts would be hampered. As a result, each measure has a detailed description (and in many cases, specification) of the specific baseline that should be used to calculate savings. Baselines in this TRM fall into one of the following four categories, and are organized within each measure characterization by the program delivery type to which it applies.

1. **Building Code:** As defined by the minimum specifications required under state energy code or applicable federal standards.
2. **Existing Equipment**: As determined by the most representative (or average) example of equipment that is in the existing stock. Existing equipment baselines apply over the equipment's remaining useful life.
3. **New Equipment:** As determined by the equipment that represents standard practice in the current market environment. New equipment baselines apply over the effective useful life of the measure.
4. **Dual Baseline:** A baseline that begins as the existing equipment and shifts to new equipment after the expected life of the existing equipment is over

# 3 Assumptions

The information contained in this TRM contains VEIC's recommendations for the content of the Illinois TRM. Sources that are cited within the TRM have been chosen based on two priorities, geography and age. Whenever possible and appropriate, VEIC has incorporated Illinois-specific information into each measure characterization. The Business TRM documents from Ameren and ComEd were reviewed, as well as program and measure specific data from evaluations, efficiency plans, and working documents.

The assumptions for these characterizations rest on our understanding of the information available. In each case, the available Illinois and Midwest-specific information was reviewed, including evaluations and support material provided by the Illinois Utilities.

When Illinois or region-specific evaluations or data were not available, best practice research and data from other jurisdictions were used, often from west- and east-coast states that have allocated large amounts of funding to evaluation work and to refining their measure characterization parameters. As a result, much of the most-defensible information originates from these regions. In every case, VEIC used the most-recent, well-designed, and best-supported studies and only if it was appropriate to generalize their conclusions to the Illinois programs.

## 3.1 Footnotes & Documentation of Sources

Each new and updated measure characterization is supported by a work paper, which is posted to the SharePoint web site (https://portal.veic.org).[23] Both the work paper and the measure characterizations themselves use footnotes to document the references that have been used to characterize the technology. The reference documents are too numerous to include in an Appendix and have instead been posted to the TRM's SharePoint website. These files can be found in the 'Sources and Reference Documents' folder in the main directory, and are also posted to the SAG's public web site (http://www.ilsag.info/technical-reference-manual.html).

## 3.2 General Savings Assumptions

The TRM savings estimates are expected to serve as average, representative values, or ways to calculate savings based on program-specific information. All information is presented on a per-measure basis. In using the measure-specific information in the TRM, it is helpful to keep the following notes in mind.

- All estimates of energy (kWh or therms) and peak (kW) savings are for first-year savings, not lifetime savings.
- Unless otherwise noted, measure life is defined to be the life of an energy consuming measure, including its equipment life and measure persistence.
- Where deemed values for savings are provided, they represent the average energy (kWh or therms) or peak (kW) savings that could be expected from the average of all measures that might be installed in Illinois in the program year.
- In general, the baselines included in the TRM are intended to represent average conditions in Illinois. Some are based on data from the state, such as household consumption characteristics provided by the Energy Information Administration. Some are extrapolated from other areas, when Illinois data are not available.

## 3.3 Shifting Baseline Assumptions

The TRM anticipates the effects of changes in efficiency codes and standards on affected measures. When these changes take effect, a shift in the baseline is usually required. This complicates the measure savings estimation somewhat, and will be handled in future versions of the TRM by describing the choice of and reasoning behind a shifting baseline assumption. In this version of the TRM, this applies to CFLs and T5/T8 Linear Fluorescents, Furnaces and Early Replacement Measures.

[23] To gain access to the SharePoint web site, please contact the TRM Administrator at iltrmadministrator@veic.org.

### 3.3.1 CFL and T5/T8 Linear Fluorescents and LED Baseline Assumptions

Specific reductions in savings have been incorporated for CFL and LED measures that relate to the shift in appropriate baseline due to changes in Federal Standards for lighting products. Federal legislation (stemming from the Energy Independence and Security Act of 2007) mandated a phase-in process that began in 2012 for all general-purpose light bulbs (defined as omnidirectional or A-lamps) between 40W and 100W to be approximately 30% more energy efficient than current incandescent bulbs, in essence beginning the phase-out of the current style, or "standard", incandescent bulbs. From 2012, standard 100W incandescent bulbs could no longer be manufactured, followed by restrictions on standard 75W bulbs in 2013 and 60W and 40W bulbs in 2014. The baseline for the CFL and LED Omnidirectional Lamp measure in the corresponding program years therefore became bulbs (improved or "efficient" incandescent, or halogen) that met the new standard and have the same lumen equivalency. In addition, a backstop provision requires replacement baseline lamps meet 45 lumens/watt from 2020. To account for this shifting baseline, annual savings are reduced within the lifetime of the measure using a midlife baseline adjustment. The magnitude and timing of these adjustments are specified within each measure.

Specialty and Directional lamps were not included in the original definition of General Service Lamps in the Energy Independence and Security Act of 2007 (EISA). Therefore, the initial baseline is an incandescent / halogen lamp described in that measure.

However, a DOE Final Rule released on 1/19/2017 updated the EISA regulations to remove the exemption for these lamp types such that they become subject to the backstop provision defined within the original legislation. There is, however, uncertainty around the final application of the EISA backstop provision, particularly whether the expanded definition will hold, as well as uncertainty regarding how the market for these products would change absent the backstop. Therefore, the 2019 version of the LED Specialty Lamp measure delays application of the midlife adjustment associated with the backstop provision to 1/1/2024. However, TAC members commit to making appropriate mid-year adjustments to the measure characterization in the event that new information adds sufficient clarity and concludes any legal challenges to support making a change to this agreement. This means that, if within PY2019 it becomes clear that the EISA backstop *will* apply to the measures characterized herein, the timing of the midlife adjustment will be changed to be applied in 2021, consistent with the omnidirectional measure. Likewise, if it becomes clear that these lamp types will revert to being exempt, the midlife adjustment will be removed. In addition, the TAC and IL TRM Administrator must consider NTG and lifetime assumptions and, if consensus is reached, apply coordinated adjustments to the TRM at that time (if consensus is not reached the most recent NTG evaluation results for these measures will be applied). Any mid-year adjustments to the TRM and NTG would be applied for all installs beginning 30 days after agreement is reached, rather than waiting for the next TRM update.

In July 14, 2012, Federal Standards were enacted that were expected to eliminate T-12s as an option for linear fluorescent fixtures. Through v3.0 of the TRM, it was assumed that the T-12 would no longer be baseline for retrofits from 1/1/2016. However, due to significant loopholes in the legislation, T-12 compliant product is still freely available, and in Illinois T-12s continue to hold a significant share of the existing and replacement lamp market. Therefore, the timing of the sunsetting of T-12s as a viable baseline was pushed back in v7.0 to 1/1/2020, and will be revisited in future update sessions and incorporate findings from any baseline studies conducted through the year.

### 3.3.2 Early Replacement Baseline Assumptions

A series of measures have an option to choose an Early Replacement Baseline if the following conditions are met:

Early Replacement determination will be based on meeting the following conditions:

- The existing unit is operational when replaced, or
- The existing unit requires minor repairs (see table below) [24].

[24] The Technical Advisory Committee agreed that if the cost of repair is less than 20% of the new baseline replacement cost it can be considered early replacement.

| Existing System | Maximum repair cost |
|---|---|
| Air Source Heat Pump | $918 |
| Central Air Conditioner | $734 |
| Boiler | $709 |
| Furnace | $528 |
| Ground Source Heat Pump | <$249 per ton |

- All other conditions will be considered Time of Sale.

The Baseline efficiency of the existing unit replaced:

- If the efficiency of the existing unit is less than the maximum shown below, the Baseline efficiency is the actual efficiency value of the unit replaced. If the efficiency is greater than the maximum, the Baseline efficiency is shown in the "New Baseline" column below:

| Existing System | Maximum efficiency for Actual | New Baseline |
|---|---|---|
| Air Source Heat Pump | 10 SEER | 14 SEER |
| Central Air Conditioner | 10 SEER | 13 SEER |
| Boiler | 75% AFUE | 82% AFUE |
| Furnace | 75% AFUE | 80% AFUE |
| Ground Source Heat Pump | 10 SEER | 13 SEER |

- If the operational status, repair cost or efficiency of the existing unit is unknown, the Baseline efficiency is the "New Baseline" column above.

### 3.3.3 Furnace Baseline

The prior national standard for residential oil and gas furnaces was 78% AFUE. DOE raised the standard in 2007 to 80% AFUE, effective 2015. However, virtually all furnaces on the market have an AFUE of 80% or better, which prompted states and environmental and consumer groups to sue DOE over its 2007 decision. In April 2009, DOE accepted a "voluntary remand" in that litigation. In October 2009, manufacturers and efficiency advocates negotiated an agreement that, for the first time, included different standard levels in three climate regions: the North, South, and Southwest. DOE issued a direct final rule (DFR) in June 2011 reflecting the standard levels in the consensus agreement. The DFR became effective on October 25, 2011 establishing new standards: In the North, most furnaces will be required to have an AFUE of 90%.The 80% AFUE standard for the South and Southwest will remain unchanged at 80%. Oil furnaces will be required to have an AFUE of 83% in all three regions. The amended standards will become effective in May 2013 for non-weatherized furnaces and in January 2015 for weatherized furnaces. DOE estimates that the standards will save about 3.3 quads (quadrillion Btu) of energy over 30 years and yield a net present value of about $14 billion at a 3 percent discount rate.

Update*:* On January 14th 2013, the U.S. Department of Energy (DOE) proposed to settle a lawsuit brought by the American Public Gas Association (APGA) that seeks to roll back gas furnace efficiency standards. As a result, the new standards, completed in 2011 and slated to take effect in May 2013, would be eliminated in favor of yet another round of DOE hearings and studies. Even if DOE completes a new rulemaking in two years, it's unlikely to take effect before 2020.[25]

As a result, each of the furnace measures contains the following language describing the baseline assumption:

"Although the current Federal Standard for gas furnaces is an AFUE rating of 78%, based upon review of available product in the AHRI database, the baseline efficiency for this characterization is assumed to be 80%. The baseline

[25] Appliance Standards Awareness Project, http://www.appliance-standards.org/product/furnaces

will be adjusted when the Federal Standard is updated."

## 3.4 Glossary

**Baseline Efficiency:** The assumed standard efficiency of equipment, absent an efficiency program.

**Building Types[26]:**

Note where a measure installation is within a building or application that does not fit with any of the defined building types below, the user should apply custom assumptions where it is reasonable to estimate them, else the building of best fit should be used.

| Building Type | Definition |
|---|---|
| Assisted Living MultiFamily | Applies to residential buildings of three of more units with staff to assist the occupants. Gross Floor Area should include all fully-enclosed space within the exterior walls of the building(s) including individual rooms or units, wellness centers, exam rooms, community rooms, small shops or service areas for residents and visitors (e.g. hair salons, convenience stores), staff offices, lobbies, atriums, cafeterias, kitchens, storage areas, hallways, basements, stairways, corridors between buildings, and elevator shafts. |
| Auditorium/Assembly | Applies to any performance space such as a theater, arena, or hall. Gross Floor Area should include all space within the building(s), including seating, stage and backstage areas, food service areas, retail areas, rehearsal studios, administrative/office space, mechanical rooms, storage areas, elevator shafts, and stairwells. |
| Childcare/Pre-school | Applies to any building providing childcare to pre-kindergarten age children. |
| College/University | Applies to facility space used for higher education. Relevant buildings include administrative headquarters, residence halls, athletic and recreation facilities, laboratories, etc. The total gross floor area should include all supporting functions such as kitchens used by staff, lobbies, atria, conference rooms and auditoria, fitness areas for staff, storage areas, stairways, elevator shafts, etc. |
| Convenience Store | Applies to facility space used for the retail sale of a limited selection of food and beverage products. The total gross floor area should include all supporting functions such as kitchens and break rooms used by staff, storage areas (refrigerated and non-refrigerated), and administrative areas. |
| Elementary School | Applies to a school serving children In any grades from Kindergarten through sixth grade. The total gross floor area should include all supporting functions such as administrative space, conference rooms, kitchens used by staff, lobbies, cafeterias, gymnasiums, auditoria, laboratory classrooms, portable classrooms, greenhouses, stairways, atria, elevator shafts, small landscaping sheds, storage areas, etc. |
| Exterior | Applies to unconditioned spaces that are outside of the building envelope. |
| Garage | Applies to unconditioned spaces either attached or detached from the primary building envelope that are not used for living space. |
| Grocery | Applies to facility space used for the retail sale of food and beverage products. It should not be used by restaurants. The total gross floor area should include all supporting functions such as kitchens and break rooms used by staff, storage areas (refrigerated and non-refrigerated), administrative areas, stairwells, atria, lobbies, etc. |
| Healthcare Clinic | Applies to a facility space used to provide diagnosis and treatment for medical, dental, or psychiatric outpatient care. Gross Floor Area should include all space within the building(s) including offices, exam rooms, laboratories, lobbies, atriums, conference rooms and auditoriums, employee break rooms and kitchens, rest rooms, elevator shafts, stairways, mechanical rooms, and storage areas. |

[26] Source: US EPA, www.energystar.gov, Space Type Definitions, or definitions as developed through the Technical Advisory Committee.

| Building Type | Definition |
|---|---|
| High School/Middle School | Applies to facility space used as a school building for 7th through 12th grade students. This does not include college or university classroom facilities and laboratories, vocational, technical, or trade schools. The total gross floor area should include all supporting functions such as administrative space, conference rooms, kitchens used by staff, lobbies, cafeterias, gymnasiums, auditoria, laboratory classrooms, portable classrooms, greenhouses, stairways, atria, elevator shafts, small landscaping sheds, storage areas, etc. |
| Hospital | Applies to a general medical and surgical hospital (including critical access hospitals and children's hospitals) that is either a stand-alone building or a campus of buildings. Spaces more accurately characterized as a Healthcare Clinic should use that definition.<br>The definition of Hospital accounts for all space types that are located within the Hospital building/campus, such as medical offices, administrative offices, and skilled nursing. The total floor area should include the aggregate floor area of all buildings on the campus as well as all supporting functions such as: stairways, connecting corridors between buildings, medical offices, exam rooms, laboratories, lobbies, atria, cafeterias, storage areas, elevator shafts, and any space affiliated with emergency medical care, or diagnostic care. |
| Hotel/Motel Combined<br>(All Spaces) | Applies to buildings that rent overnight accommodations on a room/suite basis, typically including a bath/shower and other facilities in guest rooms. The total gross floor area should include all interior space, including guestrooms, halls, lobbies, atria, food preparation and restaurant space, conference and banquet space, health clubs/spas, indoor pool areas, and laundry facilities, as well as all space used for supporting functions such as elevator shafts, stairways, mechanical rooms, storage areas, employee break rooms, back-of-house offices, etc. Hotel does not apply to fractional ownership properties such as condominiums or vacation timeshares. Hotel properties should be owned by a single entity and have rooms available on a nightly basis.<br>Where distinction between Hotel and Motel is necessary:<br>Hotel: Room entrances and Corridors are located in the *interior* of the building. Corridors are conditioned spaces. Building can be significantly larger in size/height.<br>Motel: Room entrances and Corridors are located on the *exterior* of the building. Corridors are not conditioned spaces. Buildings tend to be two to three stories in height. |
| Hotel/Motel Common Areas | All the common areas open to guests of the hotel such as the lobby, corridors and stairways, and other spaces that may have continuous or large lighting and HVAC hours. |
| Hotel/Motel Guest Room | Applies to the guest rooms of the hotel or motel. These spaces are occupied intermittently. |
| Low-use Small Business | Any business type with low (<3000) operating hours (provided as option in lighting measures). |
| Manufacturing | Applies to buildings that are dedicated to manufacturing activities. Includes light industry buildings characterized by consumer product and component manufacturing and heavy industry buildings typically characterized by a plant that includes a main production area that has high-ceilings and contains heavy equipment used for assembly line production. These building types may be distinguished by categorizing NAICS (SIC) codes according to the needs of the Program Administrator. |
| Miscellaneous | Applies to spaces that do not fit clearly within any available categories should be designated as "miscellaneous". |
| Mobile Home | A mobile home is a prefabricated structure, built in a factory on a permanently attached chassis before being transported to site.<br>Use single family assumptions throughout the TRM unless otherwise specified. |
| Movie Theater | Applies to buildings used for public or private film screenings. Gross Floor Area should include all space within the building(s), including seating areas, lobbies, concession stands, bathrooms, administrative/office space, mechanical rooms, storage areas, |

| Building Type | Definition |
|---|---|
| | elevator shafts, and stairwells. |
| Multifamily-Mid Rise | Applies to residential buildings with up to four floors, including all public and multiuse spaces within the building envelope. Small Multifamily buildings best described as a house should use the residential measure characterizations. |
| Multifamily-High Rise Combined (All Spaces) | Applies to residential buildings with five or more floors, including all public and multiuse spaces within the building envelope. Gross Floor Area should include all fully-enclosed space within the exterior walls of the building(s) including living space in each unit (including occupied and unoccupied units), interior common areas (e.g. lobbies, offices, community rooms, common kitchens, fitness rooms, indoor pools), hallways, stairwells, elevator shafts, connecting corridors between buildings, storage areas, and mechanical space such as a boiler room. Open air stairwells, breezeways, and other similar areas that are not fully-enclosed should not be included in the Gross Floor Area. |
| Multifamily-High Rise Common Areas | All the common areas open to occupants of the building such as the lobby, corridors and stairways, and other spaces that may have continuous or high lighting and HVAC hours. |
| Multifamily-High Rise Residential Units | Applies to the residential units in the building only. |
| Office-Low Rise | Applies to facility spaces in buildings with four floors or fewer used for general office, professional, and administrative purposes. The total gross floor area should include all supporting functions such as kitchens used by staff, lobbies, atria, conference rooms and auditoria, fitness areas for staff, storage areas, stairways, elevator shafts, etc. |
| Office-Mid Rise | Applies to facility spaces in buildings with five to nine floors used for general office, professional, and administrative purposes. The total gross floor area should include all supporting functions such as kitchens used by staff, lobbies, atria, conference rooms and auditoria, fitness areas for staff, storage areas, stairways, elevator shafts, etc. |
| Office-High Rise | Applies to facility spaces in buildings with ten floors or more used for general office, professional, and administrative purposes. The total gross floor area should include all supporting functions such as kitchens used by staff, lobbies, atria, conference rooms and auditoria, fitness areas for staff, storage areas, stairways, elevator shafts, etc. |
| Religious Worship/Church | Applies to buildings that are used as places of worship. This includes churches, temples, mosques, synagogues, meetinghouses, or any other buildings that primarily function as a place of religious worship. Gross Floor Area should include all areas inside the building that includes the primary worship area, including food preparation, community rooms, classrooms, and supporting areas such as restrooms, storage areas, hallways, and elevator shafts. |
| Restaurant | Applies to a subcategory of Retail/Service space that is used to provide commercial food services to individual customers, and includes kitchen, dining, and common areas. |
| Retail/Service-Department store | Applies to facility space used to conduct the retail sale of consumer product goods. Stores must be at least 30,000 square feet and have an exterior entrance to the public. The total gross floor area should include all supporting functions such as kitchens and break rooms used by staff, storage areas, administrative areas, elevators, stairwells, etc. Retail segments typically included under this definition are: Department Stores, Discount Stores, Supercenters, Warehouse Clubs, Drug Stores, Dollar Stores, Home Center/Hardware Stores, and Apparel/Hard Line Specialty Stores (e.g., books, clothing, office products, toys, home goods, electronics). Retail segments excluded under this definition are: Grocery, Convenience Stores, Automobile Dealerships, and Restaurants. |
| Retail/Service- Strip Mall | Applies to facility space used to conduct the retail sale of consumer product goods. Stores must less than 30,000 square feet and have an exterior entrance to the public. The total gross floor area should include all supporting functions such as kitchens and break rooms used by staff, storage areas, administrative areas, elevators, stairwells, etc. Retail segments excluded under this definition are: Grocery, Convenience Stores, |

| Building Type | Definition |
|---|---|
| | Automobile Dealerships, and Restaurants. |
| Warehouse | Applies to unrefrigerated or refrigerated buildings that are used to store goods, manufactured products, merchandise or raw materials. The total gross floor area of Refrigerated Warehouses should include all temperature controlled area designed to store perishable goods or merchandise under refrigeration at temperatures below 50 degrees Fahrenheit. The total gross floor area of Unrefrigerated Warehouses should include space designed to store non-perishable goods and merchandise. Unrefrigerated warehouses also include distribution centers. The total gross floor area of refrigerated and unrefrigerated warehouses should include all supporting functions such as offices, lobbies, stairways, rest rooms, equipment storage areas, elevator shafts, etc. Existing atriums or areas with high ceilings should only include the base floor area that they occupy. The total gross floor area of refrigerated or unrefrigerated warehouse should not include outside loading bays or docks. Self-storage facilities, or facilities that rent individual storage units, are not eligible for a rating using the warehouse model. |

**Coincidence Factor** (CF): Coincidence factors represent the fraction of connected load expected to be coincident with a particular system peak period, on a diversified basis. Coincidence factors are provided for summer peak periods.

**Commercial & Industrial:** The market sector that includes measures that apply to any of the building types defined in this TRM, which includes multifamily common areas and public housing[27].

**Connected Load**: The maximum wattage of the equipment, under normal operating conditions.

**Deemed Value:** A value that has been assumed to be representative of the average condition of an input parameter.

**Default Value**: When a measure indicates that an input to a prescriptive saving algorithm may take on a range of values, an average value is also provided in many cases. This value is considered the default input to the algorithm, and should be used when the other alternatives listed in the measure are not applicable.

**End-use Category:** A general term used to describe the categories of equipment that provide a service to an individual or building. See Table 2.1 for a list of the end-use categories that are incorporated in this TRM.

**Energy Efficiency:** "Energy efficiency" means measures that reduce the amount of electricity or natural gas consumed in order to achieve a given end use. "Energy efficiency" includes voltage optimization measures that optimize the voltage at points on the electric distribution voltage system and thereby reduce electricity consumption by electric customers' end use devices. "Energy efficiency" also includes measures that reduce the total Btus of electricity, natural gas and other fuels needed to meet the end use or uses (20 ILCS 3855/1-10). For purposes of this Section, "energy efficiency" means measures that reduce the amount of energy required to achieve a given end use. "Energy efficiency" also includes measures that reduce the total Btus of electricity and natural gas needed to meet the end use or uses (220 ILCS 5/8-104(b)).

**Equivalent Full Load Hours** (EFLH): The equivalent hours that equipment would need to operate at its peak capacity in order to consume its estimated annual kWh consumption (annual kWh/connected kW) or therms.

**High Efficiency**: General term for technologies and processes that require less energy, water, or other inputs to operate.

**Lifetime**: The number of years (or hours) that the new high efficiency equipment is expected to function. These are generally based on engineering lives, but sometimes adjusted based on expectations about frequency of removal, remodeling or demolition. Two important distinctions fall under this definition; Effective Useful Life (EUL) and Remaining Useful Life (RUL).

[27] Measures that apply to the multifamily and public housing building types describe how to handle tenant versus master metered buildings.

**EUL** – EUL is based on the manufacturers rating of the effective useful life; how long the equipment will last. For example, a CFL that operates x hours per year will typically have an EUL of y. A house boiler may have a lifetime of 20 years but the EUL is only 15 years since after that time it may be operating at a non-efficient point. An estimate of the median number of years that the measures installed under a program are still in place and operable.

**RUL** – Applies to retrofit or replacement measures. For example, if an existing working refrigerator is replaced with a high efficiency unit, the RUL is an assumption of how many more years the existing unit would have lasted. As a general rule the RUL is usually assumed to be 1/3 of the EUL.

**Load Factor** (LF): The fraction of full load (wattage) for which the equipment is typically run.

**Measure Cost**: The incremental (for time of sale measures) or full cost (both capital and labor for retrofit measures) of implementing the High Efficiency equipment. See Section 3.8 Measure Incremental Cost Definition for full definition.

**Measure Description**: A detailed description of the technology and the criteria it must meet to be eligible as an energy efficient measure.

**Measure:** An efficient technology or procedure that results in energy savings as compared to the baseline efficiency.

**Residential:** The market sector that includes measures that apply only to detached, residential buildings or duplexes.

**Operation and Maintenance (O&M) Cost Adjustments:** The dollar impact resulting from differences between baseline and efficient case Operation and Maintenance costs.

**Operating Hours** (HOURS): The annual hours that equipment is expected to operate.

**Program:** The mode of delivering a particular measure or set of measures to customers. See Table 2.4 for a list of program descriptions that are presently operating in Illinois.

**Rating Period Factor** (RPF): Percentages for defined times of the year that describe when energy savings will be realized for a specific measure.

**Stakeholder Advisory Group (SAG):** The Illinois Energy Efficiency Stakeholder Advisory Group (SAG) was first defined in the electric utilities' first energy efficiency Plan Orders to include "… the Utility, DCEO, Staff, the Attorney General, BOMA and CUB and representation from a variety of interests, including residential consumers, business consumers, environmental and energy advocacy organizations, trades and local government... [and] a representative from the ARES (alternative retail electric supplier) community should be included."[28] A group of stakeholders who have an interest in Illinois' energy efficiency programs and who meet regularly to share information and work toward consensus on various energy efficiency issues. The Utilities in Illinois have been directed by the ICC to work with the SAG on the development of a statewide TRM.

**Table 3.1: Degree-Day Zones and Values by Market Sector**

| | Residential | | C&I | | |
|---|---|---|---|---|---|
| Zone | HDD | CDD | HDD | CDD | Weather Station / City |
| 1 | 5,352 | 820 | 4,272 | 2,173 | Rockford AP / Rockford |
| 2 | 5,113 | 842 | 4,029 | 2,181 | Chicago O'Hare AP / Chicago |
| 3 | 4,379 | 1,108 | 3,406 | 2,666 | Springfield #2 / Springfield |
| 4 | 3,378 | 1,570 | 2,515 | 3,358 | Belleville SIU RSCH / Belleville |
| 5 | 3,438 | 1,370 | 2,546 | 3,090 | Carbondale Southern IL AP / Marion |
| Average | 4,860 | 947 | 3,812 | 2,362 | Weighted by occupied housing units |

[28] ICC Docket No. 07-0540, Final Order at 32-33, February 6, 2008.
http://www.icc.illinois.gov/downloads/public/edocket/215193.pdf

| | Residential | | C&I | | |
|---|---|---|---|---|---|
| Zone | HDD | CDD | HDD | CDD | Weather Station / City |
| Base Temp | 60F | 65F | 55F | 55F | Year climate normals, 1981-2010 |

## 3.5 Electrical Loadshapes (kWh)

Loadshapes are an integral part of the measure characterization and are used to divide energy savings into appropriate periods using Rating Period Factors (RPFs) such that each have variable avoided cost values allocated to them for the purpose of estimating cost effectiveness.

For the purposes of assigning energy savings (kWh) periods, the TRM TAC has agreed to use the industry standards for wholesale power market transactions as shown in the following table.

**Table 3.2: On and Off Peak Energy Definitions**

| Period Category | Period Definition (Central Prevailing Time) |
|---|---|
| Winter On-Peak Energy | 8AM - 11PM, weekdays, Oct – Apr, No NERC holidays |
| Winter Off-Peak Energy | All other hours |
| Summer On-Peak Energy | 8AM - 11PM, weekdays, May – Sept, No NERC holidays |
| Summer Off-Peak Energy | All other hours |

Loadshapes have been developed for each end-use by assigning Rating Period Factor percentages to each of the four periods above. Three methodologies were used:

1. Itron eShapes data for Missouri, provided by Ameren and reconciled to Illinois loads, were used to calculate the percentage of load in to the four categories above.
2. Where the Itron eShapes data did not provide a particular end-use or specific measure load profile, loadshapes that have been developed over many years by Efficiency Vermont and that have been reviewed by the Vermont Department of Public Service were adjusted to match Illinois period definitions. Note – no weather sensitive loadshapes were based on this method. Any of these load profiles that relate to High Impact Measures should be an area of future evaluation.
3. Loadshapes have also been developed from primary research studies conducted in Illinois or other jurisdictions if robust datasets were available to support hourly analysis of end use consumption.

The following pages provide the loadshape values for most measures provided in the TRM[29]. The source of the loadshape is also provided.

ComEd uses the DSMore™ (Integral Analytics DSMore™ Demand Side Management Option/Risk Evaluator) software to screen the efficiency measures for cost effectiveness. Since this tool requires a loadshape value for weekdays and weekends in each month (i.e., 24 inputs), the percentages for the four period categories above were calculated by weighting the proportion of weekdays/weekends in each month to the total within each period. The results of these calculations are also provided below.

[29] All loadshape information has been posted to the VEIC SharePoint site, and is publicly accessible through the Stakeholder Advisory Group's web site. http://www.ilsag.info/technical-reference-manual.html
http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Residential_Loadshapes_References.zip
http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Commercial_Loadshapes_References.zip
http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_3/Final_Draft/Sources%20and%20References%20-%20Loadshapes/TRM_Version_3_Loadshapes_2.24.zip
http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/2018_Loadshape_Files.zip

**Table 3.3: Loadshapes by Season**

| | Loadshape Reference Number | Winter Peak<br>Oct-Apr, M-F, non-holiday, 8AM - 11PM | Winter Off-peak<br>Oct-Apr, All other time | Summer Peak<br>May-Sept, M-F, non-holiday, 8AM - 11PM | Summer Off-peak<br>May- Sept, All other time | Loadshape Source |
|---|---|---|---|---|---|---|
| Residential Clothes Washer | R01 | 47.0% | 11.1% | 34.0% | 8.0% | Itron eShapes |
| Residential Dish Washer | R02 | 49.3% | 8.7% | 35.7% | 6.3% | Itron eShapes |
| Residential Electric DHW | R03 | 43.2% | 20.6% | 24.5% | 11.7% | Itron eShapes |
| Residential Freezer | R04 | 38.9% | 16.4% | 31.5% | 13.2% | Itron eShapes |
| Residential Refrigerator | R05 | 37.0% | 18.1% | 30.1% | 14.7% | Itron eShapes |
| Residential Indoor Lighting | R06 | 35.1% | 26.1% | 22.0% | 16.8% | Opinion Dynamics IL Metering Study[30] |
| Residential Outdoor Lighting | R07 | 18.0% | 44.1% | 9.4% | 28.4% | Efficiency Vermont |
| Residential Cooling | R08 | 4.1% | 0.7% | 71.3% | 23.9% | Itron eShapes |
| Residential Electric Space Heat | R09 | 57.8% | 38.8% | 1.7% | 1.7% | Itron eShapes |
| Residential Electric Heating and Cooling | R10 | 35.2% | 22.8% | 31.0% | 11.0% | Itron eShapes |
| Residential Ventilation | R11 | 25.8% | 32.3% | 18.9% | 23.0% | Efficiency Vermont |
| Residential - Dehumidifier | R12 | 12.9% | 16.2% | 31.7% | 39.2% | Efficiency Vermont |
| Residential Standby Losses - Entertainment Center | R13 | 26.0% | 32.5% | 18.9% | 22.6% | Efficiency Vermont |
| Residential Standby Losses - Home Office | R14 | 23.9% | 34.6% | 17.0% | 24.5% | Efficiency Vermont |
| Residential Pool Pumps | R15 | 0% | 0% | 58.9% | 41.1% | Efficiency Vermont |
| Residential Holiday String Lighting | R16 | 43.1% | 56.9% | 0% | 0% | Estimate[31] |
| | | | | | | |
| Commercial Electric Cooking | C01 | 40.6% | 18.2% | 28.7% | 12.6% | Itron eShapes |
| Commercial Electric DHW | C02 | 40.5% | 18.2% | 28.5% | 12.8% | Itron eShapes |
| Commercial Cooling | C03 | 4.9% | 0.8% | 66.4% | 27.9% | Itron eShapes |
| Commercial Electric Heating | C04 | 53.5% | 43.2% | 1.9% | 1.4% | Itron eShapes |
| Commercial Electric Heating and Cooling | C05 | 19.4% | 13.5% | 47.1% | 19.9% | Itron eShapes |
| Commercial Indoor Lighting | C06 | 30.1% | 27.5% | 22.8% | 19.7% | Navigant EmPOWER study[32] |

[30] See 'IL Res Indoor LED Lighting Load Shape_2018-06-06' and 'IL Res Indoor LED Lighting Load Shape Development Methodology_2018-05-18' for details.
[31] Based on average of Residential Indoor and Outdoor lighting winter usage only.
[32] See '3.5 Electrical Load Shapes_Il TRM Workpapre_CI_Ltg_2018-06-28' and 'IL Commercial Lighting Load Shape Development Methodology_2018-06-28' for

| | Loadshape Reference Number | Winter Peak<br>Oct-Apr, M-F, non-holiday, 8AM - 11PM | Winter Off-peak<br>Oct-Apr, All other time | Summer Peak<br>May-Sept, M-F, non-holiday, 8AM - 11PM | Summer Off-peak<br>May- Sept, All other time | Loadshape Source |
|---|---|---|---|---|---|---|
| Grocery/Conv. Store Indoor Lighting | C07 | 28.0% | 30.2% | 20.3% | 21.5% | Navigant EmPOWER study |
| Health Indoor Lighting | C08 | 29.1% | 28.9% | 21.6% | 20.3% | Navigant EmPOWER study |
| Office Indoor Lighting | C09 | 29.9% | 28.2% | 22.3% | 19.6% | Navigant EmPOWER study |
| Restaurant Indoor Lighting | C10 | 32.1% | 25.7% | 23.4% | 18.8% | Efficiency Vermont |
| Retail Indoor Lighting | C11 | 32.6% | 25.4% | 24.2% | 17.9% | Navigant EmPOWER study |
| Warehouse Indoor Lighting | C12 | 26.0% | 29.0% | 22.4% | 22.6% | Navigant EmPOWER study |
| Education Indoor Lighting | C13 | 34.7% | 26.2% | 23.6% | 15.5% | Navigant EmPOWER study |
| Indust. 1-shift (8/5) (e.g., comp. air, lights) | C14 | 50.5% | 7.2% | 37.0% | 5.3% | Efficiency Vermont |
| Indust. 2-shift (16/5) (e.g., comp. air, lights) | C15 | 47.5% | 10.2% | 34.8% | 7.4% | Efficiency Vermont |
| Indust. 3-shift (24/5) (e.g., comp. air, lights) | C16 | 34.8% | 23.2% | 25.5% | 16.6% | Efficiency Vermont |
| Indust. 4-shift (24/7) (e.g., comp. air, lights) | C17 | 25.8% | 32.3% | 18.9% | 23.0% | Efficiency Vermont |
| Industrial Indoor Lighting | C18 | 44.3% | 13.6% | 32.4% | 9.8% | Efficiency Vermont |
| Industrial Outdoor Lighting | C19 | 18.0% | 44.1% | 9.4% | 28.4% | Efficiency Vermont |
| Commercial Outdoor Lighting | C20 | 16.8% | 44.6% | 9.3% | 29.3% | Navigant EmPOWER study |
| Commercial Office Equipment | C21 | 37.7% | 20.9% | 26.7% | 14.7% | Itron eShapes |
| Commercial Refrigeration | C22 | 38.5% | 20.6% | 26.7% | 14.2% | Itron eShapes |
| Commercial Ventilation | C23 | 38.1% | 20.6% | 29.7% | 11.6% | Itron eShapes |
| Traffic Signal - Red Balls, always changing or flashing | C24 | 25.8% | 32.3% | 18.9% | 23.0% | Efficiency Vermont |
| Traffic Signal - Red Balls, changing day, off night | C25 | 37.0% | 20.9% | 27.1% | 14.9% | Efficiency Vermont |
| Traffic Signal - Green Balls, always changing | C26 | 25.8% | 32.3% | 18.9% | 23.0% | Efficiency Vermont |
| Traffic Signal - Green Balls, changing day, off night | C27 | 37.0% | 20.9% | 27.1% | 14.9% | Efficiency Vermont |
| Traffic Signal - Red Arrows | C28 | 25.8% | 32.3% | 18.9% | 23.0% | Efficiency Vermont |
| Traffic Signal - Green Arrows | C29 | 25.8% | 32.3% | 18.9% | 23.0% | Efficiency Vermont |
| Traffic Signal - Flashing Yellows | C30 | 25.8% | 32.3% | 18.9% | 23.0% | Efficiency Vermont |
| Traffic Signal - “Hand” Don’t Walk Signal | C31 | 25.8% | 32.3% | 18.9% | 23.0% | Efficiency Vermont |
| Traffic Signal - “Man” Walk Signal | C32 | 25.8% | 32.3% | 18.9% | 23.0% | Efficiency Vermont |
| Traffic Signal - Bi-Modal Walk/Don’t Walk | C33 | 25.8% | 32.3% | 18.9% | 23.0% | Efficiency Vermont |
| Industrial Motor | C34 | 47.5% | 10.2% | 34.8% | 7.4% | Efficiency Vermont |

details.

| | Loadshape Reference Number | Winter Peak<br>Oct-Apr, M-F, non-holiday, 8AM - 11PM | Winter Off-peak<br>Oct-Apr, All other time | Summer Peak<br>May-Sept, M-F, non-holiday, 8AM - 11PM | Summer Off-peak<br>May- Sept, All other time | Loadshape Source |
|---|---|---|---|---|---|---|
| Industrial Process | C35 | 47.5% | 10.2% | 34.8% | 7.4% | Efficiency Vermont |
| HVAC Pump Motor (heating) | C36 | 38.7% | 48.6% | 5.9% | 6.8% | Efficiency Vermont |
| HVAC Pump Motor (cooling) | C37 | 7.8% | 9.8% | 36.8% | 45.6% | Efficiency Vermont |
| HVAC Pump Motor (unknown use) | C38 | 23.2% | 29.2% | 21.4% | 26.2% | Efficiency Vermont |
| VFD - Supply fans <10 HP | C39 | 38.8% | 16.1% | 28.4% | 16.7% | Efficiency Vermont |
| VFD - Return fans <10 HP | C40 | 38.8% | 16.1% | 28.4% | 16.7% | Efficiency Vermont |
| VFD - Exhaust fans <10 HP | C41 | 34.8% | 23.2% | 20.3% | 21.7% | Efficiency Vermont |
| VFD - Boiler feedwater pumps <10 HP | C42 | 42.9% | 44.2% | 6.6% | 6.3% | Efficiency Vermont |
| VFD - Chilled water pumps <10 HP | C43 | 11.2% | 5.5% | 40.7% | 42.6% | Efficiency Vermont |
| VFD Boiler circulation pumps <10 HP | C44 | 42.9% | 44.2% | 6.6% | 6.3% | Efficiency Vermont |
| Refrigeration Economizer | C45 | 36.3% | 50.8% | 5.6% | 7.3% | Efficiency Vermont |
| Evaporator Fan Control | C46 | 24.0% | 35.9% | 16.7% | 23.4% | Efficiency Vermont |
| Standby Losses - Commercial Office | C47 | 8.2% | 50.5% | 5.6% | 35.7% | Efficiency Vermont |
| VFD Boiler draft fans <10 HP | C48 | 37.3% | 48.9% | 6.4% | 7.3% | Efficiency Vermont |
| VFD Cooling Tower Fans <10 HP | C49 | 7.9% | 5.2% | 54.0% | 32.9% | Efficiency Vermont |
| Engine Block Heater Timer | C50 | 26.5% | 61.0% | 4.1% | 8.5% | Efficiency Vermont |
| Door Heater Control | C51 | 30.4% | 69.6% | 0.0% | 0.0% | Efficiency Vermont |
| Beverage and Snack Machine Controls | C52 | 10.0% | 48.3% | 7.4% | 34.3% | Efficiency Vermont |
| Flat | C53 | 36.3% | 21.8% | 26.2% | 15.7% | Itron eShapes |
| Religious Indoor Lighting | C54 | 26.8% | 31.4% | 18.9% | 22.8% | Efficiency Vermont |
| Commercial Clothes Washer | C55 | 47.0% | 11.1% | 34.0% | 8.0% | Itron eShapes[33] |

[33] Assumed equal to R01 Residential Clothes Washer loadshape.

**Table 3.4: Loadshapes by Month and Day of Week**

| | | Jan | | Feb | | Mar | | Apr | | May | | Jun | | Jul | | Aug | | Sep | | Oct | | Nov | | Dec | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S |
| Residential Clothes Washer | R01 | 7.0% | 1.6% | 6.3% | 1.5% | 6.6% | 1.7% | 6.7% | 1.5% | 6.9% | 1.6% | 6.5% | 1.6% | 7.1% | 1.5% | 6.8% | 1.7% | 6.6% | 1.6% | 7.0% | 1.5% | 6.5% | 1.7% | 6.9% | 1.6% |
| Residential Dish Washer | R02 | 7.3% | 1.2% | 6.6% | 1.2% | 7.0% | 1.4% | 7.1% | 1.2% | 7.3% | 1.2% | 6.9% | 1.3% | 7.4% | 1.2% | 7.1% | 1.3% | 7.0% | 1.2% | 7.4% | 1.2% | 6.8% | 1.3% | 7.2% | 1.3% |
| Residential Electric DHW | R03 | 6.4% | 2.9% | 5.8% | 2.7% | 6.1% | 3.3% | 6.2% | 2.8% | 5.0% | 2.3% | 4.7% | 2.4% | 5.1% | 2.2% | 4.9% | 2.5% | 4.8% | 2.3% | 6.5% | 2.8% | 6.0% | 3.1% | 6.3% | 3.0% |
| Residential Freezer | R04 | 5.8% | 2.3% | 5.2% | 2.2% | 5.5% | 2.6% | 5.6% | 2.2% | 6.4% | 2.6% | 6.1% | 2.7% | 6.6% | 2.5% | 6.3% | 2.8% | 6.1% | 2.6% | 5.8% | 2.2% | 5.4% | 2.4% | 5.7% | 2.4% |
| Residential Refrigerator | R05 | 5.5% | 2.6% | 4.9% | 2.4% | 5.2% | 2.9% | 5.3% | 2.5% | 6.2% | 2.9% | 5.8% | 3.0% | 6.3% | 2.8% | 6.0% | 3.1% | 5.9% | 2.9% | 5.5% | 2.5% | 5.1% | 2.7% | 5.4% | 2.6% |
| Residential Indoor Lighting | R06 | 5.9% | 2.7% | 5.7% | 2.2% | 6.5% | 2.2% | 5.5% | 2.7% | 5.8% | 2.5% | 5.1% | 1.9% | 4.8% | 2.4% | 5.6% | 2.0% | 5.9% | 3.0% | 6.6% | 2.7% | 6.4% | 2.8% | 5.9% | 3.3% |
| Residential Outdoor Lighting | R07 | 2.7% | 6.2% | 2.4% | 5.9% | 2.6% | 7.0% | 2.6% | 6.0% | 1.9% | 5.7% | 1.8% | 5.8% | 2.0% | 5.3% | 1.9% | 6.0% | 1.8% | 5.7% | 2.7% | 6.0% | 2.5% | 6.6% | 2.6% | 6.4% |
| Residential Cooling | R08 | 0.6% | 0.1% | 0.5% | 0.1% | 0.6% | 0.1% | 0.6% | 0.1% | 14.6% | 4.8% | 13.7% | 4.9% | 14.9% | 4.5% | 14.2% | 5.0% | 13.9% | 4.8% | 0.6% | 0.1% | 0.6% | 0.1% | 0.6% | 0.1% |
| Residential Electric Space Heat | R09 | 8.6% | 5.5% | 7.7% | 5.1% | 8.2% | 6.1% | 8.3% | 5.3% | 0.3% | 0.3% | 0.3% | 0.3% | 0.4% | 0.3% | 0.3% | 0.4% | 0.3% | 0.3% | 8.7% | 5.3% | 8.0% | 5.8% | 8.5% | 5.6% |
| Residential Electric Heating and Cooling | R10 | 5.2% | 3.2% | 4.7% | 3.0% | 5.0% | 3.6% | 5.0% | 3.1% | 6.3% | 2.2% | 6.0% | 2.3% | 6.5% | 2.1% | 6.2% | 2.3% | 6.0% | 2.2% | 5.3% | 3.1% | 4.9% | 3.4% | 5.2% | 3.3% |
| Residential Ventilation | R11 | 3.8% | 4.6% | 3.4% | 4.3% | 3.6% | 5.1% | 3.7% | 4.4% | 3.8% | 4.6% | 3.6% | 4.7% | 3.9% | 4.3% | 3.8% | 4.8% | 3.7% | 4.6% | 3.9% | 4.4% | 3.6% | 4.8% | 3.8% | 4.7% |
| Residential - Dehumidifier | R12 | 1.9% | 2.3% | 1.7% | 2.2% | 1.8% | 2.6% | 1.8% | 2.2% | 6.5% | 7.8% | 6.1% | 8.0% | 6.6% | 7.3% | 6.3% | 8.2% | 6.2% | 7.8% | 1.9% | 2.2% | 1.8% | 2.4% | 1.9% | 2.4% |
| Residential Standby Losses - Entertainment Center | R13 | 3.8% | 4.6% | 3.5% | 4.3% | 3.7% | 5.1% | 3.7% | 4.4% | 3.9% | 4.5% | 3.7% | 4.6% | 4.0% | 4.2% | 3.8% | 4.8% | 3.7% | 4.5% | 3.9% | 4.4% | 3.6% | 4.8% | 3.8% | 4.7% |
| Residential Standby | R14 | 3.5% | 4.9% | 3.2% | 4.6% | 3.4% | 5.5% | 3.4% | 4.7% | 3.5% | 4.9% | 3.3% | 5.0% | 3.5% | 4.6% | 3.4% | 5.2% | 3.3% | 4.9% | 3.6% | 4.7% | 3.3% | 5.2% | 3.5% | 5.0% |

| | | Jan | | Feb | | Mar | | Apr | | May | | Jun | | Jul | | Aug | | Sep | | Oct | | Nov | | Dec | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S |
| Losses - Home Office | | | | | | | | | | | | | | | | | | | | | | | | | |
| Residential Holiday String Lighting | R16 | 9% | 11% | 2% | 3% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 2% | 3% | 9% | 11% | 22% | 28% |
| | | | | | | | | | | | | | | | | | | | | | | | | | |
| Commercial Electric Cooking | C01 | 6.0% | 2.6% | 5.4% | 2.4% | 5.7% | 2.9% | 5.8% | 2.5% | 5.9% | 2.5% | 5.5% | 2.6% | 6.0% | 2.4% | 5.7% | 2.6% | 5.6% | 2.5% | 6.1% | 2.5% | 5.6% | 2.7% | 5.9% | 2.6% |
| Commercial Electric DHW | C02 | 6.0% | 2.6% | 5.4% | 2.4% | 5.7% | 2.9% | 5.8% | 2.5% | 5.8% | 2.5% | 5.5% | 2.6% | 6.0% | 2.4% | 5.7% | 2.7% | 5.6% | 2.5% | 6.1% | 2.5% | 5.6% | 2.7% | 5.9% | 2.6% |
| Commercial Cooling | C03 | 0.7% | 0.1% | 0.6% | 0.1% | 0.7% | 0.1% | 0.7% | 0.1% | 13.6% | 5.5% | 12.8% | 5.7% | 13.9% | 5.2% | 13.3% | 5.9% | 13.0% | 5.5% | 0.7% | 0.1% | 0.7% | 0.1% | 0.7% | 0.1% |
| Commercial Electric Heating | C04 | 7.9% | 6.1% | 7.1% | 5.7% | 7.6% | 6.8% | 7.7% | 5.9% | 0.4% | 0.3% | 0.4% | 0.3% | 0.4% | 0.3% | 0.4% | 0.3% | 0.4% | 0.3% | 8.0% | 5.9% | 7.4% | 6.5% | 7.8% | 6.3% |
| Commercial Electric Heating and Cooling | C05 | 2.9% | 1.9% | 2.6% | 1.8% | 2.8% | 2.1% | 2.8% | 1.9% | 9.6% | 4.0% | 9.1% | 4.1% | 9.8% | 3.7% | 9.4% | 4.2% | 9.2% | 4.0% | 2.9% | 1.9% | 2.7% | 2.0% | 2.8% | 2.0% |
| Commercial Indoor Lighting | C06 | 5.5% | 2.8% | 5.2% | 2.3% | 6.2% | 2.2% | 5.4% | 2.7 % | 6.1% | 2.4% | 6.2% | 2.3% | 5.5% | 3.0% | 6.5% | 2.2% | 5.5% | 2.7 % | 5.9% | 2.5% | 5.7% | 2.5% | 5.4% | 3.1% |
| Grocery/Conv. Store Indoor Lighting | C07 | 5.7% | 2.8% | 5.5% | 2.2% | 6.3% | 2.2% | 5.5% | 2.8% | 6.0% | 2.5% | 6.0% | 2.2% | 5.4% | 3.0% | 6.3% | 2.2% | 5.5% | 2.8% | 6.0% | 2.5% | 5.7% | 2.5% | 5.5% | 3.0% |
| Health Indoor Lighting | C08 | 5.4% | 2.9% | 5.3% | 2.4% | 6.4% | 2.2% | 5.5% | 2.7% | 6.0% | 2.4% | 6.0% | 2.1% | 5.5% | 3.0% | 6.4% | 2.3% | 5.5% | 2.7% | 6.0% | 2.4% | 5.8% | 2.4% | 5.2% | 3.3% |
| Office Indoor Lighting | C09 | 5.2% | 3.0% | 5.1% | 2.6% | 6.3% | 2.4% | 5.3% | 3.0% | 5.7% | 2.6% | 6.0% | 2.4% | 5.3% | 3.2% | 6.3% | 2.3% | 5.2% | 2.9% | 5.5% | 2.7% | 5.5% | 2.8% | 5.2% | 3.3% |
| Restaurant Indoor Lighting | C10 | 4.8% | 3.6% | 4.3% | 3.4% | 4.5% | 4.1% | 4.6% | 3.5% | 4.8% | 3.7% | 4.5% | 3.8% | 4.9% | 3.5% | 4.7% | 4.0% | 4.6% | 3.7% | 4.8% | 3.5% | 4.4% | 3.8% | 4.7% | 3.7% |
| Retail Indoor Lighting | C11 | 5.6% | 2.8% | 5.4% | 2.3% | 6.3% | 2.3% | 5.5% | 2.8% | 6.0% | 2.5% | 6.0% | 2.2% | 5.4% | 3.0% | 6.4% | 2.3% | 5.5% | 2.7% | 5.9% | 2.5% | 5.7% | 2.5% | 5.5% | 3.1% |
| Warehouse Indoor Lighting | C12 | 5.4% | 2.8% | 4.7% | 2.1% | 5.8% | 1.9% | 5.0% | 2.3% | 6.5% | 2.3% | 7.1% | 2.2% | 6.2% | 2.8% | 7.3% | 2.2% | 5.8% | 2.6% | 6.0% | 2.3% | 5.9% | 2.4% | 5.3% | 3.2% |
| Education | C13 | 5.1% | 2.8% | 5.7% | 3.3% | 7.8% | 1.9% | 6.9% | 2.5% | 7.2% | 2.1% | 5.5% | 1.6% | 4.2% | 1.7% | 6.4% | 1.6% | 6.3% | 2.4% | 6.6% | 2.1% | 6.2% | 2.1% | 4.9% | 3.0% |

| | | Jan | | Feb | | Mar | | Apr | | May | | Jun | | Jul | | Aug | | Sep | | Oct | | Nov | | Dec | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S |
| Indoor Lighting | | | | | | | | | | | | | | | | | | | | | | | | | |
| Indust. 1-shift (8/5) (e.g., comp. air, lights) | C14 | 7.5% | 1.0% | 6.7% | 1.0% | 7.1% | 1.1% | 7.2% | 1.0% | 7.5% | 1.1% | 7.1% | 1.1% | 7.7% | 1.0% | 7.4% | 1.1% | 7.2% | 1.1% | 7.6% | 1.0% | 7.0% | 1.1% | 7.4% | 1.0% |
| Indust. 2-shift (16/5) (e.g., comp. air, lights) | C15 | 7.0% | 1.4% | 6.3% | 1.4% | 6.7% | 1.6% | 6.8% | 1.4% | 7.1% | 1.5% | 6.7% | 1.5% | 7.3% | 1.4% | 6.9% | 1.6% | 6.8% | 1.5% | 7.1% | 1.4% | 6.6% | 1.5% | 7.0% | 1.5% |
| Indust. 3-shift (24/5) (e.g., comp. air, lights) | C16 | 5.1% | 3.3% | 4.6% | 3.1% | 4.9% | 3.7% | 5.0% | 3.2% | 5.2% | 3.3% | 4.9% | 3.4% | 5.3% | 3.1% | 5.1% | 3.5% | 5.0% | 3.3% | 5.2% | 3.2% | 4.8% | 3.5% | 5.1% | 3.4% |
| Indust. 4-shift (24/7) (e.g., comp. air, lights) | C17 | 3.8% | 4.6% | 3.4% | 4.3% | 3.6% | 5.1% | 3.7% | 4.4% | 3.8% | 4.6% | 3.6% | 4.7% | 3.9% | 4.3% | 3.8% | 4.8% | 3.7% | 4.6% | 3.9% | 4.4% | 3.6% | 4.8% | 3.8% | 4.7% |
| Industrial Indoor Lighting | C18 | 6.6% | 1.9% | 5.9% | 1.8% | 6.3% | 2.1% | 6.3% | 1.9% | 6.6% | 1.9% | 6.2% | 2.0% | 6.8% | 1.8% | 6.5% | 2.0% | 6.3% | 1.9% | 6.6% | 1.9% | 6.1% | 2.0% | 6.5% | 2.0% |
| Industrial Outdoor Lighting | C19 | 2.7% | 6.2% | 2.4% | 5.9% | 2.6% | 7.0% | 2.6% | 6.0% | 1.9% | 5.7% | 1.8% | 5.8% | 2.0% | 5.3% | 1.9% | 6.0% | 1.8% | 5.7% | 2.7% | 6.0% | 2.5% | 6.6% | 2.6% | 6.4% |
| Commercial Outdoor Lighting | C20 | 6.1% | 3.2% | 6.3% | 2.5% | 6.8% | 2.4% | 5.3% | 2.7 % | 5.8% | 2.4% | 5.2% | 1.9% | 4.8% | 2.6% | 5.8% | 2.0% | 5.5% | 2.7 % | 6.0% | 2.5% | 5.8% | 2.5% | 6.0% | 3.4% |
| Commercial Office Equipment | C21 | 5.6% | 3.0% | 5.0% | 2.8% | 5.3% | 3.3% | 5.4% | 2.9% | 5.4% | 2.9% | 5.1% | 3.0% | 5.6% | 2.7% | 5.3% | 3.1% | 5.2% | 2.9% | 5.6% | 2.9% | 5.2% | 3.1% | 5.5% | 3.0% |
| Commercial Refrigeration | C22 | 5.7% | 2.9% | 5.1% | 2.7% | 5.4% | 3.2% | 5.5% | 2.8% | 5.5% | 2.8% | 5.1% | 2.9% | 5.6% | 2.7% | 5.3% | 3.0% | 5.2% | 2.8% | 5.8% | 2.8% | 5.3% | 3.1% | 5.6% | 3.0% |
| Commercial Ventilation | C23 | 5.6% | 2.9% | 5.1% | 2.7% | 5.4% | 3.3% | 5.4% | 2.8% | 6.1% | 2.3% | 5.7% | 2.4% | 6.2% | 2.2% | 5.9% | 2.4% | 5.8% | 2.3% | 5.7% | 2.8% | 5.3% | 3.1% | 5.6% | 3.0% |
| Traffic Signal - Red Balls, always changing or flashing | C24 | 3.8% | 4.6% | 3.4% | 4.3% | 3.6% | 5.1% | 3.7% | 4.4% | 3.8% | 4.6% | 3.6% | 4.7% | 3.9% | 4.3% | 3.8% | 4.8% | 3.7% | 4.6% | 3.9% | 4.4% | 3.6% | 4.8% | 3.8% | 4.7% |

| | | Jan | | Feb | | Mar | | Apr | | May | | Jun | | Jul | | Aug | | Sep | | Oct | | Nov | | Dec | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S |
| Traffic Signal - Red Balls, changing day, off night | C25 | 5.5% | 2.9% | 4.9% | 2.8% | 5.2% | 3.3% | 5.3% | 2.9% | 5.5% | 3.0% | 5.2% | 3.1% | 5.7% | 2.8% | 5.4% | 3.1% | 5.3% | 3.0% | 5.5% | 2.9% | 5.1% | 3.1% | 5.4% | 3.0% |
| Traffic Signal - Green Balls, always changing | C26 | 3.8% | 4.6% | 3.4% | 4.3% | 3.6% | 5.1% | 3.7% | 4.4% | 3.8% | 4.6% | 3.6% | 4.7% | 3.9% | 4.3% | 3.8% | 4.8% | 3.7% | 4.6% | 3.9% | 4.4% | 3.6% | 4.8% | 3.8% | 4.7% |
| Traffic Signal - Green Balls, changing day, off night | C27 | 5.5% | 2.9% | 4.9% | 2.8% | 5.2% | 3.3% | 5.3% | 2.9% | 5.5% | 3.0% | 5.2% | 3.1% | 5.7% | 2.8% | 5.4% | 3.1% | 5.3% | 3.0% | 5.5% | 2.9% | 5.1% | 3.1% | 5.4% | 3.0% |
| Traffic Signal - Red Arrows | C28 | 3.8% | 4.6% | 3.4% | 4.3% | 3.6% | 5.1% | 3.7% | 4.4% | 3.8% | 4.6% | 3.6% | 4.7% | 3.9% | 4.3% | 3.8% | 4.8% | 3.7% | 4.6% | 3.9% | 4.4% | 3.6% | 4.8% | 3.8% | 4.7% |
| Traffic Signal - Green Arrows | C29 | 3.8% | 4.6% | 3.4% | 4.3% | 3.6% | 5.1% | 3.7% | 4.4% | 3.8% | 4.6% | 3.6% | 4.7% | 3.9% | 4.3% | 3.8% | 4.8% | 3.7% | 4.6% | 3.9% | 4.4% | 3.6% | 4.8% | 3.8% | 4.7% |
| Traffic Signal - Flashing Yellows | C30 | 3.8% | 4.6% | 3.4% | 4.3% | 3.6% | 5.1% | 3.7% | 4.4% | 3.8% | 4.6% | 3.6% | 4.7% | 3.9% | 4.3% | 3.8% | 4.8% | 3.7% | 4.6% | 3.9% | 4.4% | 3.6% | 4.8% | 3.8% | 4.7% |
| Traffic Signal - “Hand” Don’t Walk Signal | C31 | 3.8% | 4.6% | 3.4% | 4.3% | 3.6% | 5.1% | 3.7% | 4.4% | 3.8% | 4.6% | 3.6% | 4.7% | 3.9% | 4.3% | 3.8% | 4.8% | 3.7% | 4.6% | 3.9% | 4.4% | 3.6% | 4.8% | 3.8% | 4.7% |
| Traffic Signal - “Man” Walk Signal | C32 | 3.8% | 4.6% | 3.4% | 4.3% | 3.6% | 5.1% | 3.7% | 4.4% | 3.8% | 4.6% | 3.6% | 4.7% | 3.9% | 4.3% | 3.8% | 4.8% | 3.7% | 4.6% | 3.9% | 4.4% | 3.6% | 4.8% | 3.8% | 4.7% |
| Traffic Signal - Bi-Modal Walk/Don’t Walk | C33 | 3.8% | 4.6% | 3.4% | 4.3% | 3.6% | 5.1% | 3.7% | 4.4% | 3.8% | 4.6% | 3.6% | 4.7% | 3.9% | 4.3% | 3.8% | 4.8% | 3.7% | 4.6% | 3.9% | 4.4% | 3.6% | 4.8% | 3.8% | 4.7% |
| Industrial Motor | C34 | 7.0% | 1.4% | 6.3% | 1.4% | 6.7% | 1.6% | 6.8% | 1.4% | 7.1% | 1.5% | 6.7% | 1.5% | 7.3% | 1.4% | 6.9% | 1.6% | 6.8% | 1.5% | 7.1% | 1.4% | 6.6% | 1.5% | 7.0% | 1.5% |
| Industrial Process | C35 | 7.0% | 1.4% | 6.3% | 1.4% | 6.7% | 1.6% | 6.8% | 1.4% | 7.1% | 1.5% | 6.7% | 1.5% | 7.3% | 1.4% | 6.9% | 1.6% | 6.8% | 1.5% | 7.1% | 1.4% | 6.6% | 1.5% | 7.0% | 1.5% |
| HVAC Pump Motor (heating) | C36 | 5.7% | 6.9% | 5.2% | 6.4% | 5.5% | 7.7% | 5.5% | 6.6% | 1.2% | 1.4% | 1.1% | 1.4% | 1.2% | 1.3% | 1.2% | 1.4% | 1.2% | 1.4% | 5.8% | 6.6% | 5.3% | 7.3% | 5.7% | 7.1% |
| HVAC Pump Motor (cooling) | C37 | 1.2% | 1.4% | 1.0% | 1.3% | 1.1% | 1.5% | 1.1% | 1.3% | 7.5% | 9.1% | 7.1% | 9.3% | 7.7% | 8.5% | 7.3% | 9.6% | 7.2% | 9.1% | 1.2% | 1.3% | 1.1% | 1.5% | 1.1% | 1.4% |

| | | Jan | | Feb | | Mar | | Apr | | May | | Jun | | Jul | | Aug | | Sep | | Oct | | Nov | | Dec | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S |
| HVAC Pump Motor (unknown use) | C38 | 3.4% | 4.1% | 3.1% | 3.9% | 3.3% | 4.6% | 3.3% | 4.0% | 4.4% | 5.2% | 4.1% | 5.4% | 4.5% | 4.9% | 4.3% | 5.5% | 4.2% | 5.2% | 3.5% | 4.0% | 3.2% | 4.4% | 3.4% | 4.2% |
| VFD - Supply fans <10 HP | C39 | 5.7% | 2.3% | 5.2% | 2.1% | 5.5% | 2.5% | 5.6% | 2.2% | 5.8% | 3.3% | 5.5% | 3.4% | 5.9% | 3.1% | 5.7% | 3.5% | 5.5% | 3.3% | 5.8% | 2.2% | 5.4% | 2.4% | 5.7% | 2.3% |
| VFD - Return fans <10 HP | C40 | 5.7% | 2.3% | 5.2% | 2.1% | 5.5% | 2.5% | 5.6% | 2.2% | 5.8% | 3.3% | 5.5% | 3.4% | 5.9% | 3.1% | 5.7% | 3.5% | 5.5% | 3.3% | 5.8% | 2.2% | 5.4% | 2.4% | 5.7% | 2.3% |
| VFD - Exhaust fans <10 HP | C41 | 5.1% | 3.3% | 4.6% | 3.1% | 4.9% | 3.7% | 5.0% | 3.2% | 4.1% | 4.3% | 3.9% | 4.4% | 4.2% | 4.1% | 4.1% | 4.6% | 4.0% | 4.3% | 5.2% | 3.2% | 4.8% | 3.5% | 5.1% | 3.4% |
| VFD - Boiler feedwater pumps <10 HP | C42 | 6.4% | 6.2% | 5.7% | 5.9% | 6.1% | 7.0% | 6.1% | 6.0% | 1.3% | 1.3% | 1.3% | 1.3% | 1.4% | 1.2% | 1.3% | 1.3% | 1.3% | 1.3% | 6.4% | 6.0% | 5.9% | 6.6% | 6.3% | 6.4% |
| VFD - Chilled water pumps <10 HP | C43 | 1.7% | 0.8% | 1.5% | 0.7% | 1.6% | 0.9% | 1.6% | 0.8% | 8.3% | 8.5% | 7.8% | 8.7% | 8.5% | 8.0% | 8.1% | 8.9% | 7.9% | 8.5% | 1.7% | 0.8% | 1.6% | 0.8% | 1.6% | 0.8% |
| VFD Boiler circulation pumps <10 HP | C44 | 6.4% | 6.2% | 5.7% | 5.9% | 6.1% | 7.0% | 6.1% | 6.0% | 1.3% | 1.3% | 1.3% | 1.3% | 1.4% | 1.2% | 1.3% | 1.3% | 1.3% | 1.3% | 6.4% | 6.0% | 5.9% | 6.6% | 6.3% | 6.4% |
| Refrigeration Economizer | C45 | 5.4% | 7.2% | 4.8% | 6.7% | 5.1% | 8.0% | 5.2% | 7.0% | 1.1% | 1.5% | 1.1% | 1.5% | 1.2% | 1.4% | 1.1% | 1.5% | 1.1% | 1.5% | 5.4% | 7.0% | 5.0% | 7.6% | 5.3% | 7.4% |
| Evaporator Fan Control | C46 | 3.6% | 5.1% | 3.2% | 4.8% | 3.4% | 5.7% | 3.4% | 4.9% | 3.4% | 4.7% | 3.2% | 4.8% | 3.5% | 4.4% | 3.3% | 4.9% | 3.3% | 4.7% | 3.6% | 4.9% | 3.3% | 5.4% | 3.5% | 5.2% |
| Standby Losses - Commercial Office | C47 | 1.2% | 7.1% | 1.1% | 6.7% | 1.2% | 8.0% | 1.2% | 6.9% | 1.1% | 7.1% | 1.1% | 7.3% | 1.2% | 6.7% | 1.1% | 7.5% | 1.1% | 7.1% | 1.2% | 6.9% | 1.1% | 7.5% | 1.2% | 7.3% |
| VFD Boiler draft fans <10 HP | C48 | 5.5% | 6.9% | 5.0% | 6.5% | 5.3% | 7.7% | 5.3% | 6.7% | 1.3% | 1.5% | 1.2% | 1.5% | 1.3% | 1.4% | 1.3% | 1.5% | 1.2% | 1.5% | 5.6% | 6.7% | 5.2% | 7.3% | 5.5% | 7.1% |
| VFD Cooling Tower Fans <10 HP | C49 | 1.2% | 0.7% | 1.1% | 0.7% | 1.1% | 0.8% | 1.1% | 0.7% | 11.0% | 6.5% | 10.4% | 6.7% | 11.3% | 6.2% | 10.8% | 6.9% | 10.5% | 6.5% | 1.2% | 0.7% | 1.1% | 0.8% | 1.2% | 0.8% |
| Engine Block Heater Timer | C50 | 3.9% | 8.6% | 3.5% | 8.1% | 3.7% | 9.6% | 3.8% | 8.3% | 0.8% | 1.7% | 0.8% | 1.7% | 0.8% | 1.6% | 0.8% | 1.8% | 0.8% | 1.7% | 4.0% | 8.3% | 3.7% | 9.1% | 3.9% | 8.9% |
| Door Heater Control | C51 | 4.5% | 9.8% | 4.0% | 9.2% | 4.3% | 11.0% | 4.3% | 9.5% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 4.5% | 9.5% | 4.2% | 10.4% | 4.4% | 10.1 % |

| | | Jan | | Feb | | Mar | | Apr | | May | | Jun | | Jul | | Aug | | Sep | | Oct | | Nov | | Dec | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S | M-F | S-S |
| Beverage and Snack Machine Controls | C52 | 1.5% | 6.8% | 1.3% | 6.4% | 1.4% | 7.6% | 1.4% | 6.6% | 1.5% | 6.8% | 1.4% | 7.0% | 1.5% | 6.4% | 1.5% | 7.2% | 1.4% | 6.8% | 1.5% | 6.6% | 1.4% | 7.2% | 1.5% | 7.0% |
| Flat | C53 | 5.4% | 3.1% | 4.8% | 2.9% | 5.1% | 3.4% | 5.2% | 3.0% | 5.3% | 3.1% | 5.0% | 3.2% | 5.5% | 2.9% | 5.2% | 3.3% | 5.1% | 3.1% | 5.4% | 3.0% | 5.0% | 3.3% | 5.3% | 3.2% |
| Religious Indoor Lighting | C54 | 4.0% | 4.4% | 3.6% | 4.2% | 3.8% | 5.0% | 3.8% | 4.3% | 3.9% | 4.5% | 3.6% | 4.7% | 3.9% | 4.3% | 3.8% | 4.8% | 3.7% | 4.5% | 4.0% | 4.3% | 3.7% | 4.7% | 3.9% | 4.6% |
| Commercial Clothes Washer | C55 | 7.0% | 1.6% | 6.3% | 1.5% | 6.6% | 1.7% | 6.7% | 1.5% | 6.9% | 1.6% | 6.5% | 1.6% | 7.1% | 1.5% | 6.8% | 1.7% | 6.6% | 1.6% | 7.0% | 1.5% | 6.5% | 1.7% | 6.9% | 1.6% |

## 3.6 Summer Peak Period Definition (kW)

To estimate the impact that an efficiency measure has on a utility's system peak, the peak itself needs to be defined. Illinois spans two different electrical control areas, the Pennsylvania – Jersey – Maryland (PJM) and the Midwest Independent System Operators (MISO). As a result, there is some disparity in the peak definition across the state. However, only PJM has a forward capacity market where an efficiency program can potentially participate. Because ComEd is part of the PJM control area, their definition of summer peak is being applied statewide in this TRM.

Because Illinois is a summer peaking state, only the summer peak period is defined for the purpose of this TRM. The coincident summer peak period is defined as 1:00-5:00 PM Central Prevailing Time on non-holiday weekdays, June through August.

Summer peak coincidence factors can be found within each measure characterization. The source is provided and is based upon evaluation results, analysis of load shape data (e.g., the Itron eShapes data provided by Ameren), or through a calculation using stated assumptions.

For measures that are not weather-sensitive, the summer peak coincidence factor is estimated whenever possible as the average of savings within the peak period defined above. For weather sensitive measures such as cooling, the summer peak coincidence factor is provided in two different ways. The first method is to estimate demand savings during the utility's peak hour (as provided by Ameren). This is likely to be the most indicative of actual peak benefits. The second way represents the average savings over the summer peak period, consistent with the non-weather sensitive end uses, and is presented so that savings can be bid into PJM's Forward Capacity Market.

## 3.7 Heating and Cooling Degree-Day Data

Many measures are weather sensitive. Because there is a range of climactic conditions across the state, VEIC engaged the Utilities to provide their preferences for what airports and cities are the best proxies for the weather in their service territories. The result of this engagement is in the table below. All of the data represents 30-year normals[34] from the National Climactic Data Center (NCDC). Note that the base temperature for the calculation of heating degree-days in this document does not follow the historical 65F degree base temperature convention. Instead VEIC used several different temperatures in this TRM to more accurately reflect the outdoor temperature when a heating or cooling system turns on.

Residential heating is based on 60F, in accordance with regression analysis of heating fuel use and weather by state by the Pacific Northwest National Laboratory[35]. Residential cooling is based on 65F in agreement with a field study in Wisconsin[36]. These are lower than typical thermostat set points because internal gains, such as appliances, lighting, and people, provide some heating. In C&I settings, internal gains are often much higher; the base temperatures for both heating and cooling is 55F[37]. Custom degree-days with building-specific base temperatures are recommended for large C&I projects.

**Table 3.5: Degree-Day Zones and Values by Market Sector**

| | Residential | | C&I | | |
|---|---|---|---|---|---|
| Zone | HDD | CDD | HDD | CDD | Weather Station / City |
| 1 | 5,352 | 820 | 4,272 | 2,173 | Rockford AP / Rockford |
| 2 | 5,113 | 842 | 4,029 | 3,357 | Chicago O'Hare AP / Chicago |
| 3 | 4,379 | 1,108 | 3,406 | 2,666 | Springfield #2 / Springfield |

[34] 30-year normals have been used instead of Typical Meteorological Year (TMY) data due to the fact that few of the measures in the TRM are significantly affected by solar insolation, which is one of the primary benefits of using the TMY approach.
[35] Belzer and Cort, Pacific Northwest National Laboratory in "Statistical Analysis of Historical State-Level Residential Energy Consumption Trends," 2004.
[36] Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research", p. 32 (amended in 2010).
[37] This value is based upon experience, and it is preferable to use building-specific base temperatures when available.

| | Residential | | C&I | | |
|---|---|---|---|---|---|
| Zone | HDD | CDD | HDD | CDD | Weather Station / City |
| 4 | 3,378 | 1,570 | 2,515 | 3,090 | Belleville SIU RSCH / Belleville |
| 5 | 3,438 | 1,370 | 2,546 | 2,182 | Carbondale Southern IL AP / Marion |
| Average | 4,860 | 947 | 3,812 | 3,051 | Weighted by occupied housing units |
| Base Temp | 60F | 65F | 55F | 55F | 30 year climate normals, 1981-2010 |

This table assigns each of the proxy cities to one of five climate zones. The following graphics from the Illinois State Water Survey show isobars (lines of equal degree-days), and we have color-coded the counties in each of these graphics using those isobars as a dividing line. Using this approach, the state divides into five cooling degree-day zones and five heating degree-day zones. Note that although the heating and cooling degree-day maps are similar, they are not the same, and the result is that there are a total of 10 climate zones in the state. The counties are listed in the tables following the figures for ease of reference. In addition, an Excel file containing all Illinois Zip Codes with the corresponding Heating and Cooling Degree-day zones is provided on the SharePoint site within the 'TRM Reference Documents' section.

**Figure 3.1: Cooling Degree-Day Zones by County**

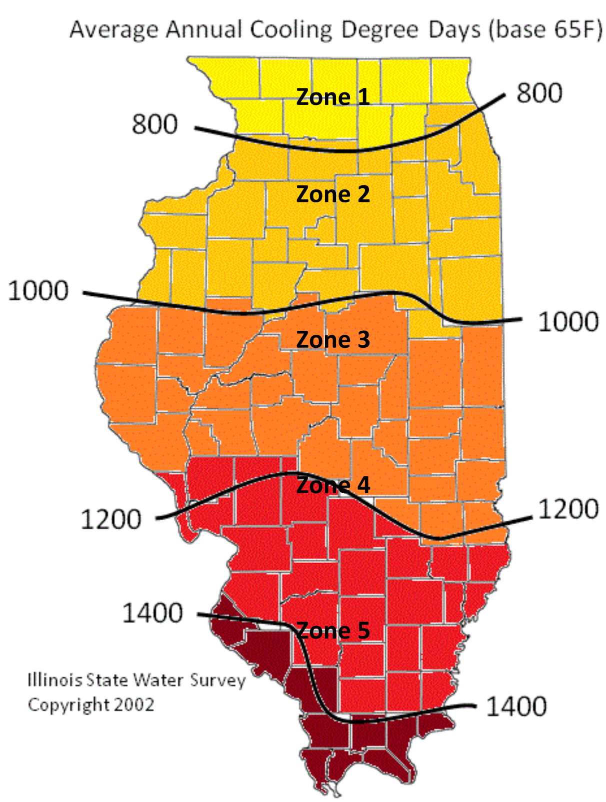


**Figure 3.2: Heating Degree-Day Zones by County**

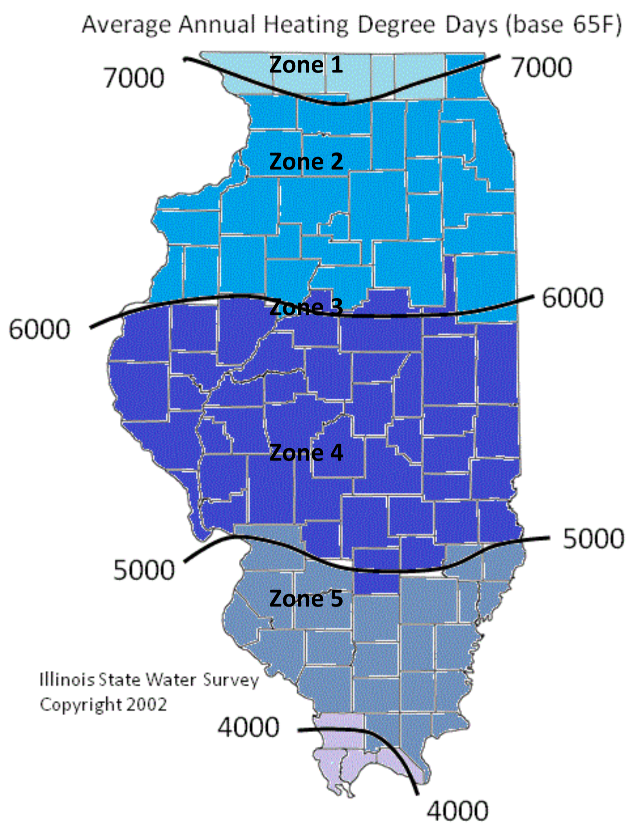



**Table 3.6: Heating Degree-Day Zones by County**

| Zone 1 | Zone 2 | Zone 3 | Zone 4 | Zone 5 |
|---|---|---|---|---|
| Boone County | Bureau County | Adams County | Clinton County | Alexander County |
| Jo Daviess County | Carroll County | Bond County | Edwards County | Massac County |
| Stephenson County | Cook County | Brown County | Franklin County | Pulaski County |
| Winnebago County | DeKalb County | Calhoun County | Gallatin County | Union County |
| | DuPage County | Cass County | Hamilton County | |
| | Grundy County | Champaign County | Hardin County | |
| | Henderson County | Christian County | Jackson County | |
| | Henry County | Clark County | Jefferson County | |
| | Iroquois County | Clay County | Johnson County | |
| | Kane County | Coles County | Lawrence County | |
| | Kankakee County | Crawford County | Madison County | |
| | Kendall County | Cumberland County | Marion County | |
| | Knox County | De Witt County | Monroe County | |
| | Lake County | Douglas County | Perry County | |
| | LaSalle County | Edgar County | Pope County | |
| | Lee County | Effingham County | Randolph County | |
| | Livingston County | Fayette County | Richland County | |
| | Marshall County | Ford County | Saline County | |

| Zone 1 | Zone 2 | Zone 3 | Zone 4 | Zone 5 |
|---|---|---|---|---|
| | McHenry County | Fulton County | St. Clair County | |
| | Mercer County | Greene County | Wabash County | |
| | Ogle County | Hancock County | Washington County | |
| | Peoria County | Jasper County | Wayne County | |
| | Putnam County | Jersey County | White County | |
| | Rock Island County | Logan County | Williamson County | |
| | Stark County | Macon County | | |
| | Warren County | Macoupin County | | |
| | Whiteside County | Mason County | | |
| | Will County | McDonough County | | |
| | Woodford County | McLean County | | |
| | | Menard County | | |
| | | Montgomery | | |
| | | Morgan County | | |
| | | Moultrie County | | |
| | | Piatt County | | |
| | | Pike County | | |
| | | Sangamon County | | |
| | | Schuyler County | | |
| | | Scott County | | |
| | | Shelby County | | |
| | | Tazewell County | | |
| | | Vermilion County | | |

**Table 3.7: Cooling Degree-day Zones by County**

| Zone 1 | Zone 2 | Zone 3 | Zone 4 | Zone 5 |
|---|---|---|---|---|
| Boone County | Bureau County | Adams County | Bond County | Alexander County |
| Carroll County | Cook County | Brown County | Clay County | Hardin County |
| DeKalb County | DuPage County | Calhoun County | Clinton County | Johnson County |
| Jo Daviess County | Grundy County | Cass County | Edwards County | Massac County |
| Kane County | Henderson County | Champaign County | Fayette County | Pope County |
| Lake County | Henry County | Christian County | Franklin County | Pulaski County |
| McHenry County | Iroquois County | Clark County | Gallatin County | Randolph County |
| Ogle County | Kankakee County | Coles County | Hamilton County | Union County |
| Stephenson County | Kendall County | Crawford County | Jackson County | |
| Winnebago County | Knox County | Cumberland County | Jefferson County | |
| | LaSalle County | De Witt County | Jersey County | |
| | Lee County | Douglas County | Lawrence County | |
| | Livingston County | Edgar County | Macoupin County | |
| | Marshall County | Effingham County | Madison County | |
| | Mercer County | Ford County | Marion County | |
| | Peoria County | Fulton County | Monroe County | |
| | Putnam County | Greene County | Montgomery | |
| | Rock Island County | Hancock County | Perry County | |
| | Stark County | Jasper County | Richland County | |
| | Warren County | Logan County | Saline County | |
| | Whiteside County | Macon County | St. Clair County | |
| | Will County | Mason County | Wabash County | |

| Zone 1 | Zone 2 | Zone 3 | Zone 4 | Zone 5 |
|---|---|---|---|---|
| | Woodford County | McDonough County | Washington County | |
| | | McLean County | Wayne County | |
| | | Menard County | White County | |
| | | Morgan County | Williamson County | |
| | | Moultrie County | | |
| | | Piatt County | | |
| | | Pike County | | |
| | | Sangamon County | | |
| | | Schuyler County | | |
| | | Scott County | | |
| | | Shelby County | | |
| | | Tazewell County | | |
| | | Vermilion County | | |

## 3.8 Measure Incremental Cost Definition

Incremental Costs means the difference between the cost of the efficient Measure and the cost of the most relevant baseline measure that would have been installed (if any) in the absence of the efficiency Program. Installation costs (material and labor) and Operations and Maintenance (O&M) costs shall be included if there is a difference between the efficient Measure and the baseline measure. In cases where the efficient Measure has a significantly shorter or longer life than the relevant baseline measure (e.g., LEDs versus halogens), the avoided baseline replacement measure costs should be accounted for in the TRC analysis. The Customer's value of service lost, the Customer's value of their lost amenity, and the Customer's transaction costs shall be included in the TRC analysis where a reasonable estimate or proxy of such costs can be easily obtained (e.g., Program Administrator payment to a Customer to reduce load during a demand response event, Program Administrator payment to a Customer as an inducement to give up duplicative functioning equipment). This Incremental Cost input in the TRC analysis is not reduced by the amount of any Incentives (any Financial Incentives Paid to Customers or Incentives Paid to Third Parties by a Program Administrator that is intended to reduce the price of the efficient Measure to the Customer). Incremental Cost calculations will vary depending on the type of efficient Measure being implemented, as outlined in the examples provided below and as set forth in the IL-TRM.

Examples of Incremental Cost calculations include:

a. The Incremental Cost for an efficient Measure that is installed in new construction or is being purchased at the time of natural installation, investment, or replacement is the additional cost incurred to purchase an efficient Measure over and above the cost of the baseline/standard (i.e., less efficient) measure (including any incremental installation, replacement, or O&M costs if there is a difference between the efficient Measure and baseline measure).

b. For a retrofit Measure where the efficiency Program caused the Customer to update their existing equipment, facility, or processes (e.g., air sealing, insulation, tank wrap, controls), where the Customer would not have otherwise made a purchase, the appropriate baseline is zero expenditure, and the Incremental Cost is the full cost of the new retrofit Measure (including installation costs).

c. For the early replacement of a functioning measure with a new efficient Measure, where the Customer would not have otherwise made a purchase for a number of years, the appropriate baseline is a dual baseline that begins as the existing measure and shifts to the new standard measure after the expected remaining useful life of the existing measure ends. Thus, the Incremental Cost is the full cost of the new efficient Measure (including installation costs) being purchased to replace a still-functioning measure less the present value of the assumed deferred replacement cost of replacing the existing measure with a new baseline measure at the end of the existing measure's life (described in section 3.9). This deferred credit may not be necessary when the lifetime of the measure is short, the costs are very low, or for other reasons (e.g., certain Direct Install Measures, Measures provided in Kits to Customers).

d. For study-based services (e.g., facility energy audits, energy surveys, energy assessments, retro-commissioning) that are truly necessary for a Customer to implement efficient Measures, as opposed to being principally intended to be a form of marketing, the Incremental Cost is the full cost of the study-based service. Even if the study-based service is performed entirely by a Program Administrator’s implementation contractor, the full cost of the study-based service charged by the implementation contractor is the Incremental Cost, because this is assumed to be the cost of the study-based service that would have been incurred by the Customer if the Customer were to have the study-based service performed in the absence of the efficiency Program. If the Customer implements efficient Measures as a result of the study-based service provided by the efficiency Program, the Incremental Cost for those efficient Measures should also be classified as Incremental Costs in the TRC analysis.

e. For the early retirement of duplicative functioning equipment before its expected life is over (e.g., appliance recycling Programs), the Incremental Costs are composed of the Customer’s value placed on their lost amenity, any Customer transaction costs, and the pickup and recycling cost. The Incremental Costs include the actual cost of the pickup and recycling of the equipment (often paid for by a Program Administrator to an implementation contractor) because this is assumed to be the cost of recycling the equipment that would have been incurred by the Customer if the Customer were to recycle the equipment on their own in the absence of the efficiency Program. The payment a Program Administrator makes to the Customer serves as a proxy for the value the Customer places on their lost amenity and any Customer transaction costs.

## 3.9 Discount Rates, Inflation Rates, and O&M Costs

The Illinois Utilities use screening tools that apply an appropriate discount rate to any future costs or benefits. The societal discount rate, required for use by all electric utilities, is defined as a nominal discount rate of 2.38%, or a real (inflation-adjusted) discount rate of 0.46%[38].

Where a future cost is provided within the TRM (e.g., in early replacement measures where a deferred baseline replacement cost is provided) and the future cost has been adjusted using an inflation rate (based upon the 20-year Treasury yield of 1.91%[39]), the nominal discount rate should be used to discount to the present value. Where future costs have not been adjusted for inflation, the real discount rate should be used to discount to present value.

Some measures specify an operations and maintenance (O&M) parameter that describes the incremental O&M cost savings that can be expected over the measure’s lifetime. For most measures the TRM does not specify the NPV of the O&M costs. Instead, the necessary information required to calculate the NPV is included. An example is provided below:

| | |
|---|---|
| Baseline Case: | O&M costs equal $150 every two years. |
| Efficient Case: | O&M costs equal $50 every five years. |

Given this information, the incremental O&M costs can be determined by discounting the cash flows in the Baseline Case and the Efficient Case separately using the real discount rate.

For a select few measures that include baseline shifts that result in multiple component costs and lifetimes over the lifetime of the measure, this standard method cannot be used. In only these cases, the O&M costs are presented both as Annual Levelized equivalent cost (i.e., the annual payment that results in an equivalent NPV to the actual stream of O&M costs) and as NPVs using a real societal discount rate of 0.46%.

## 3.10 Interactive Effects

The TRM presents engineering equations for most measures. This approach is desirable because it conveys information clearly and transparently, and is widely accepted in the industry. Unlike simulation model results,

[38] Based on the current 10 year Treasury bond yield rates, as of January 2017. The 10 year rates are used to be consistent with the average measure life of the measures specified within this TRM.

[39] Established for use in the TRM in late 2015.

engineering equations also provide flexibility and the opportunity for users to substitute local, specific information for specific input values. Furthermore, the parameters can be changed in TRM updates to be applied in future years as better information becomes available.

One limitation is that some interactive effects between measures are not automatically captured. Because we cannot know what measures will be implemented at the same time with the same customer, we cannot always capture the interactions between multiple measures within individual measure characterizations. However, interactive effects with different end-uses are included in individual measure characterizations whenever possible[40]. For instance, waste heat factors are included in the lighting characterizations to capture the interaction between more-efficient lighting measures and the amount of heating and/or cooling that is subsequently needed in the building.

By contrast, no effort is made to account for interactive effects between an efficient air conditioning measure and an efficient lighting measure, because it is impossible to know the specifics of the other measure in advance of its installation. For custom measures and projects where a bundle of measures is being implemented at the same time, these kinds of interactive effects should be estimated.

[40] For more information, please refer to the document, "Dealing with interactive Effects During Measure Characterization" Memo to the Stakeholder Advisory Group dated 12/13/11. http://portal.veic.org/projects/illinoistrm/Shared%20Documents/Memos/Interactive_Effects_Memo_121311.docx

# 2019 Illinois Statewide Technical Reference Manual for Energy Efficiency

# Version 7.0

# Volume 2: Commercial and Industrial Measures

## FINAL

## September 28, 2018

## Effective:

## January 1, 2019

[INTENTIONALLY LEFT BLANK]

# Volume 2: Commercial and Industrial Measures

## 4.1 Agricultural End Use

### 4.1.1 Engine Block Timer for Agricultural Equipment

**DESCRIPTION**

The measure is a plug-in timer that is activated below a specific outdoor temperature to control an engine block heater in agricultural equipment. Engine block heaters are typically used during cold weather to pre-warm an engine prior to start, for convenience, heaters are typically plugged in considerably longer than necessary to improve startup performance. A timer allows a user to preset the heater to come on for only the amount of time necessary to pre-warm the engine block, reducing unnecessary run time even if the baseline equipment has an engine block temperature sensor.

This measure was developed to be applicable to the following program types: RF. If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

The efficient measure is an engine block heater operated by an outdoor plug-in timer (15 amp or greater) that turns on the heater only when the outdoor temperature is below 25 °F.

**DEFINITION OF BASELINE EQUIPMENT**

The baseline scenario is an engine block heater that is manually plugged in by the farmer to facilitate equipment startup at a later time.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected measure life if assumed to be 3 years[1]

**DEEMED MEASURE COST**

The incremental cost per installed plug-in timer is $10.19[2].

**COINCIDENCE FACTOR**

Engine block timers only operate in the winter so the summer peak demand savings is zero.

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

$$\Delta kWh = ISR * Use\ Season * \%Days * HrSave/Day * kW_{heater} - ParaLd$$

Where:

ISR = In Service Rate

= 78.39%[3]

[1] Equipment life is expected to be longer, but measure life is more conservative to account for possible attrition in use over time.

[2] Based on bulk pricing reported by EnSave, which administers the rebate in Vermont

[3] Efficiency Vermont (EVT) Technical Reference Manual (TRM), Measure Savings Algorithms and Cost Assumptions, March 16, 2015. Based on field study conducted by Efficiency Vermont on 352 sites in Vermont and Minnesota.

Use Season = The number of days in the use season in which the temperature drops below 25°F in the state of Illinois

= 75 days[4]

%Days = Propoortion of days timer is used with the Use Season

= 84.23%[5]

HrSave/Day = Hours of savings per day when timer is used

= 7.765 hours per day[6]

$kW_{heater}$ = Connected load of the engine block heater

= 1.5 kW[7]

ParaLd = Parasitic load

= 5.46 kWh[8]

For example, using the default assumptions on the installation of a timer on an engine block with a 1.5 kW heater:

$$\Delta kWh = 78.39\% * 75 \text{ days} * 84.23\% * 7.765 \text{ Hr/Day} * 1.5 \text{ kW} - 5.46 \text{ kWh}$$

$$= 571 \text{ kWh}$$

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

N/A

**NATURAL GAS ENERGY SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-AGE-EBLT-V02-190101**

**REVIEW DEADLINE: 1/1/2024**

[4] The number of days in the use season in which the temperature drops below 25°F in the state of Illinois. The data is sourced as an average from TMY3 weather data for five different weather zones within the state.
[5] EVT TRM, March 16, 2015. Based on field study conducted by EVT on 352 sites in Vermont and Minnesota.
[6] Ibid. The hours per day saved is sourced as the difference between the baseline run hours per day without the timer, 10.66 hours, and the efficient run hours per day with the timer, 2.90 hours.
[7] Ibid. Based on an average sized engine block heater, which typically ranges in connected load from 0.20 kW and 2 kW, as sourced from Efficiency Vermont program data.
[8] Ibid.

## 4.1.2 High Volume Low Speed Fans

### Description

The measure applies to 20-24 foot diameter horizontally mounted ceiling high volume low speed (HVLS) fans that are replacing multiple non HVLS fans that have reached the end of useful life in agricultural applications.

This measure was developed to be applicable to the following program types: TOS. If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

In order for this characterization to apply, the efficient equipment is assumed to be classified as HVLS and have a VFD[9].

### Definition of Baseline Equipment

In order for this characterization to apply, the baseline condition is assumed to be multiple non HVLS existing fans that have reached the end of useful life.

### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 10 years[10].

### Deemed Measure Cost

The incremental capital cost for the fans are as follows[11]:

| Fan Diameter Size (feet) | Incremental Cost |
|---|---|
| 20 | $4150 |
| 22 | $4180 |
| 24 | $4225 |

### Loadshape

Loadshape C34 - Industrial Motor

### Coincidence Factor

The measure has deemed kW savings therefore, a coincidence factor is not applied.

**Algorithm**

### Calculation of Savings

### Electric Energy Savings [12]

The annual electric savings from this measure are deemed values depending on fan size and apply to all building types:

| Fan Diameter Size (feet) | kWh Savings |
|---|---|
| 20 | 6,577 |
| 22 | 8,543 |
| 24 | 10,018 |

[9] Act on Energy Commercial Technical Reference Manual No. 2010-4
[10] Ibid.
[11] Ibid.
[12] Ibid.

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**[13]

The annual kW savings from this measure are deemed values depending on fan size and apply to all building types:

| Fan Diameter Sixe (feet) | kW Savings |
|---|---|
| 20 | 2.4 |
| 22 | 3.1 |
| 24 | 3.7 |

**NATURAL GAS ENERGY SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-AGE-HVSF-V02-190101**

**REVIEW DEADLINE: 1/1/2024**

[13] Ibid.

## 4.1.3 High Speed Fans

### Description

The measure applies to high speed exhaust, ventilation and circulation fans that are replacing an existing unit that reached the end of its useful life in agricultural applications.

This measure was developed to be applicable to the following program types: TOS. If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

In order for this characterization to apply, the efficient equipment is assumed to be diffuser equipped and meet the following minimum efficiency criteria[14].

| Diameter of Fan (inches) | Minimum Efficiency for Exhasut & Ventilation Fans | Minimum Efficiency for Circulation Fans |
|---|---|---|
| 24 through 35 | 14.0 cfm/W at 0.10 static pressure | 12.5 lbf/kW |
| 36 through 47 | 17.1 cfm/W at 0.10 static pressure | 18.2 lbf/kW |
| 48 through 71 | 20.3 cfm/W at 0.10 static pressure | 23.0 lbf/kW |

### Definition of Baseline Equipment

In order for this characterization to apply, the baseline condition is assumed to be an existing fan that reached the end of its useful life.

### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 7 years[15].

### Deemed Measure Cost

The incremental capital cost for all fan sizes is $150[16].

### Loadshape

Loadshape C34 - Industrial Motor

### Coincidence Factor

The measure has deemed kW savings therefore, a coincidence factor is not applied.

**Algorithm**

### Calculation of Savings

### Electric Energy Savings [17]

The annual electric savings from this measure are deemed values depending on fan size and apply to all building types:

| Diameter of Fan (inches) | kWh |
|---|---|
| 24 through 35 | 372 |
| 36 through 47 | 625 |

[14] Act on Energy Commercial Technical Reference Manual No. 2010-4
[15] Ibid.
[16] Ibid.
[17] Ibid.

| Diameter of Fan (inches) | kWh |
|---|---|
| 48 through 71 | 1,122 |

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**[18]

The annual kW savings from this measure are deemed values depending on fan size and apply to all building types:

| Diameter of Fan (inches) | kW |
|---|---|
| 24 through 35 | 0.118 |
| 36 through 47 | 0.198 |
| 48 through 71 | 0.356 |

**NATURAL GAS ENERGY SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-AGE-HSF_-V02-190101**

**REVIEW DEADLINE: 1/1/2024**

[18] Ibid.

### 4.1.4 Livestock Waterer

**DESCRIPTION**

This measure applies to the replacement of electric open waterers with sinking or floating water heaters with equivalent herd size watering capacity of the old unit. Livestock waterers utilize electric heating elements and are used in cold climate locations in order to prevent water from freezing. Energy efficient livestock waterers, also called no or low energy livestock waterers, are closed and insulated watering containers that use lower wattage heating elements, thermostatically controlled, and water agitation (either in the form of air bubbles or floating balls), to prevent water from freezing.

This measure was developed to be applicable to the following program types: TOS. If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

In order for this characterization to apply, the efficient equipment is assumed to an electrically heated thermally insulated waterer with minimum 2 inches of insulation. A thermostat is required on unit with heating element greater than or equal to 250 watts[19].

**DEFINITION OF BASELINE EQUIPMENT**

In order for this characterization to apply, the baseline equipment is assumed to be an electric open waterer with sinking or floating water heaters that have reached the end of useful life.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected measure life is assumed to be 10 years[20].

**DEEMED MEASURE COST**

The incremental capital cost for the waters are $787.50:[21]

**LOADSHAPE**

Loadshape C04 - Non-Residential Electric Heating

**COINCIDENCE FACTOR**

Heated livestock waterers only operate in the winter in order to keep water from freezing so the summer peak coincident demand savings is zero.

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS [22]**

The annual electric savings from this measure is a deemed value and assumed to be 1,592.85 kWh.

[19] Act on Energy Commercial Technical Reference Manual No. 2010-4
[20] Ibid.
[21] Ibid.
[22] Ibid.

### Summer Coincident Peak Demand Savings

The annual kW savings from this measure is a deemed value and assumed to be 0.525 kW. [23]

### Natural Gas Energy Savings

N/A

### Water Impact Descriptions and Calculation

N/A

### Deemed O&M Cost Adjustment Calculation

N/A

**Measure Code: CI-AGE-LSW1-V02-190101**

**Review Deadline: 1/1/2024**

[23] Ibid.

# 4.2 Food Service Equipment End Use

## 4.2.1 Combination Oven

### DESCRIPTION

This measure applies to both natural gas fired and electric high efficiency combination convection and steam ovens installed in a commercial kitchen.

This measure was developed to be applicable to the following program types: TOS, RF. If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be a new natural gas or electric combination oven meeting the ENERGY STAR idle rate and cooking efficiency requirements as specified below.[24]

**ENERGY STAR Requirements (Version 2.1, Effective January 1, 2014)**

| Fuel Type | Operation | Idle Rate (Btu/h for Gas, kW for Electric) | Cooking-Energy Efficiency, (%) |
|---|---|---|---|
| Natural Gas | Steam Mode | ≤ 200P+6,511 | ≥ 41 |
| | Convection Mode | ≤ 150P+5,425 | ≥ 56 |
| Electric | Steam Mode | ≤ 0.133P+0.6400 | ≥ 55 |
| | Convection Mode | ≤ 0.080P+0.4989 | ≥ 76 |

Note: P = Pan capacity as defined in Section 1.S, of the Commercial Ovens Program Requirements Version 2.1[25]

### DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a natural gas or electric combination oven that is not ENERGY STAR certified.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years.[26]

### DEEMED MEASURE COST

The costs vary based on the efficiency and make of the equipment. Actual costs should be used.

### LOADSHAPE

Loadshape C01 - Commercial Electric Cooking

### COINCIDENCE FACTOR

Summer Peak Coincidence Factor for measure is provided below for different building type[27]:

| Location | CF |
|---|---|
| Fast Food Limited Menu | 0.32 |
| Fast Food Expanded Menu | 0.41 |
| Pizza | 0.46 |

[24] ENERGY STAR Commercial Ovens Key Product Criteria, version 2.2, effective October 7, 2015
[25] Ibid. Pan capacity is defined as the number of steam table pans the combination oven is able to accommodate as per the ASTM F-1495-05 standard specification.
[26] The measure life is sourced from the Food Service Technology Center's energy savings calculator for combination ovens.
[27]Values taken from Minnesota Technical Reference Manual (Version 2.2, effective May 2, 2018), 'Electric Oven and Range' measure and are based upon "Project on Restaurant Energy Performance-End-Use Monitoring and Analysis", Appendixes I and II, Claar, et. al., May 1985

| Location | CF |
|---|---|
| Full Service Limited Menu | 0.51 |
| Full Service Expanded Menu | 0.36 |
| Cafeteria | 0.39 |

## Algorithm

### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

The algorithm below applies to electric combination ovens only.[28]

$\Delta kWh = (\Delta CookingEnergy_{ConvElec} + \Delta CookingEnergy_{SteamElec} + \Delta IdleEnergy_{ConvElec} + \Delta IdleEnergy_{SteamElec}) * Days / 1{,}000$

Where:

$\Delta CookingEnergy_{ConvElec}$ = Change in total daily cooking energy consumed by electric oven in convection mode

$= LB_{Elec} * (EFOOD_{ConvElec} / ElecEFF_{ConvBase} - EFOOD_{ConvElec} / ElecEFF_{ConvEE}) * \%_{Conv}$

$\Delta CookingEnergy_{SteamElec}$ = Change in total daily cooking energy consumed by electric oven in steam mode

$= LB_{Elec} * (EFOOD_{SteamElec} / ElecEFF_{SteamBase} – EFOOD_{SteamElec} / ElecEFF_{SteamEE}) * \%_{Steam}$

$\Delta IdleEnergy_{ConvElec}$ = Change in total daily idle energy consumed by electric oven in convection mode

$= [(ElecIDLE_{ConvBase} * ((HOURS – LB_{Elec}/ElecPC_{ConvBase}) * \%_{Conv})) - (ElecIDLE_{ConvEE} * ((HOURS - LB_{Elec}/ElecPC_{ConvEE}) * \%_{Conv}))]$

$\Delta IdleEnergy_{SteamElec}$ = Change in total daily idle energy consumed by electric oven in convection mode

$= [(ElecIDLE_{SteamBase} * ((HOURS – LB_{Elec}/ElecPC_{SteamBase}) * \%_{Steam})) - (ElecIDLE_{SteamEE} * ((HOURS - LB_{Elec}/ElecPC_{SteamEE}) * \%_{Steam}))]$

Where:

$LB_{Elec}$ = Estimated mass of food cooked per day for electric oven (lbs/day)

= Custom, or if unknown, use 200 lbs (If P <15) or 250 lbs (If P >= 15)

$EFOOD_{ConvElec}$ = Energy absorbed by food product for electric oven in convection mode

= Custom or if unknown, use 73.2 Wh/lb

ElecEFF = Cooking energy efficiency of electric oven

= Custom or if unknown, use values from table below

| | Base | EE |
|---|---|---|
| $ElecEFF_{Conv}$ | 72% | 76% |

[28] Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator

| | Base | EE |
|---|---|---|
| $ElecEFF_{Steam}$ | 49% | 55% |

$\%_{Conv}$ = Percentage of time in convection mode

= Custom or if unknown, use 50%

$EFOOD_{SteamElec}$ = Energy absorbed by food product for electric oven in steam mode

= Custom or if unknown, use 30.8 Wh/lb

$\%_{steam}$ = Percentage of time in steam mode

= $1 - \%_{conv}$

$ElecIDLE_{Base}$ = Idle energy rate (W) of baseline electric oven

= Custom or if unknown, use values from table below

| Pan Capacity | Convection Mode ($ElecIDLE_{ConvBase}$) | Steam Mode ($ElecIDLE_{SteamBase}$) |
|---|---|---|
| < 15 | 1,320 | 5,260 |
| > = 15 | 2,280 | 8,710 |

HOURS = Average daily hours of operation

= Custom or if unknown, use 12 hours

$ElecPC_{Base}$ = Production capacity (lbs/hr) of baseline electric oven

= Custom of if unknown, use values from table below

| Pan Capacity | Convection Mode ($ElecPC_{ConvBase}$) | Steam Mode ($ElecPC_{SteamBase}$) |
|---|---|---|
| < 15 | 79 | 126 |
| > = 15 | 166 | 295 |

$ElecIDLE_{ConvEE}$ = Idle energy rate of ENERGY STAR electric oven in convection mode

= $(0.08*P +0.4989)*1000$

$ElecPC_{EE}$ = Production capacity (lbs/hr) of ENERGY STAR electric oven

= Custom of if unknown, use values from table below

| Pan Capacity | Convection Mode ($ElecPC_{ConvEE}$) | Steam Mode ($ElecPC_{SteamEE}$) |
|---|---|---|
| < 15 | 119 | 177 |
| > = 15 | 201 | 349 |

$ElecIDLE_{SteamEE}$ = Idle energy rate of ENERGY STAR electric oven in steam mode

= $(0.133* P+0.64)*1000$

Days = Days of operation per year

= Custom or if unknown, use 365 days per year

1,000 = Wh to kWh conversion factor

**EXAMPLE**

For example, a 10-pan capacity electric combination oven would save:

$\Delta kWh = (\Delta CookingEnergy_{ConvElec} + \Delta CookingEnergy_{SteamElec} + \Delta IdleEnergy_{ConvElec} + \Delta IdleEnergy_{SteamElec}) * Days / 1{,}000$

$\Delta CookingEnergy_{ConvElec} = 200 * (73.2 / 0.72 – 73.2 / 0.76) * 0.50$

$= 535$ Wh

$\Delta CookingEnergy_{SteamElec} = 200 * (30.8 / 0.49 – 30.8 / 0.55) * (1 – 0.50)$

$= 686$ Wh

$\Delta IdleEnergy_{ConvElec} = [(1{,}320 * ((12 – 200/79) * 0.50)) - (1{,}299 *((12 - 200/119) * 0.50))]$

$= -453$ Wh

$\Delta IdleEnergy_{SteamElec} = [(5{,}260 * ((12 – 200/126) * (1 – 0.50))) - (1{,}970 * ((12 - 200/177) * (1 – 0.50)))]$

$= 16{,}678$ Wh

$\Delta kWh = (535 + 686 + -453 + 16{,}678) * 365 /1{,}000$

$= 6{,}368$ kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$\Delta kW = \Delta kWh / (HOURS * DAYS) *CF$

Where:

CF = Summer peak coincidence factor is dependent on building type[29]:

| Location | CF |
|---|---|
| Fast Food Limited Menu | 0.32 |
| Fast Food Expanded Menu | 0.41 |
| Pizza | 0.46 |
| Full Service Limited Menu | 0.51 |
| Full Service Expanded Menu | 0.36 |
| Cafeteria | 0.39 |

All other variables as defined above.

**EXAMPLE**

For example, a 10-pan capacity electric combination oven in a Full Service Limited Menu restaurant would save:

$\Delta kW = \Delta kWh / (HOURS * DAYS) *CF$

$= 6{,}368/ (12 * 365) * 0.51$

$= 0.74$ kW

**NATURAL GAS ENERGY SAVINGS**

The algorithm below applies to natural gas combination ovens only.[30]

[29] Values taken from Minnesota Technical Reference Manual (Version 2.2, effective May 2, 2018), 'Electric Oven and Range' measure and are based upon "Project on Restaurant Energy Performance-End-Use Monitoring and Analysis", Appendixes I and II, Claar, et. al., May 1985

[30] Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator

$$\Delta Therms = (\Delta CookingEnergy_{ConvGas} + \Delta CookingEnergy_{SteamGas} + \Delta IdleEnergy_{ConvGas} + \Delta IdleEnergy_{SteamGas}) * Days / 100{,}000$$

Where:

$\Delta CookingEnergy_{ConvGas}$ = Change in total daily cooking energy consumed by gas oven in convection mode

$= LB_{Gas} * (EFOOD_{ConvGas} / GasEFF_{ConvBase} - EFOOD_{ConvGas} / GasEFF_{ConvEE}) * \%_{Conv}$

$\Delta CookingEnergy_{SteamGas}$ = Change in total daily cooking energy consumed by gas oven in steam mode

$= LB_{Gas} * (EFOOD_{SteamGas} / GasEFF_{SteamBase} – EFOOD_{SteamGas} / GasEFF_{SteamEE}) * \%_{Steam}$

$\Delta IdleEnergy_{ConvGas}$ = Change in total daily idle energy consumed by gas oven in convection mode

$= [(GasIDLE_{ConvBase} * ((HOURS – LB_{Gas}/GasPC_{ConvBase}) * \%_{Conv})) - (GasIDLE_{ConvEE} * ((HOURS - LB_{Gas}/GasPC_{ConvEE}) * \%_{Conv}))]$

$\Delta IdleEnergy_{SteamGas}$ = Change in total daily idle energy consumed by gas oven in convection mode

$= [(GasIDLE_{SteamBase} * ((HOURS – LB_{Gas}/GasPC_{SteamBase}) * \%_{Steam})) - (GasIDLE_{SteamEE} * ((HOURS - LB_{Gas}/GasPC_{SteamEE}) * \%_{Steam}))]$

Where:

$LB_{Gas}$ = Estimated mass of food cooked per day for gas oven (lbs/day)

= Custom, or if unknown, use 200 lbs (If P <15), 250 lbs (If 15 <= P 30), or 400 lbs (If P = >30)

$EFOOD_{ConvGas}$ = Energy absorbed by food product for gas oven in convection mode

= Custom or if unknown, use 250 Btu/lb

GasEFF = Cooking energy efficiency of gas oven

= Custom or if unknown, use values from table below

| | Base | EE |
|---|---|---|
| $GasEFF_{Conv}$ | 52% | 56% |
| $GasEFF_{Steam}$ | 39% | 41% |

$EFOOD_{SteamGas}$ = Energy absorbed by food product for gas oven in steam mode

= Custom or if unknown, use 105 Btu/lb

$GasIDLE_{Base}$ = Idle energy rate (Btu/hr) of baseline gas oven

= Custom or if unknown, use values from table below

| Pan Capacity | Convection Mode ($GasIDLE_{ConvBase}$) | Steam Mode ($GasIDLE_{SteamBase}$) |
|---|---|---|
| < 15 | 8,747 | 18,656 |
| 15-30 | 10,788 | 24,562 |
| >30 | 13,000 | 43,300 |

$GasPC_{Base}$ = Production capacity (lbs/hr) of baseline gas oven

= Custom of if unknown, use values from table below

| Pan Capacity | Convection Mode ($GasPC_{ConvBase}$) | Steam Mode ($GasPC_{SteamBase}$) |
|---|---|---|
| < 15 | 125 | 195 |
| 15-30 | 176 | 211 |
| >30 | 392 | 579 |

$GasIDLE_{ConvEE}$ = Idle energy rate of ENERGY STAR gas oven in convection mode

= 150*P + 5,425

$GasPC_{EE}$ = Production capacity (lbs/hr) of ENERGY STAR gas oven

= Custom of if unknown, use values from table below

| Pan Capacity | Convection Mode ($GasPC_{ConvEE}$) | Steam Mode ($GasPC_{SteamEE}$) |
|---|---|---|
| < 15 | 124 | 172 |
| 15-30 | 210 | 277 |
| >30 | 394 | 640 |

$GasIDLE_{SteamEE}$ = Idle energy rate of ENERGY STAR gas oven in steam mode

= 200 * P +6511

100,000 = Conversion factor from Btu to therms

All other variables as defined above.

**EXAMPLE**

For example, a 10-pan capacity gas combination oven would save:

ΔTherms = ($\Delta CookingEnergy_{ConvGas}$ + $\Delta CookingEnergy_{SteamGas}$ + $\Delta IdleEnergy_{ConvGas}$ + $\Delta IdleEnergy_{SteamGas}$) * Days / 100,000

$\Delta CookingEnergy_{ConvGas}$ = 200 * (250 / 0.52 – 250 / 0.56) * 0.50

=3,434 therms

$\Delta CookingEnergy_{SteamGas}$ = 200 * (105 / 0.39 – 105 / 0.41) * (1 – 0.50)

= 1,313 therms

$\Delta IdleEnergy_{ConvGas}$ = [(8,747 * ((12 – 200/125) * 0.50)) - (6,925 *((12 - 200/124) * 0.50))]

= 9,519 therms

$\Delta IdleEnergy_{SteamGas}$ = [(18,658 * ((12 – 200/195) * (1 – 0.50))) - (8,511 * ((12 - 200/172) * (1 – 0.50)))]

= 56,251 therms

ΔTherms = (3,434 + 1,313 + 9,519 + 56,251) * 365 /100,000

= 257 therms

### Water Impact Descriptions and Calculation

N/A

### Deemed O&M Cost Adjustment Calculation

N/A

**MEASURE CODE: CI-FSE-CBOV-V02-160601**

**REVIEW DEADLINE: 1/1/2023**

## 4.2.2 Commercial Solid and Glass Door Refrigerators & Freezers

### DESCRIPTION

This measure relates to the installation of a new reach-in commercial refrigerator or freezer meeting ENERGY STAR efficiency standards. ENERGY STAR labeled commercial refrigerators and freezers are more energy efficient because they are designed with components such as ECM evaporator and condenser fan motors, hot gas anti-sweat heaters, or high-efficiency compressors, which will significantly reduce energy consumption.

This measure was developed to be applicable to the following program types: TOS and NC. If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the efficient equipment is assumed to be a new ENERGY STAR certified vertical closed solid or glass door refrigerator or freezer meeting energy consumptions requirements as determined by door type (solid or glass) and refrigerated volume (V).

**ENERGY STAR Requirements (Version 4.0, Effective March 27, 2017)**

| Volume ($ft^3$) | Maximum Daily Energy Consumption (kWh/day) | |
|---|---|---|
| | Refrigerator | Freezer |
| **Vertical Closed** | | |
| Solid Door | | |
| 0 < V < 15 | ≤ 0.022V + 0.97 | ≤ 0.21V + 0.9 |
| 15 ≤ V < 30 | ≤ 0.066V + 0.31 | ≤ 0.12V + 2.248 |
| 30 ≤ V < 50 | ≤ 0.04V + 1.09 | ≤ 0.285V -2.703 |
| V ≥ 50 | ≤ 0.024V + 1.89 | ≤ 0.142V + 4.445 |
| Glass Door | | |
| 0 < V < 15 | ≤ 0.095V + 0.445 | ≤ 0.232V + 2.36 |
| 15 ≤ V < 30 | ≤ 0.05V + 1.12 | |
| 30 ≤ V < 50 | ≤ 0.076V + 0.34 | |
| V ≥ 50 | ≤ 0.105V – 1.111 | |

### DEFINITION OF BASELINE EQUIPMENT

In order for this characterization to apply, the baseline equipment is assumed to be a new vertical closed solid or glass door refrigerator or freezer that is not ENERGY STAR certified.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years [31].

### DEEMED MEASURE COST

The incremental capital cost per cubic foot of chilled or frozen compartment volume for this measure is provided below[32].

| Equipment Type | Incremental Cost per Cubic Foot ($ft^3$) |
|---|---|
| Solid Door | |

[31] 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values", California Public Utilities Commission, December 16, 2008.

[32] Incremental costs are based on the Northwest Regional Technical Forum, ENERGY STAR Version 4.0 Analysis. For cost calculation details, see the CostData&Analysis tab within the file Commercial Refrigerators & Freezers_Costs_Nov 2017.xlsm.

| Equipment Type | Incremental Cost per Cubic Foot ($ft^3$) |
|---|---|
| Refrigerator | $24.21 |
| Freezer | $30.41 |
| Glass Door | |
| Refrigerator | $24.77 |
| Freezer | $33.01 |

### LOADSHAPE

Loadshape C23 - Commercial Refrigeration

### COINCIDENCE FACTOR

The summer peak coincidence factor for this measure is assumed to be 0.937.[33]

## Algorithm

### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

ΔkWh = (kWhbase – kWhee) * 365.25

Where:

kWhbase= baseline maximum daily energy consumption in kWh

= calculated using actual chilled or frozen compartment volume (V) of the efficient unit as shown in the table below.

| Type | kWhbase[34] |
|---|---|
| Solid Door Refrigerator | 0.05 * V + 1.36 |
| Glass Door Refrigerator | 0.1 * V + 0.86 |
| Solid Door Freezer | 0.22 * V + 1.38 |
| Glass Door Freezer | 0.29 * V + 2.95 |

kWhee[35] = efficient maximum daily energy consumption in kWh

= calculated using actual chilled or frozen compartment volume (V) of the efficient unit as shown in the table below.

| Volume ($ft^3$) | kWhee | |
|---|---|---|
| | Refrigerator | Freezer |
| **Vertical Closed** | | |
| Solid Door | | |
| 0 < V < 15 | ≤ 0.022V + 0.97 | ≤ 0.21V + 0.9 |
| 15 ≤ V < 30 | ≤ 0.066V + 0.31 | ≤ 0.12V + 2.248 |
| 30 ≤ V < 50 | ≤ 0.04V + 1.09 | ≤ 0.285V -2.703 |
| V ≥ 50 | ≤ 0.024V + 1.89 | ≤ 0.142V + 4.445 |

[33] The CF for Commercial Refrigeration was calculated based upon the Ameren provided eShapes

[34] Federal standards for equipment manufactured on or after March 27, 2017: 10 CFR §431.66 - Energy Conservation Standards for Commercial Refrigerators, Freezers and Refrigerator-Freezers.

[35] ENERGY STAR Program Requirements for Commercial Refrigerators and Freezers Partner Commitments Version 4.0, effective March 27, 2017

| Volume ($ft^3$) | kWhee | |
|---|---|---|
| | Refrigerator | Freezer |
| Glass Door | | |
| 0 < V < 15 | ≤ 0.095V + 0.445 | ≤ 0.232V + 2.36 |
| 15 ≤ V < 30 | ≤ 0.05V + 1.12 | |
| 30 ≤ V < 50 | ≤ 0.076V + 0.34 | |
| V ≥ 50 | ≤ 0.105V – 1.111 | |

V = the chilled or frozen compartment volume ($ft^3$) (as defined in the Association of Home Appliance Manufacturers Standard HRF1–1979)

= Actual installed

365.25 = days per year

For example, a solid door refrigerator with a volume of 15 would save

ΔkWh = (2.11 – 1.30) * 365.25

= 296 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = ΔkWh / HOURS * CF

Where:

HOURS = equipment is assumed to operate continuously, 24 hours per day, 365.25 days per year.

= 8766

CF = Summer Peak Coincidence Factor for measure

= 0.937

For example a solid door refrigerator with a volume of 15 would save

ΔkW = 296/ 8766 * .937

=0.0316 kW

**NATURAL GAS ENERGY SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-FSE-CSDO-V02-190101**

**REVIEW DEADLINE: 1/1/2024**

## 4.2.3 Commercial Steam Cooker

### Description

To qualify for this measure the installed equipment must be an ENERGY STAR® steamer in place of a standard steamer in a commercial kitchen. Savings are presented dependent on the pan capacity and corresponding idle rate at heavy load cooking capacity and if the steamer is gas or electric.

This measure was developed to be applicable to the following program types: TOS. If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

To qualify for this measure the installed equipment must be as follows:

| Gas | Electric |
|---|---|
| ENERGY STAR® qualified with 38% minimum cooking energy efficiency at heavy load (potato) cooking capacity for gas steam cookers. | ENERGY STAR® qualified with 50% minimum cooking energy efficiency at heavy load (potato) cooking capacity for electric steam cookers. |

### Definition of Baseline Equipment

The baseline condition is assumed to be a non-ENERGY STAR® commercial steamer at end of life. It is assumed that the efficient equipment and baseline equipment have the same number of pans.

### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 12 years[36]

### Deemed Measure Cost

The incremental capital cost for this measure is $998[37] for a natural gas steam cooker or $2490[38] for an electric steam cooker.

### Loadshape

Loadshape C01 - Commercial Electric Cooking

### Coincidence Factor

Summer Peak Coincidence Factor for measure is provided below for different building type[39]:

| Location | CF |
|---|---|
| Fast Food Limited Menu | 0.32 |
| Fast Food Expanded Menu | 0.41 |
| Pizza | 0.46 |
| Full Service Limited Menu | 0.51 |
| Full Service Expanded Menu | 0.36 |

[36]California DEER 2008 which is also used by both the Food Service Technology Center and ENERGY STAR®.
[37]Source for incremental cost for efficient natural gas steamer is RSG Commercial Gas Steamer Workpaper, January 2012.
[38]Source for efficient electric steamer incremental cost is $2,490 per 2009 PG&E Workpaper - PGECOFST104.1 - Commercial Steam Cooker - Electric and Gas as reference by KEMA in the ComEd C & I TRM.
[39] Values taken from Minnesota Technical Reference Manual (Version 2.2, effective May 2, 2018), 'Electric Oven and Range' measure and are based upon "Project on Restaurant Energy Performance-End-Use Monitoring and Analysis", Appendixes I and II, Claar, et. al., May 1985.Unknown is an average of other location types

| Location | CF |
|---|---|
| Cafeteria | 0.39 |
| Unknown | 0.41 |

## Algorithm

### CALCULATION OF SAVINGS

Formulas below are applicable to both gas and electric steam cookers. Please use appropriate lookup values and identified flags.

### ENERGY SAVINGS

$\Delta$Savings = ($\Delta$Idle Energy + $\Delta$Preheat Energy + $\Delta$Cooking Energy) * Z

For a gas cooker: $\Delta$Savings = $\Delta$Btu * 1/100,000 * Z

For an electric steam cooker: $\Delta$Savings = $\Delta$kWh *Z

Where:

Z = days/yr steamer operating (use 365.25 days/yr if heavy use restaurant and exact number unknown)

$\Delta$Idle Energy = $((((1- CSM_{\%Baseline})* IDLE_{BASE} + CSM_{\%Baseline} * PC_{BASE} * E_{FOOD} / EFF_{BASE}) * (HOURS_{day} - (F / PC_{Base}) - ( PRE_{number} *0.25))) - (((1- CSM_{\%ENERGYSTAR}) * IDLE_{ENERGYSTAR} + CSM_{\%ENERGYSTAR} * PC_{ENERGY} * E_{FOOD} / EFF_{ENERGYSTAR}) * (HOURS_{Day} - (F l/ PC_{ENERGY} ) - (PRE_{number} * 0.25 ))))$

Where:

$CSM_{\%Baseline}$ = Baseline Steamer Time in Manual Steam Mode (% of time)

= 90%[40]

$IDLE_{Base}$ = Idle Energy Rate of Base Steamer[41]

| Number of Pans | $IDLE_{BASE}$ - Gas, Btu/hr | $IDLE_{BASE}$ - Electric, kw |
|---|---|---|
| 3 | 11,000 | 1.0 |
| 4 | 14,667 | 1.33 |
| 5 | 18,333 | 1.67 |
| 6 | 22,000 | 2.0 |

$PC_{Base}$ = Production Capacity of Base Steamer[42]

| Number of Pans | $PC_{BASE}$, gas (lbs/hr) | $PC_{BASE}$, electric (lbs/hr) |
|---|---|---|
| 3 | 65 | 70 |
| 4 | 87 | 93 |
| 5 | 108 | 117 |
| 6 | 130 | 140 |

[40] Food Service Technology Center 2011 Savings Calculator

[41] Food Service Technology Center 2011 Savings Calculator

[42] Production capacity per Food Service Technology Center 2011 Savings Calculator of 23.3333 lb/hr per pan for electric baseline steam cookers and 21.6667 lb/hr per pan for natural gas baseline steam cookers. ENERGY STAR® savings calculator uses 23.3 lb/hr per pan for both electric and natural gas baseline steamers.

$E_{FOOD}$= Amount of Energy Absorbed by the food during cooking known as ASTM Energy to Food (Btu/lb or kW/lb)

=105 Btu/lb[43] (gas steamers) or 0.0308[8] (electric steamers)

$EFF_{BASE}$ =Heavy Load Cooking Efficiency for Base Steamer

=15%[44] (gas steamers) or 26%[9] (electric steamers)

$HOURS_{day}$ = Average Daily Operation (hours)

| Type of Food Service | Hoursday[45] |
|---|---|
| Fast Food, limited menu | 4 |
| Fast Food, expanded menu | 5 |
| Pizza | 8 |
| Full Service, limited menu | 8 |
| Full Service, expanded menu | 7 |
| Cafeteria | 6 |
| Unknown | 6[46] |
| Custom | Varies |

F = Food cooked per day (lbs/day)

= custom or if unknown, use 100 lbs/day[47]

$CSM_{\%ENERGYSTAR}$ = ENERGY *STAR Steamer's Time in Manual Steam Mode (% of time)*[48]

*= 0%*

*$IDLE_{ENERGYSTAR}$* = *Idle E*nergy Rate of ENERGY STAR®[49]

| Number of Pans | $IDLE_{ENERGY\ STAR}$ – gas, (Btu/hr) | $IDLE_{ENERGY\ STAR}$ – electric, (kW) |
|---|---|---|
| 3 | 6,250 | 0.40 |
| 4 | 8,333 | 0.53 |
| 5 | 10,417 | 0.67 |
| 6 | 12,500 | 0.80 |

$PC_{ENERGY}$ = Production Capacity of ENERGY STAR® Steamer[50]

[43]ENERGY STAR Commercial Kitchen Equipment Savings Calculator, Steam Cooker Calculations
**[44]**Reference Food Service Technology Center 2011 Savings Calculator values as used by Consortium for Energy Efficiency, Inc. for baseline electric and natural gas steamer heavy cooking load energy efficiencies.
[45] Values taken from Minnesota Technical Reference Manual (Version 2.2, effective May 2, 2018), 'Electric Oven and Range' measure and are based upon "Project on Restaurant Energy Performance-End-Use Monitoring and Analysis", Appendixes I and II, Claar, et. al., May 1985.
**[46]**Unknown is average of other locations
[47]Reference amount used by both Food Service Technology Center and ENERGY STAR® savings calculator
[48]Reference information from the Food Service Technology Center siting that ENERGY STAR® steamers are not typically operated in constant steam mode, but rather are used in timed mode. Reference ENERGY STAR Commercial Kitchen Equipment Savings Calculator, Steam Cooker CalculationsBoth baseline & efficient steamer mode values should be considered for users in Illinois market.
[49]Food Service Technology Center 2011 Savings Calculator
[50]Production capacity per Food Service Technology Center 2011 Savings Calculator of 18.3333 lb/hr per pan for gas ENERGY STAR® steam cookers and 16.6667 lb/hr per pan for electric ENERGY STAR® steam cookers. ENERGY STAR® savings calculator uses 16.7 lb/hr per pan for electric and 20 lb/hr for natural gas ENERGY STAR® steamers.

| Number of Pans | $PC_{ENERGY}$ - gas(lbs/hr) | $PC_{ENERGY}$ – electric (lbs/hr) |
|---|---|---|
| 3 | 55 | 50 |
| 4 | 73 | 67 |
| 5 | 92 | 83 |
| 6 | 110 | 100 |

$EFF_{ENERGYSTAR}$ = Heavy Load Cooking Efficiency for ENERGY STAR® Steamer(%)

=38%[51] (gas steamer) or 50%[15] (electric steamer)

$PRE_{number}$ = Number of preheats per day

=1[52] (if unknown, use 1)

ΔPreheat Energy = ( $PRE_{number}$ * Δ $Pre_{heat}$)

Where:

$PRE_{number}$ = Number of Preheats per Day

=1[53](if unknown, use 1)

$PRE_{heat}$ = Preheat energy savings per preheat

= 11,000 Btu/preheat[54] (gas steamer) or 0.5 kWh/preheat[55] (electric steamer)

ΔCooking Energy = ((1/ EFFBASE) - (1/ EFFENERGY STAR®)) * F * $E_{FOOD}$

Where:

$EFF_{BASE}$ =Heavy Load Cooking Efficiency for Base Steamer

=15%[56] (gas steamer) or 26%[28] (electric steamer)

$EFF_{ENERGYSTAR}$ =Heavy Load Cooking Efficiency for ENERGY STAR® Steamer

=38%[57] (gas steamer) or 50%[23] (electric steamer)

F = Food cooked per day (lbs/day)

= custom or if unknown, use 100 lbs/day[58]

$E_{FOOD}$ = Amount of Energy Absorbed by the food during cooking known as ASTM Energy to Food[59]

---

[51]Reference Food Service Technology Center 2011 Savings Calculator values as used by Consortium for Energy Efficiency, Inc. for Tier 1A and Tier 1B qualified electric and natural gas steamer heavy cooking load energy efficiencies, as sourced from ENERGY STAR Program Requirements Product Specification for Commercial Steam Cookers, version 1.2, effective August 1, 2013.

[52]Reference ENERGY STAR Commercial Kitchen Equipment Savings Calculator, Steam Cooker Calculations

[53]Ibid.

[54]Ohio TRM which references 2002 Food Service Technology Center "Commercial Cooking Appliance Technology Assessment" Chapter 8: Steamers. This is also used by the ENERGY STAR Commercial Kitchen Equipment Savings Calculator. 11,000 Btu/preheat is from 72,000 Btu/hr * 15 min/hr /60 min/hr for gas steamers and 0.5 kWh/preheat is from 6 kW/preheat * 15 min/hr / 60 min/hr

[55] Reference Food Service Technology Center 2011 Savings Calculator values for Baseline Preheat Energy.

[56] Reference Food Service Technology Center 2011 Savings Calculator values as used by Consortium for Energy Efficiency, Inc. for baseline electric and natural gas steamer heavy cooking load energy efficiencies.

[57] Ibid.

[58]Amount used by both Food Service Technology Center and ENERGY STAR® savings calculator

[59]Reference ENERGY STAR Commercial Kitchen Equipment Savings Calculator, Steam Cooker Calculations.

| $E_{FOOD}$ - gas(Btu/lb) | $E_{FOOD}$ (kWh/lb) |
|---|---|
| 105[60] | 0.0308[61] |

**EXAMPLE**

For a gas steam cooker: A 3 pan steamer in a full service restaurant

ΔSavings = (ΔIdle Energy + ΔPreheat Energy + ΔCooking Energy) * Z * 1/100.000

ΔIdle Energy = ((((1- 0.9)* 11000 + 0.9 * 65 * 105 /0.15 )*(7 - (100 / 65)-(1*0.25))) - (((1-0) * 6250 + 0 * 55 * 105 / 0.38) * (7 - (100 / 55) - (1*0.25))))

= 188,321

ΔPreheat Energy = (1 *11,000)

= 11,000

ΔCooking Energy = (((1/ 0.15) - (1/ 0.38)) * (100 lb/day * 105 btu/lb)))

= 42368

ΔTherms = (188321 + 11000 + 42368) * 365.25 *1/100,000

= 883 therms

For an electric steam cooker: A 3 pan steamer in a cafeteria:

ΔSavings = (ΔIdle Energy + ΔPreheat Energy + ΔCooking Energy) * Z

ΔIdle Energy = ((((1- .9)* 1.0 + .9 * 70 * 0.0308 /0.26 )*(6 - (100 / 70)-(1*.25))) - (((1-0) * 0.4 + 0 * 50 * 0.0308 / 0.50) * (6 - (100 / 50) - (1*0.25))))

= 31.18

ΔPreheat Energy = (1 *0.5))

= 0.5

ΔCooking Energy = (((1/ 0.26) - (1/ 0.5)) * (100 * 0.0308)))

= 5.69

ΔkWh = (31.18 + 0.5 + 5.69) * 365.25 days

= 13,649 kWh

Secondary kWh Savings for Water Supply and Wastewater Treatment

The following savings should be included in the total savings for this measure, but should not be included in TRC tests to avoid double counting the economic benefit of water savings.

$$\Delta kWh_{water} = \Delta Water\ (gallons) / 1{,}000{,}000 * E_{water\ supply}$$

Where

$E_{water\ supply}$ = IL Supply Energy Factor (kWh/Million Gallons)

=2,571[62]

[60] Ibid.

[61] Ibid.

[62] This factor include 2571 kWh/MG for water supply based on Illinois energy intensity data from a 2012 ISAWWA study. For more information please review Elevate Energy's 'IL TRM: Energy per Gallon Factor, May 2018 paper'. Note that the Commercial Steam Cooker does not discharge its water into the wastewater system so only the water supply factor is used here.

**EXAMPLE**

For example, an electric 3 pan steamer with average efficiency in a full service restaurant

$\Delta$Water (gallons) = (40 - 10) * 7 * 365.25

= 76,703 gallons

$\Delta kWh_{water}$ = 76,703/1,000,000*2,571

= 197 kWh

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

This is only applicable to the electric steam cooker.

$$\Delta kW = (\Delta kWh/(HOURSDay * DaysYear)) * CF$$

Where:

$\Delta$kWh = Annual kWh savings from measure as calculated above. Note do not include the secondary savings in this calculation.

CF =Summer Peak Coincidence Factor for measure is provided below for different locations[63]:

| Location | CF |
|---|---|
| Fast Food Limited Menu | 0.32 |
| Fast Food Expanded Menu | 0.41 |
| Pizza | 0.46 |
| Full Service Limited Menu | 0.51 |
| Full Service Expanded Menu | 0.36 |
| Cafeteria | 0.39 |

$Days_{Year}$ =Annual Days of Operation

=custom or 365.25 days a year

Other values as defined above

**EXAMPLE**

For 3 pan electric steam cooker located in a cafeteria:

$\Delta kW$ = $(\Delta kWh/(HOURS_{Day} * Days_{Year})) * CF$

= (13,649/ (6 * 365.25)) * 0.39

= 2.43 kW

### WATER IMPACT DESCRIPTIONS AND CALCULATION

This is applicable to both gas and electric steam cookers.

$$\Delta Water\ (gallons) = (W_{BASE} - W_{ENERGYSTAR®}) * HOURS_{Day} * Days_{Year}$$

Where

[63]Values taken from Minnesota Technical Reference Manual (Version 2.2, effective May 2, 2018), 'Electric Oven and Range' measure and are based upon "Project on Restaurant Energy Performance-End-Use Monitoring and Analysis", Appendixes I and II, Claar, et. al., May 1985.

$W_{BASE}$ = Water Consumption Rate of Base Steamer (gal/hr)

= 40[64]

$W_{ENERGYSTAR}$ = Water Consumption Rate of ENERGY STAR® Steamer look up[65]

| CEE Tier | gal/hr |
|---|---|
| Tier 1A | 15 |
| Tier 1B | 4 |
| Avg Efficient | 10 |
| Avg Most Efficient | 3 |

$Days_{Year}$ =Annual Days of Operation

=custom or 365.25 days a year[66]

**EXAMPLE**

For example, an electric 3 pan steamer with average efficiency in a full service restaurant

ΔWater (gallons) = (40 -10) * 7 * 365.25

= 76,703 gallons

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-FSE-STMC-V05-190101**

**REVIEW DEADLINE: 1/1/2023**

[64] FSTC (2002). Commercial Cooking Appliance Technology Assessment. Chapter 8: Steamers.

[65] Source Consortium for Energy Efficiency, Inc. September 2010 "Program Design Guidance for Steamers" for Tier 1A and Tier 1B water requirements. Ohio Technical Reference Manual 2010 for 10 gal/hr water consumption which can be used when Tier level is not known.

[66] Source for 365.25 days/yr is ENERGY STAR® savings calculator which references Food Service Technology research on average use, 2009.

## 4.2.4 Conveyor Oven

**DESCRIPTION**

This measure applies to natural gas fired high efficiency conveyor ovens installed in commercial kitchens replacing existing natural gas units with conveyor width greater than 25 inches.

Conveyor ovens are available using four different heating processes: infrared, natural convection with a ceramic baking hearth, forced convection or air impingement, or a combination of infrared and forced convection. Conveyor ovens are typically used for producing a limited number of products with similar cooking requirements at high production rates. They are highly flexible and can be used to bake or roast a wide variety of products including pizza, casseroles, meats, breads, and pastries.

Some manufacturers offer an air-curtain feature at either end of the cooking chamber that helps to keep the heated air inside the conveyor oven. The air curtain operates as a virtual oven wall and helps reduce both the idle energy of the oven and the resultant heat gain to the kitchen.

This measure was developed to be applicable to the following program types: TOS. If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

To qualify for this measure the installed equipment must be a natural gas conveyor oven with a tested baking energy efficiency > 42% and an idle energy consumption rate < 57,000 Btu/hr utilizing ASTM standard F1817.

**DEFINITION OF BASELINE EQUIPMENT**

The baseline equipment is an existing pizza deck oven at end of life.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected measure life is assumed to be 17 years.[67]

**DEEMED MEASURE COST**

The incremental capital cost for this measure is $1800[68].

**LOADSHAPE**

N/A

**COINCIDENCE FACTOR**

N/A

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

N/A

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

N/A

[67] See ‘Arkansas Deemed TRM Table for GasFoodService.xls’ from v3.0 Arkansas Technical Reference Manual.
[68] Ibid.

**NATURAL GAS ENERGY SAVINGS**

The annual natural gas energy savings from this measure is a deemed value equaling 884 Therms[69].

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-FSE-CVOV-V02-180101**

**REVIEW DEADLINE: 1/1/2024**

[69] The Resource Solutions Group Commercial Conveyor Oven – Gas workpaper from January 2012; Commercial Gas Conveyor Oven – Large Gas Savings (therms/unit).

## 4.2.5 ENERGY STAR Convection Oven

**DESCRIPTION**

This measure applies to natural gas fired ENERGY STAR convection ovens installed in a commercial kitchen.

This measure was developed to be applicable to the following program types: TOS. If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

To qualify for this measure the installed equipment must be a natural gas convection oven with a cooking efficiency ≥ 46% utilizing ASTM standard 1496 and an idle energy consumption rate < 12,000 Btu/hr[70]

**DEFINITION OF BASELINE EQUIPMENT**

The baseline equipment is a natural gas convection oven that is not ENERGY STAR certified and is at end of life.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected measure life is assumed to be 12 years[71]

**DEEMED MEASURE COST**

The incremental capital cost for this measure is $50[72]

**LOADSHAPE**

N/A

**COINCIDENCE FACTOR**

N/A

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

N/A

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

N/A

**NATURAL GAS ENERGY SAVINGS**

ustom calculation below, otherwise use deemed value of 306 therms. [73]

ΔTherms = (ΔDailyIdle Energy + ΔDailyPreheat Energy + ΔDailyCooking Energy) * Days /100000

Where:

[70] Version 2.2. of the ENERGY STAR specification.

[71] Lifetime from ENERGY STAR Commercial Kitchen Equipment Savings Calculator, Oven Calculations, which cites reference as "FSTC research on available models, 2009".

[72] Measure cost from ENERGY STAR Commercial Kitchen Equipment Savings Calculator which cites reference as "EPA research on available models using AutoQuotes, 2010".

[73] Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator, Oven Calculations.

ΔDailyIdleEnergy = (IdleBase* IdleBaseTime)- (IdleENERGYSTAR * IdleENERGYSTARTime)

ΔDailyPreheatEnergy = (PreHeatNumberBase * PreheatTimeBase / 60 * PreheatRateBase) – (PreheatNumberENERGYSTAR * PreheatTimeENERGYSTAR/60 * PreheatRateENERGYSTAR)

ΔDailyCookingEnergy = (LB * EFOOD/ EffBase) - (LB * EFOOD/ EffENERGYSTAR)

Where:

HOURSday = Average Daily Operation

= custom or if unknown, use 12 hours

Days = Annual days of operation

= custom or if unknown, use 365.25 days a year

LB = Food cooked per day

= custom or if unknown, use 100 pounds

EffENERGYSTAR = Cooking Efficiency ENERGY STAR

= custom or if unknown, use 46%

EffBase = Cooking Efficiency Baseline

= custom or if unknown, use 30%

PCENERGYSTAR = Production Capacity ENERGY STAR

= custom or if unknown, use 80 pounds/hr

PCBase = Production Capacity base

= custom or if unknown, use 70 pounds/hr

PreheatNumberENERGYSTAR = Number of preheats per day

= custom or if unknown, use 1

PreheatNumberBase = Number of preheats per day

= custom or if unknown, use 1

PreheatTimeENERGYSTAR = preheat length

= custom or if unknown, use 15 minutes

PreheatTimeBase = preheat length

= custom or if unknown, use 15 minutes

PreheatRateENERGYSTAR = preheat energy rate high efficiency

= custom or if unknown, use 44000 btu/h

PreheatRateBase = preheat energy rate baseline

= custom or if unknown, use 76000 btu/h

IdleENERGYSTAR = Idle energy rate

= custom or if unknown, use 12000 btu/h

IdleBase = Idle energy rate

= custom or if unknown, use 18000 btu/h

| | |
|---|---|
| IdleENERGYSTARTime | = ENERGY STAR Idle Time |
| | =HOURsday-LB/PCENERGYSTAR –PreHeatTimeENERGYSTAR/60 |
| | =12 – 100/80 – 15/60 |
| | =10.5 hours |
| IdleBaseTime | = BASE Idle Time |
| | = HOURsday-LB/PCbase –PreHeatTimeBase/60 |
| | =Custom or if unknown, use |
| | =12 – 100/70-15/60 |
| | =10.3 hours |
| EFOOD | = ASTM energy to food |
| | = 250 btu/pound |

**EXAMPLE**

For example, an ENERGY STAR Oven with a cooking energy efficiency of 46% and default values from above would save.

ΔTherms = (ΔIdle Energy + ΔPreheat Energy + ΔCooking Energy) * Days /100000

Where:

| | |
|---|---|
| ΔDailyIdleEnergy | =(18000*10.3)- (12000*10.5) |
| | = 59,400 btu |
| ΔDailyPreheatEnergy | = (1 * 15 / 60 *76000) – (1 * 15 / 60 *44000) |
| | = 8,000 btu |
| ΔDailyCookingEnergy | = (100 * 250/ .30) - (100 * 250/ .46) |
| | =28,986 btu |
| ΔTherms | = (59,400 + 8,000 + 28,986) * 365.25 /100000 |
| | = 352 therms |

### Water Impact Descriptions and Calculation

N/A

### Deemed O&M Cost Adjustment Calculation

N/A

### Measure Code: CI-FSE-ESCV-V02-180101

### Review Deadline: 1/1/2024

## 4.2.6 ENERGY STAR Dishwasher

### Description

This measure applies to ENERGY STAR high and low temp under counter, stationary single tank door type, single tank conveyor, and multiple tank conveyor dishwashers, as well as high temp pot, pan, and utensil dishwashers installed in a commercial kitchen.

This measure was developed to be applicable to the following program types: TOS. If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

To qualify for this measure the installed equipment must be an ENERGY STAR certified dishwasher meeting idle energy rate (kW) and water consumption (gallons/rack) limits, as determined by both machine type and sanitation approach (chemical/low temp versus high temp).

**ENERGY STAR Requirements (Effective February 1, 2013)**

| Dishwasher Type | High Temp Efficiency Requirements | | Low Temp Efficiency Requirements | |
|---|---|---|---|---|
| | Idle Energy Rate | Water Consumption | Idle Energy Rate | Water Consumption |
| Under Counter | ≤ 0.50 kW | ≤ 0.86 GPR | ≤ 0.50 kW | ≤ 1.19 GPR |
| Stationary Single Tank Door | ≤ 0.70 kW | ≤ 0.89 GPR | ≤ 0.60 kW | ≤ 1.18 GPR |
| Pot, Pan, and Utensil | ≤ 1.20 kW | ≤ 0.58 GPSF | ≤ 1.00 kW | ≤ 0.58 GPSF |
| Single Tank Conveyor | ≤ 1.50 kW | ≤ 0.70 GPR | ≤ 1.50 kW | ≤ 0.79 GPR |
| Multiple Tank Conveyor | ≤ 2.25 kW | ≤ 0.54 GPR | ≤ 2.00 kW | ≤ 0.54 GPR |

### Definition of Baseline Equipment

The baseline equipment is a new dishwasher that is not ENERGY STAR certified.

### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be[74]

| Dishwasher Type | | Equipment Life |
|---|---|---|
| Low Temp | Under Counter | 10 |
| | Stationary Single Tank Door | 15 |
| | Single Tank Conveyor | 20 |
| | Multi Tank Conveyor | 20 |
| High Temp | Under Counter | 10 |
| | Stationary Single Tank Door | 15 |
| | Single Tank Conveyor | 20 |
| | Multi Tank Conveyor | 20 |
| | Pot, Pan, and Utensil | 10 |

### Deemed Measure Cost

The incremental capital cost for this measure is provided below:[75]

| Dishwasher Type | | Incremental Cost |
|---|---|---|
| Low | Under Counter | $50 |

[74] Lifetime from ENERGY STAR Commerical Kitchen Equipment Savings Calculator which cites reference as "EPA/FSTC research on available models, 2013"

[75] Measure cost from ENERGY STAR Commercial Kitchen Equipment Savings Calculator which cites reference as "EPA research on available models using AutoQuotes, 2012"

| Dishwasher Type | | Incremental Cost |
|---|---|---|
| Temp | Stationary Single Tank Door | $0 |
| | Single Tank Conveyor | $0 |
| | Multi Tank Conveyor | $970 |
| High Temp | Under Counter | $120 |
| | Stationary Single Tank Door | $770 |
| | Single Tank Conveyor | $2,050 |
| | Multi Tank Conveyor | $970 |
| | Pot, Pan, and Utensil | $1,710 |

**LOADSHAPE**

Loadshape C01 - Commercial Electric Cooking

**COINCIDENCE FACTOR**

Summer Peak Coincidence Factor for measure is provided below for different restaurant types[76]:

| Location | CF |
|---|---|
| Fast Food Limited Menu | 0.32 |
| Fast Food Expanded Menu | 0.41 |
| Pizza | 0.46 |
| Full Service Limited Menu | 0.51 |
| Full Service Expanded Menu | 0.36 |
| Cafeteria | 0.39 |

**Algorithm**

**CALCULATION OF SAVINGS**

ENERGY STAR dishwashers save energy in three categories: building water heating, booster water heating and idle energy. Building water heating and booster water heating could be either electric or natural gas.

**ELECTRIC ENERGY SAVINGS**

Custom calculation below, otherwise use deemed values found within the tables that follow.

$$\Delta kWh^{77} = \Delta BuildingEnergy + \Delta BoosterEnergy^{78} + \Delta IdleEnergy$$

Where:

ΔBuildingEnergy = Change in annual electric energy consumption of building water heater

$= [(WaterUse_{Base} * RacksWashed * Days) * (\Delta T_{in} *1.0 * 8.2 \div Eff_{Heater} \div 3,412)] - [(WaterUse_{ESTAR} * RacksWashed * Days) * (\Delta T_{in} *1.0 * 8.2 \div Eff_{Heater} \div 3,412)]$

ΔBoosterEnergy = Annual electric energy consumption of booster water heater

$= [(WaterUse_{Base} * RacksWashed * Days) * (\Delta T_{in} *1.0 * 8.2 \div Eff_{Heater} \div 3,412)] - [(WaterUse_{ESTAR} * RacksWashed * Days) * (\Delta T_{in} *1.0 * 8.2 \div Eff_{Heater} \div 3,412)]$

[76] Values taken from Minnesota Technical Reference Manual (Version 2.2, effective May 2, 2018), 'Electric Oven and Range' measure and are based upon "Project on Restaurant Energy Performance-End-Use Monitoring and Analysis", Appendixes I and II, Claar, et. al., May 1985

[77] Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator.

[78] Booster water heater energy only applies to high-temperature dishwashers.

$\Delta$IdleEnergy = Annual idle electric energy consumption of dishwasher

= [$IdleDraw_{Base}$* (Hours *Days – Days * RacksWashed * WashTime ÷ 60)] – [$IdleDraw_{ESTAR}$* (Hours *Days – Days * RacksWashed * WashTime ÷ 60)]

Where:

$WaterUse_{Base}$ = Water use per rack (gal) of baseline dishwasher

= Custom or if unknown, use value from table below as determined by machine type and sanitation method

$WaterUse_{ESTAR}$ = Water use per rack (gal) of ENERGY STAR dishwasher

= Custom or if unknown, use value from table below as determined by machine type and sanitation method

RacksWashed = Number of racks washed per day

= Custom or if unknown, use value from table below as determined by machine type and sanitation method

Days = Annual days of dishwasher operation

= Custom or if unknown, use 365.25 days per year

$\Delta T_{in}$ = Inlet water temperature increase (°F)

= Custom or if unknown, use 70 °F for building water heaters and 40 °F for booster water heaters

1.0 = Specific heat of water (Btu/lb/°F)

8.2 = Density of water (lb/gal)

$Eff_{Heater}$ = Efficiency of water heater

= Custom or if unknown, use 98% for electric building and booster water heaters

3,412 = kWh to Btu conversion factor

$IdleDraw_{Base}$ = Idle power draw (kW) of baseline dishwasher

= Custom or if unknown, use value from table below as determined by machine type and sanitation method

$IdleDraw_{ESTAR}$ = Idle power draw (kW) of ENERGY STAR dishwasher

= Custom or if unknown, use value from table below as determined by machine type and sanitation method

Hours = Average daily hours of dishwasher operation

= Custom or if unknown, use 18 hours per day

WashTime = Typical wash time (min)

= Custom or if unknown, use value from table below as determined by machine type and sanitation method

60 = Minutes to hours conversion factor

**EXAMPLE**

For example, an ENERGY STAR high-temperature, under counter dishwasher with electric building and electric booster water heating with defaults from the calculation above and the table below would save:

$$\Delta kWh = \Delta BuildingEnergy + \Delta BoosterEnergy + \Delta IdleEnergy$$

Where:

ΔBuildingEnergy = [(1.09 * 75 * 365.25) * (70 *1.0 * 8.2 ÷ 0.98 ÷ 3,412)] - [(0.86 * 75 * 365.25) * (70 *1.0 * 8.2 ÷ 0.98 ÷ 3,412)]

= 1,082 kWh

ΔBoosterEnergy = [(1.09 * 75 * 365.25) * (40 *1.0 * 8.2 ÷ 0.98 ÷ 3,412)] - [(0.86 * 75 * 365.25) * (40 *1.0 * 8.2 ÷ 0.98 ÷ 3,412)]

= 618 kWh

ΔIdleEnergy = [0.76 * (18 *365.25 – 365.25 * 75 * 2.0 ÷ 60)] – [0.50 * (18 *365.25 – 365.25 * 75 * 2.0 ÷ 60)]

= 1,472 Wh

ΔkWh = 1,082 + 618 + 1,472

= 3,172 kWh

Default values for WaterUse, RacksWashed, $kW_{Idle}$, and WashTime are presented in the table below.

| | RacksWashed | WashTime | WaterUse | | IdleDraw | |
|---|---|---|---|---|---|---|
| **Low Temperature** | **All Dishwashers** | **All Dishwashers** | **Conventional** | **ENERGY STAR** | **Conventional** | **ENERGY STAR** |
| Under Counter | 75 | 2.0 | 1.73 | 1.19 | 0.50 | 0.50 |
| Stationary Single Tank Door | 280 | 1.5 | 2.10 | 1.18 | 0.60 | 0.60 |
| Single Tank Conveyor | 400 | 0.3 | 1.31 | 0.79 | 1.60 | 1.50 |
| Multi Tank Conveyor | 600 | 0.3 | 1.04 | 0.54 | 2.00 | 2.00 |
| **High Temperature** | **All Dishwashers** | **All Dishwashers** | **Conventional** | **ENERGY STAR** | **Conventional** | **ENERGY STAR** |
| Under Counter | 75 | 2.0 | 1.09 | 0.86 | 0.76 | 0.50 |
| Stationary Single Tank Door | 280 | 1.0 | 1.29 | 0.89 | 0.87 | 0.70 |
| Single Tank Conveyor | 400 | 0.3 | 0.87 | 0.70 | 1.93 | 1.50 |
| Multi Tank Conveyor | 600 | 0.2 | 0.97 | 0.54 | 2.59 | 2.25 |
| Pot, Pan, and Utensil | 280 | 3.0<br>3.0 | 0.70 | 0.58 | 1.20 | 1.20 |

Savings for all water heating combinations are presented in the tables below (calculated without rounding variables as provided above).

Electric building and electric booster water heating

| Dishwasher type | | $kWh_{Base}$ | $kWh_{ESTAR}$ | ΔkWh |
|---|---|---|---|---|
| **Low Temp** | Under Counter | 10,972 | 8,431 | 2,541 |
| | Stationary Single Tank Door | 39,306 | 23,142 | 16,164 |
| | Single Tank Conveyor | 42,230 | 28,594 | 13,636 |
| | Multi Tank Conveyor | 50,112 | 31,288 | 18,824 |
| **High Temp** | Under Counter | 12,363 | 9,191 | 3,173 |
| | Stationary Single Tank Door | 39,852 | 27,981 | 11,871 |
| | Single Tank Conveyor | 45,593 | 36,375 | 9,218 |
| | Multi Tank Conveyor | 72,523 | 45,096 | 27,426 |

| Dishwasher type | | $kWh_{Base}$ | $kWh_{ESTAR}$ | ΔkWh |
|---|---|---|---|---|
| | Pot, Pan, and Utensil | 21,079 | 17,766 | 3,313 |

Electric building and natural gas booster water heating

| Dishwasher type | | $kWh_{Base}$ | $kWh_{ESTAR}$ | ΔkWh |
|---|---|---|---|---|
| Low Temp | Under Counter | 10,972 | 8,431 | 2,541 |
| | Stationary Single Tank Door | 39,306 | 23,142 | 16,164 |
| | Single Tank Conveyor | 42,230 | 28,594 | 13,636 |
| | Multi Tank Conveyor | 50,112 | 31,288 | 18,824 |
| High Temp | Under Counter | 9,432 | 6,878 | 2,554 |
| | Stationary Single Tank Door | 26,901 | 19,046 | 7,856 |
| | Single Tank Conveyor | 33,115 | 26,335 | 6,780 |
| | Multi Tank Conveyor | 51,655 | 33,479 | 18,176 |
| | Pot, Pan, and Utensil | 14,052 | 11,943 | 2,108 |

Natural gas building and electric booster water heating

| Dishwasher type | | $kWh_{Base}$ | $kWh_{ESTAR}$ | ΔkWh |
|---|---|---|---|---|
| Low Temp | Under Counter | 2,831 | 2,831 | 0 |
| | Stationary Single Tank Door | 2,411 | 2,411 | 0 |
| | Single Tank Conveyor | 9,350 | 8,766 | 584 |
| | Multi Tank Conveyor | 10,958 | 10,958 | 0 |
| High Temp | Under Counter | 7,234 | 5,143 | 2,090 |
| | Stationary Single Tank Door | 17,188 | 12,344 | 4,844 |
| | Single Tank Conveyor | 23,757 | 18,806 | 4,951 |
| | Multi Tank Conveyor | 36,004 | 24,766 | 11,238 |
| | Pot, Pan, and Utensil | 8,781 | 7,576 | 1,205 |

Natural gas building and natural gas booster water heating

| Dishwasher type | | $kWh_{Base}$ | $kWh_{ESTAR}$ | ΔkWh |
|---|---|---|---|---|
| Low Temp | Under Counter | 2,831 | 2,831 | 0 |
| | Stationary Single Tank Door | 2,411 | 2,411 | 0 |
| | Single Tank Conveyor | 9,350 | 8,766 | 584 |
| | Multi Tank Conveyor | 10,958 | 10,958 | 0 |
| High Temp | Under Counter | 4,303 | 2,831 | 1,472 |
| | Stationary Single Tank Door | 4,237 | 3,409 | 828 |
| | Single Tank Conveyor | 11,279 | 8,766 | 2,513 |
| | Multi Tank Conveyor | 15,136 | 13,149 | 1,987 |
| | Pot, Pan, and Utensil | 1,753 | 1,753 | 0 |

Secondary kWh Savings for Water Supply and Wastewater Treatment

The following savings should be included in the total savings for this measure, but should not be included in TRC tests to avoid double counting the economic benefit of water savings.

$$\Delta kWh_{water} = \Delta Water\ (gallons) / 1{,}000{,}000 * E_{water\ total}$$

Where

$E_{water\ total}$ = IL Total Water Energy Factor (kWh/Million Gallons)

=5,010[79]

**EXAMPLE**

For example, an ENERGY STAR low-temperature, under counter dishwasher with defaults from the calculation above and the table within the electric energy savings characterization would save:

$\Delta Water = (WaterUse_{Base} * RacksWashed * Days) - (WaterUse_{ESTAR} * RacksWashed * Days)$

ΔWater (gallons) = (1.73 * 75 * 365.25) - (1.19 * 75 * 365.25)

= 14,793 gallons

$\Delta kWh_{water}$ = 14,793/1,000,000*5,010

= 74 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = ΔkWh/ AnnualHours * CF

Where:

ΔkWh = Annual kWh savings from measure as calculated above. Note do not include the secondary savings in this calculation.

AnnualHours = Hours * Days

= Custom or if unknown assume (18 * 365.25 =) 6575 annual hours

CF = Summer Peak Coincidence Factor

= dependent on restaurant type[80]:

| Location | CF |
|---|---|
| Fast Food Limited Menu | 0.32 |
| Fast Food Expanded Menu | 0.41 |
| Pizza | 0.46 |
| Full Service Limited Menu | 0.51 |
| Full Service Expanded Menu | 0.36 |
| Cafeteria | 0.39 |

Example:

A low temperature undercounter dishwasher in a Full Service Limited Menu restaurant with electric building and booster water heaters would save:

ΔkW = ΔkWh/ AnnualHours * CF

= 2541/6575*0.51

= 0.197 kW

[79] This factor include 2571 kWh/MG for water supply based on Illinois energy intensity data from a 2012 ISAWWA study and 2439 kWh/MG for wastewater treatment based on national energy intensity use estimates. For more information please review Elevate Energy's 'IL TRM: Energy per Gallon Factor, May 2018 paper'.

[80] Values taken from Minnesota Technical Reference Manual (Version 2.2, effective May 2, 2018), 'Electric Oven and Range' measure and are based upon "Project on Restaurant Energy Performance-End-Use Monitoring and Analysis", Appendixes I and II, Claar, et. al., May 1985

**NATURAL GAS ENERGY SAVINGS**

$$\Delta \text{Therms}^{81} = \Delta \text{BuildingEnergy} + \Delta \text{BoosterEnergy}$$

Where:

ΔBuildingEnergy = Change in annual natural gas consumption of building water heater

= [($WaterUse_{Base}$ * RacksWashed * Days)*($\Delta T_{in}$ * 1.0 * 8.2 ÷ $Eff_{Heater}$ ÷ 100,000)] - [($WaterUse_{ESTAR}$* RacksWashed * Days)*($\Delta T_{in}$ * 1.0*8.2 ÷ $Eff_{Heater}$ ÷ 100,000)]

ΔBoosterEnergy = Change in annual natural gas consumption of booster water heater

= [($WaterUse_{Base}$ * RacksWashed * Days)*($\Delta T_{in}$ * 1.0 * 8.2 ÷ $Eff_{Heater}$ ÷ 100,000)] - [($WaterUse_{ESTAR}$* RacksWashed * Days)*($\Delta T_{in}$ * 1.0*8.2 ÷ $Eff_{Heater}$ ÷ 100,000)]

Where:

$WaterUse_{Base}$ = Water use per rack (gal) of baseline dishwasher

= Custom or if unknown, use value from table within the electric energy savings characterization as determined by machine type and sanitation method

$WaterUse_{ESTAR}$ = Water use per rack (gal) of ENERGY STAR dishwasher

= Custom or if unknown, use value from table within the electric energy savings characterization as determined by machine type and sanitation method

RacksWashed = Number of racks washed per day

= Custom or if unknown, use value from table within the electric energy savings characterization as determined by machine type and sanitation method

Days = Annual days of dishwasher operation

= Custom or if unknown, use 365 days per year

$\Delta T_{in}$ = Inlet water temperature increase (°F)

= Custom or if unknown, use 70 °F for building water heaters and 40 °F for booster water heaters

1.0 = Specific heat of water (Btu/lb/°F)

8.2 = Density of water (lb/gal)

$Eff_{Heater}$ = Efficiency of water heater

= Custom or 80% for gas building and booster water heaters

100,000 = Therms to Btu conversion factor

[81] Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator

**EXAMPLE**

For example, an ENERGY STAR high-temperature, under counter dishwasher with gas building and gas booster water heating with defaults from the calculation above and the table within the electric energy savings characterization would save:

ΔTherms = ΔBuildingEnergy + ΔBoosterEnergy

Where:

ΔBuildingEnergy = [(1.09 * 75 * 365.25)*(70 * 1.0 * 8.2 ÷ 0.80 ÷ 100,000)] - [(0.86 * 75 * 365.25)*(70 * 1.0 * 8.2 ÷ 0.80 ÷ 100,000)]

= 45 therms

ΔBoosterEnergy = [(1.09 * 75 * 365.25)*(40 * 1.0 * 8.2 ÷ 0.80 ÷ 100,000)] - [(0.86 * 75 * 365.25)*(40 * 1.0 * 8.2 ÷ 0.80 ÷ 100,000)]

= 26 therms

ΔTherms = 45 + 26

= 71 therms

Savings for all water heating combinations are presented in the tables below.

Electric building and natural gas booster water heating

| Dishwasher type | | $Therms_{Base}$ | $Therms_{ESTAR}$ | ΔTherms |
|---|---|---|---|---|
| Low Temp | Under Counter | NA | NA | NA |
| | Stationary Single Tank Door | NA | NA | NA |
| | Single Tank Conveyor | NA | NA | NA |
| | Multi Tank Conveyor | NA | NA | NA |
| High Temp | Under Counter | 123 | 97 | 26 |
| | Stationary Single Tank Door | 541 | 374 | 168 |
| | Single Tank Conveyor | 522 | 420 | 102 |
| | Stationary Single Tank Door | 872 | 486 | 387 |
| | Pot, Pan, and Utensil | 294 | 243 | 50 |

Natural gas building and natural gas booster water heating

| Dishwasher type | | $Therms_{Base}$ | $Therms_{ESTAR}$ | ΔTherms |
|---|---|---|---|---|
| Low Temp | Under Counter | 340 | 234 | 106 |
| | Stationary Single Tank Door | 1,543 | 867 | 676 |
| | Single Tank Conveyor | 1,375 | 829 | 546 |
| | Multi Tank Conveyor | 1,637 | 850 | 787 |
| High Temp | Under Counter | 337 | 266 | 71 |
| | Stationary Single Tank Door | 1,489 | 1,027 | 462 |
| | Single Tank Conveyor | 1,435 | 1,154 | 280 |
| | Multi Tank Conveyor | 2,399 | 1,336 | 1,064 |
| | Pot, Pan, and Utensil | 808 | 669 | 139 |

Natural gas building and electric booster water heating

| Dishwasher type | | $Therms_{Base}$ | $Therms_{ESTAR}$ | ΔTherms |
|---|---|---|---|---|
| Low Temp | Under Counter | 340 | 234 | 106 |
| | Stationary Single Tank Door | 1,543 | 867 | 676 |
| | Single Tank Conveyor | 1,375 | 829 | 546 |
| | Multi Tank Conveyor | 1,637 | 850 | 787 |

| Dishwasher type | | $Therms_{Base}$ | $Therms_{ESTAR}$ | ΔTherms |
|---|---|---|---|---|
| High Temp | Under Counter | 214 | 169 | 45 |
| | Stationary Single Tank Door | 948 | 654 | 294 |
| | Single Tank Conveyor | 913 | 735 | 178 |
| | Multi Tank Conveyor | 1,527 | 850 | 677 |
| | Pot, Pan, and Utensil | 514 | 426 | 88 |

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

$$\Delta Water = (WaterUse_{Base} * RacksWashed * Days) - (WaterUse_{ESTAR} * RacksWashed * Days)$$

Where:

$WaterUse_{Base}$ = Water use per rack (gal) of baseline dishwasher

= Custom or if unknown, use value from table within the electric energy savings characterization as determined by machine type and sanitation method

$WaterUse_{ESTAR}$ = Water use per rack (gal) of ENERGY STAR dishwasher

= Custom or if unknown, use value from table within the electric energy savings characterization as determined by machine type and sanitation method

RacksWashed = Number of racks washed per day

= Custom or if unknown, use value from table within the electric energy savings characterization as determined by machine type and sanitation method

Days = Annual days of dishwasher operation

= Custom or if unknown, use 365 days per year

**EXAMPLE**

For example, an ENERGY STAR low-temperature, under counter dishwasher with defaults from the calculation above and the table within the electric energy savings characterization would save:

ΔWater = ($WaterUse_{Base}$ * RacksWashed * Days) - ($WaterUse_{ESTAR}$ * RacksWashed * Days)

ΔWater (gallons) = (1.73 * 75 * 365.25) - (1.19 * 75 * 365.25)

= 14,793 gallons

Savings for all dishwasher types are presented in the table below.

| | Annual Water Consumption (gallons) | | |
|---|---|---|---|
| | Baseline | ENERGY STAR | Savings |
| **Low Temperature** | | | |
| Under Counter | 47,391 | 32,599 | 14,793 |
| Stationary Single Tank Door | 214,767 | 120,679 | 94,088 |
| Single Tank Conveyor | 191,391 | 115,419 | 75,972 |
| Multi Tank Conveyor | 227,916 | 118,341 | 109,575 |
| **High Temperature** | | | |
| Under Counter | 29,859 | 23,559 | 6,301 |
| Stationary Single Tank Door | 131,928 | 91,020 | 40,908 |
| Single Tank Conveyor | 127,107 | 102,270 | 24,837 |
| Multi Tank Conveyor | 212,576 | 118,341 | 94,235 |
| Pot, Pan, and Utensil | 71,589 | 59,317 | 12,272 |

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-FSE-ESDW-V04-190101**

**REVIEW DEADLINE: 1/1/2023**

## 4.2.7 ENERGY STAR Fryer

### DESCRIPTION

This measure applies to electric or natural gas fired ENERGY STAR certified fryers installed in a commercial kitchen.

This measure was developed to be applicable to the following program types: TOS. If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the installed equipment must be an ENERGY STAR certified fryer meeting idle energy rate (W or Btu/hr)) and cooking efficiency (%) limits, as determined by both fuel type and fryer capacity (standard versus large vat).

**ENERGY STAR Requirements (Version 3.0, Effective October 1, 2016)**

| Fryer Capacity | Electric Efficiency Requirements | | Natural Gas Efficiency Requirements | |
|---|---|---|---|---|
| | Idle Energy Rate | Cooking Efficiency Consumption | Idle Energy Rate | Cooking Efficiency Consumption |
| Standard Open Deep-Fat Fryer | ≤ 800 W | ≥ 83% | ≤ 9,000 Btu/hr | ≥ 50% |
| Large Vat Open Deep-Fat Fryer | ≤ 1,100 W | ≥ 80% | ≤ 12,000 Btu/hr | |

### DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a new electric or natural gas fryer that is not ENERGY STAR certified.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years.[82]

### DEEMED MEASURE COST

The incremental capital cost for this measure is $1200.[83]

### LOADSHAPE

Loadshape C01 - Commercial Electric Cooking

### COINCIDENCE FACTOR

Summer Peak Coincidence Factor for measure is provided below for different building type[84]:

| Location | CF |
|---|---|
| Fast Food Limited Menu | 0.32 |
| Fast Food Expanded Menu | 0.41 |
| Pizza | 0.46 |
| Full Service Limited Menu | 0.51 |
| Full Service Expanded Menu | 0.36 |

---

[82]Lifetime from ENERGY STAR Commercial Kitchen Equipment Savings Calculator ,which cites reference as "FSTC research on available models, 2009

[83]Measure cost from ENERGY STAR Commercial Kitchen Equipment Savings Calculator which cites reference as "EPA research on available models using AutoQuotes, 2010".

[84]Values taken from Minnesota Technical Reference Manual, (Version 2.2, effective May 2, 2018), 'Electric Oven and Range' measure and are based upon "Project on Restaurant Energy Performance-End-Use Monitoring and Analysis", Appendixes I and II, Claar, et. al., May 1985

| Location | CF |
|---|---|
| Cafeteria | 0.39 |

## Algorithm

### Calculation of Savings

### Electric Energy Savings

Custom calculation for an electric fryer below, otherwise use deemed value of 2,378.0 kWh for standard fryers and 2,537.9 kWh for large vat fryers.[85]

$\Delta kWh$ = (ΔDailyIdleEnergy + ΔDailyCookingEnergy) * Days /1,000

Where:

ΔDailyIdleEnergy = ($ElecIdle_{Base}$ * (HOURS – LB/$ElecPC_{Base}$)) – ($ElecIdle_{ESTAR}$ * (HOURS – LB/$ElecPC_{ESTAR}$))

ΔDailyCookingEnergy = (LB * $EFOOD_{Elec}$/ $ElecEff_{Base}$) – (LB * $EFOOD_{Elec}$/$ElecEff_{ESTAR}$)

Where:

ΔDailyIdleEnergy = Difference in idle energy between baseline and efficient fryer

ΔDailyCookingEnergy = Difference in cooking energy between baseline and efficient fryer

Days = Annual days of operation

= Custom or if unknown, use 365.25 days per year

1,000 = Wh to kWh conversion factor

$ElecIdle_{Base}$ = Idle energy rate of baseline electric fryer

= 1,050 W for standard fryers and 1,350 W for large vat fryers

$ElecIdle_{ESTAR}$ = Idle energy rate of ENERGY STAR electric fryer

= Custom or if unknown, use 800 W for standard fryers and 1,100 for large vat fryers

HOURS = Average daily hours of operation

= Custom or if unknown, use 16 hours per day for a standard fryer and 12 hours per day for a large vat fryer

LB = Food cooked per day

= Custom or if unknown, use 150 pounds

$ElecPC_{Base}$ = Production capacity of baseline electric fryer

= 65 lb/hr for standard fryers and 100 lb/hr for large vat fryers

$ElecPC_{ESTAR}$ = Production capacity of ENERGY STAR electric fryer

= Custom or if unknown, use 70 lb/hr for standard fryers and 110 lb/hr for large vat fryers

$EFOOD_{Elec}$ = ASTM energy to food for electric fryers

[85] Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator

= 167 Wh/lb

$ElecEff_{Base}$ = Cooking efficiency of baseline electric fryer

= 75% for standard fryers and 70% for large vat fryers

$ElecEff_{ESTAR}$ = Cooking efficiency of ENERGY STAR electric fryer

= Custom or if unknown, use 83% for standard fryers and 80% for large vat fryers

**EXAMPLE**

For example, an ENERGY STAR standard-sized electric fryer, using default values from the calculation above, would save:

ΔkWh = (ΔDailyIdleEnergy + ΔDailyCookingEnergy) * Days /1,000

Where:

ΔDailyIdleEnergy = (1,050 * (16 – 150 / 65)) - (800 * (16 – 150 / 70))

= 3,291 Wh

ΔDailyCookingEnergy = (150 * 167/ 0.75) - (150 * 167/ 0.83)

= 3,219 Wh

ΔkWh = (3,291 + 3,219) * 365.25 / 1,000

= 2,378.0 kWh

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ΔkWh/(HOURS * Days) * CF

Where:

ΔkWh = Electric energy savings, calculated above

Other variables as defined above.

**EXAMPLE**

For example, an ENERGY STAR standard-sized electric fryer in a cafeteria, using default values from the calculation above, would save:

ΔkW = ΔkWh/(HOURS * Days) * CF

= 2,378.0 / (16 * 365.25) * 0.36

= 0.1465 kW

### NATURAL GAS ENERGY SAVINGS

Custom calculation for a gas fryer below, otherwise use deemed value of 507.9 therms for standard fryers and 415.1 therms for large vat fryers.[86]

ΔTherms = (ΔDailyIdle Energy + ΔDailyCooking Energy) * Days /100,000

Where:

ΔDailyIdleEnergy = $(GasIdle_{Base}$ * (HOURS – $LB/GasPC_{Base}$)) – ($GasIdle_{ESTAR}$ * (HOURS – $LB/GasPC_{ESTAR}$))

ΔDailyCookingEnergy = (LB * $EFOOD_{Gas}/ GasEff_{Base}$) – (LB * $EFOOD_{Gas}/GasEff_{ESTAR}$)

Where:

[86] Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator

| | |
|---|---|
| 100,000 | = Btu to therms conversion factor |
| $GasIdle_{Base}$ | = Idle energy rate of baseline gas fryer |
| | = 14,000 Btu/hr for standard fryers and 16,000 Btu/hr for large vat fryers |
| $GasIdle_{ESTAR}$ | = Idle energy rate of ENERGY STAR gas fryer |
| | = Custom or if unknown, use 9,000 Btu/hr for standard fryers and 12,000 Btu/hr for large vat fryers |
| $GasPC_{Base}$ | = Production capacity of baseline gas fryer |
| | = 60 lb/hr for standard fryers and 100 lb/hr for large vat fryers |
| $GasPC_{ESTAR}$ | = Production capacity of ENERGY STAR gas fryer |
| | = Custom or if unknown, use 65 lb/hr for standard fryers and 110 lb/hr for large vat fryers |
| $EFOOD_{Gas}$ | = ASTM energy to food |
| | = 570 Btu/lb |
| $GasEff_{Base}$ | = Cooking efficiency of baseline gas fryer |
| | = 35% for both standard and large vat fryers |
| $GasEff_{ESTAR}$ | = Cooking efficiency of ENERGY STAR gas fryer |
| | = Custom or if unknown, use 50% for both standard and large vat fryers |

Other variables as defined above.

**EXAMPLE**

For example, an ENERGY STAR standard-sized electric fryer, using default values from the calculation above, would save:

ΔTherms = (ΔDailyIdleEnergy + ΔDailyCookingEnergy) * Days /100,000

Where:

ΔDailyIdleEnergy = (14,000 * (16 – 150 / 60)) - (9,000 * (16 – 150 / 65))

= 65,769 Btu/day

ΔDailyCookingEnergy = (150 * 570/ 0.35) - (150 * 570/ 0.50)

=73,286 Btu/day

ΔTherms = (65,769 + 73,286) * 365.25 / 100,000

= 507.9 therms

### WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

### DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

### MEASURE CODE: CI-FSE-ESFR-V02-190101

### REVIEW DEADLINE: 1/1/2022

## 4.2.8 ENERGY STAR Griddle

### DESCRIPTION

This measure applies to electric and natural gas fired high efficiency griddle installed in a commercial kitchen.

This measure was developed to be applicable to the following program types: TOS. If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed equipment must be an ENERGY STAR natural gas or electric griddle with a tested heavy load cooking energy efficiency of 70 percent (electric) 38 percent (gas) or greater and an idle energy rate of 2,650 Btu/hr per square foot of cooking surface or less, utilizing ASTM F1275. The griddle must have an Idle Energy Consumption Rate < 2,600 Btu/hr per square foot of cooking surface.

### DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is an existing natural gas or electric griddle that's not ENERGY STAR certified and is at end of use.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years[87]

### DEEMED MEASURE COST

The incremental capital cost for this measure is $0 for and electric griddle and $60 for a gas griddle.[88]

### LOADSHAPE

Loadshape C01 - Commercial Electric Cooking

### COINCIDENCE FACTOR

Summer Peak Coincidence Factor for measure is provided below for different building type[89]:

| Location | CF |
|---|---|
| Fast Food Limited Menu | 0.32 |
| Fast Food Expanded Menu | 0.41 |
| Pizza | 0.46 |
| Full Service Limited Menu | 0.51 |
| Full Service Expanded Menu | 0.36 |
| Cafeteria | 0.39 |

87 Lifetime from ENERGY STAR Commercial Kitchen Equipment Calculator, Commercial Griddle Calculations, which cites reference as "FSTC research on available models, 2009".

88 Measure cost from ENERGY STAR Commercial Kitchen Equipment Calculator, which cites reference as "EPA research on available models using AutoQuotes, 2010".

89 Values taken from Minnesota Technical Reference Manual (Version 2.2, effective May 2, 2018), 'Electric Oven and Range' measure and are based upon "Project on Restaurant Energy Performance-End-Use Monitoring and Analysis", Appendixes I and II, Claar, et. al., May 1985

## Algorithm

### CALCULATION OF SAVINGS [90]

### ELECTRIC ENERGY SAVINGS

ΔkWh = (ΔIdle Energy + ΔPreheat Energy + ΔCooking Energy) * Days /1000

Where:

ΔDailyIdleEnergy =[(IdleBase * Width * Depth * (HOURSday – (LB/(PCBase * Width * Depth)) – (PreheatNumberBase* PreheatTimeBase/60)]- [(IdleENERGYSTAR * Width * Depth * (HOURSday – (LB/(PCENERGYSTAR * Width * Depth)) – (PreheatNumberENERGYSTAR* PreheatTimeENERGYSTAR/60]

ΔDailyPreheatEnergy = (PreHeatNumberBase * PreheatTimeBase / 60 * PreheatRateBase * Width * Depth) – (PreheatNumberENERGYSTAR* PreheatTimeENERGYSTAR/60 * PreheatRateENERGYSTAR * Width * Depth)

ΔDailyCookingEnergy = (LB * EFOOD/ EffBase) - (LB * EFOOD/ EffENERGYSTAR)

Where:

HOURSday = Average Daily Operation

= custom or if unknown, use 12 hours

Days = Annual days of operation

= custom or if unknown, use 365.25 days a year

LB = Food cooked per day

= custom or if unknown, use 100 pounds

Width = Griddle Width

= custom or if unknown, use 3 feet

Depth = Griddle Depth

= custom or if unknown, use 2 feet

EffENERGYSTAR = Cooking Efficiency ENERGY STAR

= custom or if unknown, use 70%

EffBase = Cooking Efficiency Baseline

= custom or if unknown, use 65%

PCENERGYSTAR = Production Capacity ENERGY STAR

= custom or if unknown, use 40/6 = 6.67 pounds/hr/sq ft

PCBase = Production Capacity base

= custom or if unknown, use 35/6 = 5.83 pounds/hr/sq ft

PreheatNumberENERGYSTAR = Number of preheats per day

= custom or if unknown, use 1

PreheatNumberBase = Number of preheats per day

[90] Algorithms and assumptions derived from ENERGY STAR Griddle Commercial Kitchen Equipment Savings Calculator.

| | |
|---|---|
| | = custom or if unknown, use 1 |
| PreheatTimeENERGYSTAR | = preheat length |
| | = custom or if unknown, use 15 minutes |
| PreheatTimeBase | = preheat length |
| | = custom or if unknown, use 15 minutes |
| PreheatRateENERGYSTAR | = preheat energy rate high efficiency |
| | = custom or if unknown, use 8000/6 = 1333 W/sq ft |
| PreheatRateBase | = preheat energy rate baseline |
| | = custom or if unknown, use 16000/6 = 2667 W/sq ft |
| IdleENERGYSTAR | = Idle energy rate |
| | = custom or if unknown, use 320 W/sq ft |
| IdleBase | = Idle energy rate |
| | = custom or if unknown, use 400 W/sq ft |
| EFOOD | = ASTM energy to food |
| | = 139 w/pound |

For example, an ENERGY STAR griddle with a tested heavy load cooking energy efficiency of 70 percent or greater and an idle energy rate of 320 W per square foot of cooking surface or less would save.

| | |
|---|---|
| ΔDailyIdleEnergy | =[400 * 3 * 2 * (12 – (100/(35/6 * 3 * 2)) – (1 *15/60)]- [320 * 3 * 2 * (12 – (100/(40/6 * 3 * 2)) – (1* 15/60] |
| | = 3583 W |
| ΔDailyPreheatEnergy | = (1* 15 / 60 * 16000/6 * 3 * 2) – (1* 15/60 * 8000/6 * 3 * 2) |
| | = 2000W |
| ΔDailyCookingEnergy | = (100 * 139 / 0.65) - (100 * 139 / 0.70) |
| | = 1527 W |
| ΔkWh | = (2000+1527+3583) * 365.25 /1000 |
| | = 2597 kWh |

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

kW = ΔkWh/Hours * CF

For example, an ENERGY STAR griddle in a cafeteria with a tested heavy load cooking energy efficiency of 70 percent or greater and an idle energy rate of 320 W per square foot of cooking surface or less would save

=2597 kWh/4308 * 0.39

= 0.24 kW

### NATURAL GAS ENERGY SAVINGS

Custom calculation below, otherwise use deemed value of 149 therms.

ΔTherms = (ΔIdle Energy + ΔPreheat Energy + ΔCooking Energy) * Days /100000

Where:

ΔDailyIdleEnergy =[(IdleBase * Width * Depth * (HOURSday - LB/(PCBase * Width * Depth)) – (PreheatNumberBase* PreheatTimeBase/60)]- [(IdleENERGYSTAR * Width * Depth * (HOURSday – (LB/(PCENERGYSTAR * Width * Depth)) – (PreheatNumberENERGYSTAR* PreheatTimeENERGYSTAR/60]

ΔDailyPreheatEnergy = (PreHeatNumberBase * PreheatTimeBase / 60 * PreheatRateBase * Width * Depth) – (PreheatNumberENERGYSTAR* PreheatTimeENERGYSTAR/60 * PreheatRateENERGYSTAR * Width * Depth)

ΔDailyCookingEnergy = (LB * EFOOD/ EffBase) - (LB * EFOOD/ EffENERGYSTAR)

Where (new variables only):

EffENERGYSTAR = Cooking Efficiency ENERGY STAR

= custom or if unknown, use 38%

EffBase = Cooking Efficiency Baseline

= custom or if unknown, use 32%

PCENERGYSTAR = Production Capacity ENERGY STAR

= custom or if unknown, use 45/6 = 7.5 pounds/hr/sq ft

PCBase = Production Capacity base

= custom or if unknown, use 25/6 = 4.17 pounds/hr/sq ft

PreheatRateENERGYSTAR = preheat energy rate high efficiency

= custom or if unknown, use 60000/6 = 10000 btu/h/sq ft

PreheatRateBase = preheat energy rate baseline

= custom or if unknown, use 84000/6 = 14000 btu/h/sq ft

IdleENERGYSTAR = Idle energy rate

= custom or if unknown, use 15900/6 = 2650 btu/h/sq ft

IdleBase = Idle energy rate

= custom or if unknown, use 21000/6 = 3500 btu/h/sq ft

EFOOD = ASTM energy to food

= 475 btu/pound

For example, an ENERGY STAR griddle with a tested heavy load cooking energy efficiency of 38 percent or greater and an idle energy rate of 2,650 Btu/h per square foot of cooking surface or less and an Idle Energy Consumption Rate < 2,600 Btu/h per square foot of cooking surface would save.

ΔDailyIdleEnergy =[3500 * 3 * 2 * (12 - 100/(25/6* 3 * 2)) – (1* 15/60))]- [(2650 * 3 * 2 * (12 - (100/(45/6 * 3 * 2)) – (1* 15/60)))]

= 11258 Btu

ΔDailyPreheatEnergy = (1 * 15 / 60 * 14,000 * 3 * 2) – (1* 15/60 * 10000 * 3 * 2)

= 6000 btu

ΔDailyCookingEnergy = (100 * 475/ 0.32) - (100 * 475/ 0.38)

=23438 btu

ΔTherms = (11258 + 6000 + 23438) * 365.25 /100000

=149 therms

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-FSE-ESGR-V03-190101**

**REVIEW DEADLINE: 1/1/2023**

## 4.2.9 ENERGY STAR Hot Food Holding Cabinets

### DESCRIPTION

This measure applies to electric ENERGY STAR hot food holding cabinets (HFHC) installed in a commercial kitchen.

This measure was developed to be applicable to the following program types: TOS. If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed equipment must be an ENERGY STAR certified HFHC.

### DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is an electric HFHC that's not ENERGY STAR certified and at end of life.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years[91]

### DEEMED MEASURE COST

The incremental capital cost for this measure is[92]

| HFHC Size | Incremental Cost |
|---|---|
| Full Size (20 cubic feet) | $1200 |
| ¾ Size (12 cubic feet) | $1800 |
| ½ Size (8 cubic feet) | $1500 |

### LOADSHAPE

Loadshape C01 - Commercial Electric Cooking

### COINCIDENCE FACTOR

Summer Peak Coincidence Factor for measure is provided below for different building type[93]:

| Location | CF |
|---|---|
| Fast Food Limited Menu | 0.32 |
| Fast Food Expanded Menu | 0.41 |
| Pizza | 0.46 |
| Full Service Limited Menu | 0.51 |
| Full Service Expanded Menu | 0.36 |
| Cafeteria | 0.39 |

[91] Lifetime from ENERGY STAR Commercial Kitchen Equipment Calculator, Hot Food Holding Cabinet Calculations, which cites reference as "FSTC research on available models, 2009"

[92] Measure cost from ENERGY STAR Commercial Kitchen Equipment Calculator, which cites reference as "EPA research on available models using AutoQuotes, 2010"

[93]Values taken from Minnesota Technical Reference Manual (Version 2.2, effective May 2, 2018), 'Electric Oven and Range' measure and are based upon "Project on Restaurant Energy Performance-End-Use Monitoring and Analysis", Appendixes I and II, Claar, et. al., May 1985

**Algorithm**

## CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

Custom calculation below, otherwise use deemed values depending on HFHC size[94]

| Cabinet Size | Savings (kWh) |
|---|---|
| Full Size HFHC | 9308 |
| ¾ Size HFHC | 3942 |
| ½ Size HFHC | 2628 |

ΔkWh = HFHCBaselinekWh – HFHCENERGYSTARkWh

Where:

HFHCBaselinekWh = PowerBaseline* HOURSday * Days/1000

PowerBaseline = Custom, otherwise

| Cabinet Size | Power (W) |
|---|---|
| Full Size HFHC | 2500 |
| ¾ Size HFHC | 1200 |
| ½ Size HFHC | 800 |

HOURSday = Average Daily Operation

= custom or if unknown, use 15 hours

Days = Annual days of operation

= custom or if unknown, use 365.25 days a year

HFHCENERGYSTARkWh = PowerENERGYSTAR* HOURSday * Days/1000

PowerENERGYSTAR = Custom, otherwise

| Cabinet Size | Power (W) |
|---|---|
| Full Size HFHC | 800 |
| ¾ Size HFHC | 480 |
| ½ Size HFHC | 320 |

HOURSday = Average Daily Operation

= custom or if unknown, use 15 hours

Days = Annual days of operation

= custom or if unknown, use 365.25 days a year

[94] Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator.

| |
|---|
| For example, if a full size HFHC is installed the measure would save:<br>ΔkWh = (PowerBaseline* HOURSday * Days)/1000 – (PowerENERGYSTAR* HOURSday * Days)/1000<br>= (2500*15*365.25)/1000 – (800*15*365.25)/1000<br>= 9,314 kWh |

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = ΔkWh/Hours * CF

Where: Hours = Hoursday *Days

| |
|---|
| For example, if a full size HFHC is installed in a cafeteria the measure would save:<br>= 9,314 kWh / (15*365.25)* .39<br>=0 .66 kW |

**NATURAL GAS ENERGY SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-FSE-ESHH-V03-190101**

**REVIEW DEADLINE: 1/1/2023**

## 4.2.10 ENERGY STAR Ice Maker

### Description

This measure relates to the installation of a new ENERGY STAR qualified commercial ice machine. The ENERGY STAR label applied to air-cooled, cube-type machines including ice-making head, self-contained, and remote-condensing units. This measure excludes flake and nugget type ice machines. This measure could relate to the replacing of an existing unit at the end of its useful life, or the installation of a new system in a new or existing building.

This measure was developed to be applicable to the following program types: TOS and NC. If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

In order for this characterization to apply, the efficient equipment is assumed to be a new commercial ice machine meeting the minimum ENERGY STAR efficiency level standards.

**ENERGY STAR Requirements (Version 3.0, Effective January 28, 2018)**

| ENERGY STAR Requirements for Air-Cooled Batch-Type Ice Makers | | | |
|---|---|---|---|
| **Equipment Type** | **Applicable Ice Harvest Rate Range (lbs of ice/24 hrs)** | **ENERGY STAR Energy Consumption Rate (kWh/100 lbs ice)** | **Potable Water Use (gal/100 lbs ice)** |
| IMH | H < 300 | ≤ 9.20 - 0.01134H | ≤ 20.0 |
| | 300 ≤ H < 800 | ≤ 6.49 - 0.0023H | |
| | 800 ≤ H < 1500 | ≤ 5.11 - 0.00058H | |
| | 1500 ≤ H ≤ 4000 | ≤ 4.24 | |
| RCU | H < 988 | ≤ 7.17 – 0.00308H | ≤ 20.0 |
| | 988 ≤ H ≤ 4000 | ≤ 4.13 | |
| SCU | H < 110 | ≤ 12.57 - 0.0399H | ≤ 25.0 |
| | 110 ≤ H < 200 | ≤ 10.56 - 0.0215H | |
| | 200 ≤ H ≤ 4000 | ≤ 6.25 | |
| ENERGY STAR Requirements for Air-Cooled Continuous-Type Ice Makers | | | |
| **Equipment Type** | **Applicable Ice Harvest Rate Range (lbs of ice/24 hrs)** | **ENERGY STAR Energy Consumption Rate (kWh/100 lbs ice)** | **Potable Water Use (gal/100 lbs ice)** |
| IMH | H < 310 | ≤ 7.90 – 0.005409H | ≤ 15.0 |
| | 310 ≤ H < 820 | ≤ 7.08 – 0.002752H | |
| | 820 ≤ H ≤ 4000 | ≤ 4.82 | |
| RCU | H < 800 | ≤ 7.76 – 0.00464H | ≤ 15.0 |
| | 800 ≤ H ≤ 4000 | ≤ 4.05 | |
| SCU | H < 200 | ≤ 12.37 – 0.0261H | ≤ 15.0 |
| | 200 ≤ H < 700 | ≤ 8.24 – 0.005429H | |
| | 700 ≤ H ≤ 4000 | ≤ 4.44 | |

### Definition of Baseline Equipment

In order for this characterization to apply, the baseline equipment is assumed to be a commercial ice machine meeting federal equipment standards established January 1, 2010.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 9 years[95].

### DEEMED MEASURE COST

When available, the actual cost of the measure installation and equipment shall be used. The incremental capital cost for this measure is $0 for Batch-Type and $222 for Continuous-Type ice makers.[96]

### LOADSHAPE

Loadshape C23 - Commercial Refrigeration

### COINCIDENCE FACTOR

The Summer Peak Coincidence Factor is assumed to equal 0.937

## Algorithm

### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

$\Delta kWH = [(kWh_{base} – kWh_{ee}) / 100] * (DC * H) * 365.25$

Where:

$kWh_{base}$ = maximum kWh consumption per 100 pounds of ice for the baseline equipment

= calculated as shown in the table below using the actual Harvest Rate (H) of the efficient equipment.

$kWh_{ee}$ = maximum kWh consumption per 100 pounds of ice for the efficient equipment

= calculated as shown in the table below using the actual Harvest Rate (H) of the efficient equipment.

| Energy Consumption of Air-Cooled Batch-Type Ice Makers | | | |
|---|---|---|---|
| Ice Maker Type | Applicable Ice Harvest Rate Range (lbs of ice/24 hrs) | $kWh_{Base}$ | $kWh_{ESTAR}$ |
| IMH | H < 300 | 10-0.01233H | ≤ 9.20 - 0.01134H |
| | 300 ≤ H < 800 | 7.05-0.0025H | ≤ 6.49 - 0.0023H |
| | 800 ≤ H < 1500 | 5.55-0.00063H | ≤ 5.11 - 0.00058H |
| | 1500 ≤ H ≤ 4000 | 4.61 | ≤ 4.24 |
| RCU | H < 988 | 7.97-0.00342H | ≤ 7.17 – 0.00308H |
| | 988 ≤ H ≤ 4000 | 4.59 | ≤ 4.13 |
| SCU | H < 110 | 14.79-0.0469H | ≤ 12.57 - 0.0399H |
| | 110 ≤ H < 200 | 12.42-0.02533H | ≤ 10.56 - 0.0215H |
| | 200 ≤ H ≤ 4000 | 7.35 | ≤ 6.25 |
| Energy Consumption of Air-Cooled Continuous-Type Ice Makers | | | |

[95] Based on DOE Technical Support Document, 2014 as recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.
[96]Incremental costs from ENERGY STAR Commercial Kitchen Equipment Savings Calculator. Calculator cites EPA research using AutoQuotes, 2016.

| Energy Consumption of Air-Cooled Batch-Type Ice Makers | | | |
|---|---|---|---|
| Ice Maker Type | Applicable Ice Harvest Rate Range (lbs of ice/24 hrs) | $kWh_{Base}$ | $kWh_{ESTAR}$ |
| Equipment Type | Applicable Ice Harvest Rate Range (lbs of ice/24 hrs) | $kWh_{Base}$ | $kWh_{ESTAR}$ |
| IMH | H < 310 | 9.19-0.00629H | ≤ 7.90 – 0.005409H |
| | 310 ≤ H < 820 | 8.23-0.0032H | ≤ 7.08 – 0.002752H |
| | 820 ≤ H ≤ 4000 | 5.61 | ≤ 4.82 |
| RCU | H < 800 | 9.7-0.0058H | ≤ 7.76 – 0.00464H |
| | 800 ≤ H ≤ 4000 | 5.06 | ≤ 4.05 |
| SCU | H < 200 | 14.22-0.03H | ≤ 12.37 – 0.0261H |
| | 200 ≤ H < 700 | 9.47-0.00624H | ≤ 8.24 – 0.005429H |
| | 700 ≤ H ≤ 4000 | 5.1 | ≤ 4.44 |

100 = conversion factor to convert kWhbase and kWhee into maximum kWh consumption per pound of ice.

DC = Duty Cycle of the ice machine

= 0.57[97]

H = Harvest Rate (pounds of ice made per day)

= Actual installed

365.35 = days per year

For example a batch ice machine with an ice making head producing 450 pounds of ice would save

ΔkWH = [(5.9 – 5.5) / 100] * (0.57 * 450) * 365.25

= 440 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = ΔkWh / (HOURS * DC) * CF

Where:

HOURS = annual operating hours

= 8766[98]

CF = 0.937

[97]Duty cycle varies considerably from one installation to the next. TRM assumptions from Vermont, Wisconsin, and New York vary from 40 to 57%, whereas the ENERGY STAR Commercial Ice Machine Savings Calculator assumes a value of 75%. A field study of eight ice machines in California indicated an average duty cycle of 57% (“A Field Study to Characterize Water and Energy Use of Commercial Ice-Cube Machines and Quantify Saving Potential”, Food Service Technology Center, December 2007). Furthermore, a report prepared by ACEEE assumed a value of 40% (Nadel, S., Packaged Commercial Refrigeration Equipment: A Briefing Report for Program Planners and Implementers, ACEEE, December 2002). The value of 57% was utilized since it appears to represent a high quality data source.

[98]Unit is assumed to be connected to power 24 hours per day, 365.25 days per year.

| |
|---|
| For example an ice machine with an ice making head producing 450 pounds of ice would save<br>$\Delta kW = 440/(8766 * 0.57) * .937$<br>$= 0.083$ kW |

**NATURAL GAS ENERGY SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

While the ENERGY STAR labeling criteria require that certified commercial ice machines meet certain “maximum potable water use per 100 pounds of ice made” requirements, such requirements are intended to prevent equipment manufacturers from gaining energy efficiency at the cost of water consumptions. A review of the AHRI Certification Directory[99] indicates that approximately 81% of air-cooled, cube-type machines meet the ENERGY STAR potable water use requirement. Therefore, there are no assumed water impacts for this measure.

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-FSE-ESIM-V02-190101**

**REVIEW DEADLINE: 1/1/2024**

[99] AHRI Certification Directory, Automatic Commercial Ice Makers, Accessed on 7/7/10.

## 4.2.11 High Efficiency Pre-Rinse Spray Valve

### Description

Pre-rise valves use a spray of water to remove food waste from dishes prior to cleaning in a dishwasher. More efficient spray valves use less water thereby reducing water consumption, water heating cost, and waste water (sewer) charges. Pre-rinse spray valves include a nozzle, squeeze lever, and dish guard bumper. The primary impacts of this measure are water savings. Reduced hot water consumption saves either natural gas or electricity, depending on the type of energy the hot water heater uses.

This measure was developed to be applicable to the following program types: TOS, RF, and DI. If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

To qualify for this measure, the new or replacement pre-rinse spray nozzle must use less than 1.6 gallons per minute with a cleanability performance of 26 seconds per plate or less.

### Definition of Baseline Equipment

The baseline equipment will vary based on the delivery method and is defined below:

| Time of Sale | Retrofit, Direct Install |
|---|---|
| The baseline equipment is assumed to be 1.6 gallons per minute. The Energy Policy Act (EPAct) of 2005 sets the maximum flow rate for pre-rinse spray valves at 1.6 gallons per minute at 60 pounds per square inch of water pressure when tested in accordance with ASTM F2324-03. This performance standard went into effect January 1, 2006. | The baseline equipment is assumed to be an existing pre-rinse spray valve with a flow rate of 1.9 gallons per minute.[100] If existing pre-rinse spray valve flow rate is unknown, then existing pre-rinse spray valve must have been installed prior to 2006. The Energy Policy Act (EPAct) of 2005 sets the maximum flow rate for pre-rinse spray valves at 1.6 gallons per minute at 60 pounds per square inch of water pressure when tested in accordance with ASTM F2324-03. This performance standard went into effect January 1, 2006. However, field data shows that not all nozzles in use have been replaced with the newer flow rate nozzle. Products predating this standard can use up to five gallons per minute |

### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 5 years[101]

### Deemed Measure Cost

When available, the actual cost of the measure (including labor where applicable) should be used. If unknown, a default value of $92.90[102] may be assumed.

### Loadshape

Loadshape C01 - Commercial Electric Cooking

---

[100] Verification measurements taken at 195 installations showed average pre and post flowrates of 2.23 and 1.12 gallon per minute, respectively." from IMPACT AND PROCESS EVALUATION FINAL REPORT for CALIFORNIA URBAN WATER CONSERVATION COUNCIL 2004-5 PRE-RINSE SPRAY VALVE INSTALLATION PROGRAM (PHASE 2) (PG&E Program # 1198-04; SoCalGas Program 1200-04) ("CUWCC Report", Feb 2007)

[101] Reference 2010 Ohio Technical Reference Manual, Act on Energy Business Program Technical Reference Manual Rev05, and Federal Energy Management Program (2004), "How to Buy a Low-Flow Pre-Rinse Spray Valve."

[102] Average of costs recognized by Ameren Missouri ($85.8) and KCPL ($100).

**COINCIDENCE FACTOR**

N/A

**Algorithm**

**CALCULATION OF ENERGY SAVINGS**

**ELECTRIC ENERGY SAVINGS (NOTE WATER SAVINGS MUST FIRST BE CALCULATED)**

ΔkWH = ΔWater (gallons) * 8.33 * 1 * (Tout - Tin) * (1/EFF_Elec) /3,412 * FLAG

Where:

ΔWater (gallons) = amount of water saved as calculated below

8.33 = specific mass in pounds of one gallon of water (lbm/gal)

1 = Specific heat of water: 1 Btu/lbm/°F

Tout = Water Heater Outlet Water Temperature

= custom, otherwise assume Tin + 70°F temperature rise from Tin[103]

Tin = Inlet Water Temperature

= custom, otherwise assume 54.1 °F[104]

EFF_Elec = Efficiency of electric water heater supplying hot water to pre-rinse spray valve

=custom, otherwise assume 97%[105]

Flag = 1 if electric or 0 if gas

**EXAMPLE**

Time of Sale: For example, a new spray nozzle with 1.06 gal/min flow replacing a nozzle with 1.6 gal/min flow at a large institutional establishments with a cafeteria with 70 degree temperature rise of water used by the pre-rinse spray valve that is heated by electric hot water saves annually :

ΔkWH = 30,326x 8.33 x 1 x ((70+54.1) - 54.1) x (1/.97) /3,412 x 1

= 5,343kWh

Retrofit: For example, a new spray nozzle with 1.06 gal/min flow replacing a nozzle with 1.9 gal/min flow at a large institutional establishments with a cafeteria with 70 degree temperature rise of water used by the pre-rinse spray valve that is heated by electric hot water equals:

ΔkWH = 47,175 x 8.33 x 1 x ((70+ 54.1) - 54.1) x (1/.97) /3,412 x 1

=8311 kWh

<u>Secondary kWh Savings for Water Supply and Wastewater Treatment</u>

The following savings should be included in the total savings for this measure, but should not be included in TRC tests to avoid double counting the economic benefit of water savings.

---

[103]If unknown, assume a 70 degree temperature rise from Tin per Food Service Technology Center calculator assumptions to account for variations in mixing and water heater efficiencies

[104]August 31, 2011 Memo of Savings for Hot Water Savings Measures to Nicor Gas from Navigant states that 54.1°F was calculated from the weighted average of monthly water mains temperatures reported in the 2010 Building America Benchmark Study for Chicago-Waukegan, Illinois.

[105]This efficiency value is based on IECC 2012/2015 performance requirement for electric resistant water heaters rounded without the slight adjustment allowing for reduction based on size of storage tank.

$$\Delta kWh_{water} = \Delta Water\ (gallons) / 1{,}000{,}000 * E_{water\ total}$$

Where

$E_{water\ total}$ = IL Total Water Energy Factor (kWh/Million Gallons)

=5,010[106]

> **EXAMPLE**
>
> Time of Sale: For example, a new spray nozzle with 1.06 gal/min flow replacing a nozzle with 1.6 gal/min flow at a large institutional establishment with a cafeteria equals
>
> ΔWater (gallons) = (1.6 – 1.06) * 60 * 3 * 312
>
> = 30,326 gal/yr
>
> $\Delta kWh_{water}$ = 30,326/1,000,000*5,010
>
> = 152 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

N/A

**NATURAL GAS ENERGY SAVINGS**

ΔTherms = ΔWater (gallons) * 8.33 * 1 * (Tout - Tin) * (1/EFF_Gas) /100,000 * (1 – FLAG)

Where (new variables only):

EFF_Gas = Efficiency of gas water heater supplying hot water to pre-rinse spray valve

= custom, otherwise assume 80%[107]

> **EXAMPLE**
>
> Time of Sale: For example, a new spray nozzle with 1.06 gal/min flow replacing a nozzle with 1.6 gal/min flow at a large institutional establishments with a cafeteria with 70 degree temperature of water used by the pre-rinse spray valve that is heated by fossil fuel hot water saves annually:
>
> ΔTherms = 30,326 x 8.33 x 1 x ((70+54.1) - 54.1) x (1/.80)/100,000 x (1-0)
>
> = 221 Therms
>
> Retrofit: For example, a new spray nozzle with 1.06 gal/min flow replacing a nozzle with 1.9 gal/min flow at a busy large institutional establishments with a cafeteria with 70 degree temperature rise of water used by the pre-rinse spray valve that is heated by fossil fuel hot water saves annually:
>
> ΔTherms = 47,175 x 8.33 x 1 x ((70+54.1) - 54.1) x (1/.80)/100,000 x (1-0)
>
> =344 Therms

**WATER IMPACT CALCULATION**[108]

ΔWater (gallons) = (FLObase - FLOeff) * 60 * HOURSday * DAYSyear

Where:

FLObase = Base case flow in gallons per minute, or custom (Gal/min)

---

[106] This factor include 2571 kWh/MG for water supply based on Illinois energy intensity data from a 2012 ISAWWA study and 2439 kWh/MG for wastewater treatment based on national energy intensity use estimates. For more information please review Elevate Energy's 'IL TRM: Energy per Gallon Factor, May 2018 paper'.

[107] IECC 2012/2015, Table C404.2, Minimum Performance of Water-Heating Equipment

[108] In order to calculate energy savings, water savings must first be calculated

| Time of Sale | Retrofit, Direct Install |
|---|---|
| 1.6 gal/min[109] | 1.9 gal/min[110] |

FLOeff = Efficient case flow in gallons per minute or custom (Gal/min)

| Time of Sale | Retrofit, Direct Install |
|---|---|
| 1.06 gal/min[111] | 1.06 gal/min[112] |

60 = Minutes per hour

HOURSday = Hours per day that the pre-rinse spray valve is used at the site, custom, otherwise[113]:

| Application | Hours/day |
|---|---|
| Small, quick- service restaurants | 1 |
| Medium-sized casual dining restaurants | 1.5 |
| Large institutional establishments with cafeteria | 3 |

DAYSyear = Days per year pre-rinse spray valve is used at the site, custom, otherwise 312 days/yr based on assumed 6 days/wk x 52 wk/yr = 312 day/yr.

**EXAMPLE**

Time of Sale: For example, a new spray nozzle with 1.06 gal/min flow replacing a nozzle with 1.6 gal/min flow at a large institutional establishment with a cafeteria equals

= (1.6 – 1.06) * 60 * 3 * 312

= 30,326 gal/yr

Retrofit: For example, a new spray nozzle with 106 gal/min flow replacing a nozzle with 1.9 gal/min flow at a large institutional establishments with a cafeteria equals

= (1.9 – 1.06) * 60 * 3 * 312

= 47,175 gal/yr

[109] The baseline equipment is assumed to be 1.6 gallons per minute. The Energy Policy Act (EPAct) of 2005 sets the maximum flow rate for pre-rinse spray valves at 1.6 gallons per minute at 60 pounds per square inch of water pressure when tested in accordance with ASTM F2324-03. This performance standard went into effect January 1, 2006. Federal Energy Management Program: Purchasing Specifications for Low-Flow Pre-Rinse Spray Valves , Office of Energy Efficiency & Renewable Energy

[110] Verification measurements taken at 195 installations showed average pre and post flowrates of 2.23 and 1.12 gallon per minute, respectively." from IMPACT AND PROCESS EVALUATION FINAL REPORT for CALIFORNIA URBAN WATER CONSERVATION COUNCIL 2004-5 PRE-RINSE SPRAY VALVE INSTALLATION PROGRAM (PHASE 2) (PG&E Program # 1198-04; SoCalGas Program 1200-04) ("CUWCC Report", Feb 2007)

[111] 1.6 gallons per minute used to be the high efficiency flow, but more efficient spray valves are available ranging down to 0.64 gallons per minute per Federal Energy Management Program which references the Food Services Technology Center web site with the added note that even more efficient models may be available since publishing the data. The average of the nozzles listed on the FSTC website is 1.06.

[112] 1.6 gallons per minute used to be the high efficiency flow, but more efficient spray valves are available ranging down to 0.64 gallons per minute per Federal Energy Management Program which references the Food Services Technology Center web site with the added note that even more efficient models may be available since publishing the data. The average of the nozzles listed on the FSTC website is 1.06.

[113] Hours primarily based on PG& E savings estimates, algorithms, sources (2005), Food Service Pre-Rinse Spray Valves with review of 2010 Ohio Technical Reference Manual and Act on Energy Business Program Technical Resource Manual Rev05.

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-FSE-SPRY-V05-190101**

**REVIEW DEADLINE: 1/1/2023**

## 4.2.12 Infrared Charbroiler

### DESCRIPTION

This measure applies to natural gas fired charbroilers that utilize infrared burners installed in a commercial kitchen

This measure was developed to be aptplicable to the following program types: TOS. If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed equipment must be a new natural gas charbroiler with infrared burners.

### DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is an existing natural gas charbroiler without infrared burners.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years[114]

### DEEMED MEASURE COST

The incremental capital cost for this measure is $2173[115]

### LOADSHAPE

N/A

### COINCIDENCE FACTOR

N/A

**Algorithm**

### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

N/A

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

### NATURAL GAS ENERGY SAVINGS

Custom calculation below, otherwise use deemed value of 707 therms based on default values.[116]

$$\Delta Therms = \frac{(\Delta PreheatEnergy + \ \Delta CookingEnergy) * Days}{100{,}000}$$

$$\Delta \text{PreheatEnergy} = \ (PreheatRate_{Base} - PreheatRate_{EE}) * Preheats * \frac{PreheatTime}{60}$$

[114] Lifecycle determined from Food Service Technology Center Gas Broiler Life-Cycle Cost Calculator and from FSTC Broiler Technology Assessment

[115] See 'Arkansas Deemed TRM Table for GasFoodService.xls' from v3.0 Arkansas Technical Reference Manual.

[116] Assumptions derived from Food Service Technology Center Gas Broiler Life-Cycle Cost Calculator and from FSTC Broiler Technology Assessment, Section 4: Broilers

$$\Delta \text{CookingEnergy} = (InputRate_{Base} - InputRate_{EE}) * (Duty * Hours)$$

Where:

Days = Annual days of operation

= Custom or if unknown, use 312 days per year[117]

100,000 = Btu to therms conversion factor

$PreheatRate_{Base}$ = Preheat energy rate of baseline charbroiler

= 64,000 Btu/hr

$PreheatRate_{EE}$ = Preheat energy rate of infrared charbroiler

= Custom or if unknown, use 54,000 Btu/hr

Preheats = Number of preheats per day

= Custom or if unknown, use 1 preheat per day

PreheatTime = Length of one preheat

= Custom or if unknown, use 15 minutes per preheat[118]

60 = Minutes to hours conversion factor

$InputRate_{Base}$ = Input energy rate of baseline charbroiler

= 140,000 Btu/hr

$InputRate_{EE}$ = Input energy rate of infrared charbroiler

= Custom or if unknown, use 105,000 Btu/hr

Duty = Duty cycle of charbroiler (%)

= Custom or if unknown, use 80%[119]

Hours = Average daily hours of operation

= Custom or if unknown, use 8 hours per day

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-FSE-IRCB-V02-180101**

**REVIEW DEADLINE: 1/1/2024**

[117]Typical annual operating time from FSTC Broiler Technology Assessment, Table 4.3
[118]Typical preheat time from FSTC Broiler Technology Assessment.
[119] Duty cycle from FSTC Broiler Technology Assessment, Table 4.3

## 4.2.13 Infrared Rotisserie Oven

**DESCRIPTION**

This measure applies to natural gas fired high efficiency rotisserie ovens utilizing infrared burners and installed in a commercial kitchen.

This measure was developed to be applicable to the following program types: TOS. If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

To qualify for this measure the installed equipment must be a new natural gas rotisserie oven with infrared burners.

**DEFINITION OF BASELINE EQUIPMENT**

The baseline equipment is an existing natural gas rotisserie oven without infrared burners.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected measure life is assumed to be 12 years[120]

**DEEMED MEASURE COST**

The incremental capital cost for this measure is $2665[121]

**LOADSHAPE**

N/A

**COINCIDENCE FACTOR**

N/A

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

N/A

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

N/A

**NATURAL GAS ENERGY SAVINGS**

Custom calculation below based on Food Service Technology Center calculator, otherwise use deemed value of 599 therms, based on default values.

$$\Delta Therms = \frac{(InputRate_{Base} - InputRate_{EE}) * (Duty * Hours)}{100{,}000}$$

Where:

$InputRate_{Base}$ = Energy input rate of baseline rotisserie oven (Btu/hr)

[120]Lifecycle determined from Food Service Technology Center Gas Oven Life-Cycle Cost Calculator.
[121]See 'Arkansas Deemed TRM Table for GasFoodService.xls' from v3.0 Arkansas Technical Reference Manual.

= Custom of if unknown, use 90,000 Btu/hr[122]

$InputRate_{EE}$ = Energy input rate of infrared rotisserie oven (Btu/hr)

= Custom of if unknown, use 50,000 Btu/hr[123]

Duty = Duty cycle of rotisserie oven (%)

= Custom or if unknown, use 60%[124]

Hours = Typical operating hours of rotisserie oven

= Custom or if unknown, use 2,496 hours[125]

100,000 = Btu to therms conversion factor

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-FSE-IROV-V02-180101**

**REVIEW DEADLINE: 1/1/2024**

[122] Median rated energy input for rotisserie ovens from FSTC Oven Technology Assessment, Section 7: Ovens, Table 7.2

[123] Infrared energy input rate calculated based on efficient energy input rate of 50,000 Btu/hr, baseline cooking efficiency of 25%, and infrared cooking efficiency of 45%. Efficiencies and rates derived from FSTC Gas Rotisserie Oven Test Reports and FSTC Oven Technology Assessment.

[124] Duty cycle from Food Service Technology Center Oven Technical Assessment, Table 7.2

[125] Typical operating hours based on oven operating schedule of 8 hours per day, 6 days per week, 52 weeks per year, provided in Food Service Technology Center Oven Technical Assessment, Table 7.2

## 4.2.14 Infrared Salamander Broiler

### DESCRIPTION

This measure applies to natural gas fired high efficiency salamander broilers utilizing infrared burners installed in a commercial kitchen.

This measure was developed to be applicable to the following program types: TOS. If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed equipment must be a new natural gas salamander broiler with infrared burners

### DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is an existing natural gas salamander broiler without infrared burners

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years[126]

### DEEMED MEASURE COST

The incremental capital cost for this measure is $1000[127]

### LOADSHAPE

N/A

### COINCIDENCE FACTOR

N/A

**Algorithm**

### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

N/A

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

### NATURAL GAS ENERGY SAVINGS

Custom calculation below based on Food Service Technology Center calculator, otherwise use deemed value of 240 therms, based on defaults.

$$\Delta Therms = \frac{(InputRate_{Base} - InputRate_{EE}) * (Duty * Hours)}{100{,}000}$$

Where:

[126] Lifecycle determined from Food Service Technology Center Gas Broiler Life-Cycle Cost Calculator and from FSTC Broiler Technology Assessment.

[127] See ‘Arkansas Deemed TRM Table for GasFoodService.xls’ from v3.0 Arkansas Technical Reference Manual.

$InputRate_{Base}$ = Rated energy input rate of baseline salamander broiler (Btu/hr)

= 38,500 Btu/hr[128]

$InputRate_{EE}$ = Rated energy input rate of infrared salamander broiler (Btu/hr)

= Custom or if unknown, use 24,750 Btu/hr[129]

Duty = Duty cycle of salamander broiler (%)

= Custom or if unknown, use 70%[130]

Hours = Typical operating hours of salamander broiler

= Custom or if unknown, use 2,496 hours[131]

100,000 = Btu to therms conversion factor

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-FSE-IRBL-V02-180101**

**REVIEW DEADLINE: 1/1/2024**

[128] Median rated energy input for salamander broilers from FSTC Broiler Technology Assessment, Section 4: Broilers, Table 4.3
[129] Calculated energy input rate based on baseline energy input rate of 38,500 Btu/hr, baseline cooking efficiency of 22.5%, and infrared cooking efficiency of 35%
[130] Duty cycle from Food Service Technology Center Broiler Technical Assessment, Table 4.3
[131] Typical operating hours based on broiler operating schedule of 8 hours per day, 6 days per week, 52 weeks per year, provided in Food Service Technology Center Broiler Technical Assessment, Table 4.3

## 4.2.15 Infrared Upright Broiler

### DESCRIPTION

This measure applies to natural gas fired high efficiency upright broilers utilizing infrared burners and installed in a commercial kitchen.

This measure was developed to be applicable to the following program types: TOS. If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed equipment must be a new natural gas upright broiler with infrared burners.

### DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is an existing natural gas upright broiler without infrared burners.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years[132]

### DEEMED MEASURE COST

The incremental capital cost for this measure is $4400[133]

### LOADSHAPE

N/A

### COINCIDENCE FACTOR

N/A

**Algorithm**

### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

N/A

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

### NATURAL GAS ENERGY SAVINGS

Custom calculation below based on Food Service Technology Center calculator, otherwise use deemed value of 943 therms based on default values.

$$\Delta Therms = \frac{(InputRate_{Base} - InputRate_{EE}) * (Duty * Hours)}{100{,}000}$$

Where:

[132] Lifecycle determined from Food Service Technology Center Gas Broiler Life-Cycle Cost Calculator and from FSTC Broiler Technology Assessment.

[133] See 'Arkansas Deemed TRM Table for GasFoodService.xls' from v3.0 Arkansas Technical Reference Manual.

$InputRate_{Base}$ = Rated energy input rate of baseline upright broiler (Btu/hr)

= 144,000 Btu/hr[134]

$InputRate_{EE}$ = Rated energy input rate of infrared upright broiler (Btu/hr)

= Custom or if unknown, use 90,000 Btu/hr[135]

Duty = Duty cycle of upright broiler (%)

= Custom or if unknown, use 70%[136]

Hours = Typical operating hours of upright broiler

= Custom or if unknown, use 2,496 hours[137]

100,000 = Btu to therms conversion factor

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-FSE-IRUB-V02-180101**

**REVIEW DEADLINE: 1/1/2024**

[134] Baseline energy input rate calculated based on efficient energy input rate of 90,000 Btu/hr, baseline cooking efficiency of 25%, and infrared cooking efficiency of 40%

[135] Median rated energy input for upright broilers from FSTC Broiler Technology Assessment, Section 4.0: Broiler, Table 4.3

[136] Duty cycle from Food Service Technology Center Broiler Technical Assessment, Table 4.3

[137] Typical operating hours based on broiler operating schedule of 8 hours per day, 6 days per week, 52 weeks per year, provided in Food Service Technology Center Broiler Technical Assessment, Table 4.3

## 4.2.16 Kitchen Demand Ventilation Controls

### Description

Installation of commercial kitchen demand ventilation controls that vary the ventilation based on cooking load and/or time of day.

This measure was developed to be applicable to the following program types: TOS. If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

To qualify for this measure the installed equipment must be a control system that varies the exhaust rate of kitchen ventilation (exhaust and/or makeup air fans) based on the energy and effluent output from the cooking appliances (i.e., the more heat and smoke/vapors generated, the more ventilation needed). This involves installing a new temperature sensor in the hood exhaust collar and/or an optic sensor on the end of the hood that sense cooking conditions which allows the system to automatically vary the rate of exhaust to what is needed by adjusting the fan speed accordingly.

### Definition of Baseline Equipment

The baseline equipment is kitchen ventilation that has constant speed ventilation motor.

### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 15 years.[138]

### Deemed Measure Cost

The incremental capital cost for this measure is[139]

| Measure Category | Incremental Cost $/HP of fan |
|---|---|
| DVC Control Retrofit | $1,988 |
| DVC Control New | $1,000 |

### Loadshape

Loadshape C23 - Commercial Ventilation

### Coincidence Factor

The measure has deemed peak kW savings therefore a coincidence factor does not apply

**Algorithm**

### Calculation of Savings

Annual energy use was based on monitoring results from five different types of sites, as summarized in PG&E Food Service Equipment work paper.

### Electric Energy Savings

kWh savings are assumed to be 4966 kWh per horsepower of the fan[140]

---

138 PG&E Workpaper: Commercial Kitchen Demand Ventilation Controls-Electric, 2004 - 2005
139 Ibid.
140 Based on data provided in PGE Workpaper, Commercial Kitchen Demand Ventilation Controls, PGECOFST116, June 1, 2009. See 'Kitchen DCV.xls' for details.

### Summer Coincident Peak Demand Savings

kW savings are assumed to be 0.68 kW per horsepower of the fan[141]

### Natural Gas Energy Savings

ΔTherms = CFM * HP* Annual Heating Load /(Eff(heat) * 100,000)

Where:

CFM = the average airflow reduction with ventilation controls per hood

= 430 cfm/HP[142]

HP = actual if known, otherwise assume 7.75 HP[143]

Annual Heating Load = Annual heating energy required to heat fan exhaust make-up air, Btu/cfm dependent on location[144]:

| Zone | Annual Heating Load, Btu/cfm |
|---|---|
| 1 (Rockford) | 154,000 |
| 2-(Chicago) | 144,000 |
| 3 (Springfield) | 132,000 |
| 4-(Belleville) | 102,000 |
| 5-(Marion) | 104,000 |

Eff(heat) = Heating Efficiency

= actual if known, otherwise assume 80%[145]

100,000 = conversion from Btu to Therm

**EXAMPLE**

For example, a kitchen hood in Rockford, IL with a 7.75 HP ventilation motor

ΔTherms = 430 * 7.75*154,000 / (0.80 * 100,000)

= 6,415 Therms

### Water Impact Descriptions and Calculation

N/A

### Deemed O&M Cost Adjustment Calculation

N/A

[141] Based on data provided in PGE Workpaper, Commercial Kitchen Demand Ventilation Controls, PGECOFST116, June 1, 2009. See 'Kitchen DCV.xls' for details.

[142] Based on data provided in PGE Workpaper, Commercial Kitchen Demand Ventilation Controls, PGECOFST116, June 1, 2009. See 'Kitchen DCV.xls' for details.

[143] Average of units in PGE Workpaper, Commercial Kitchen Demand Ventilation Controls, PGECOFST116, June 1, 2009.

[144] Food Service Technology Center Outside Air Load Calculator, with inputs of one cfm, and hours from Commercial Kitchen Demand Ventilation Controls (Average 17.8 hours a day 4.45 am to 10.30 pm). Savings for Rockford, Chicago, and Springfield were obtained from the calculator; values for Belleview and Marion were obtained by using the average savings per HDD from the other values.

[145]Work Paper WPRRSGNGRO301 CLEAResult"Boiler Tune-Up" which cites Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0, PA Consulting, KEMA, March 22, 2010

**MEASURE CODE: CI-FSE-VENT-V03-160601**

**REVIEW DEADLINE: 1/1/2021**

## 4.2.17 Pasta Cooker

### DESCRIPTION

This measure applies to natural gas fired dedicated pasta cookers as determined by the manufacturer and installed in a commercial kitchen.

This measure was developed to be applicable to the following program types: TOS. If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed equipment must be a new natural gas fired paste cooker.

### DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is an existing natural gas fired stove where pasta is cooked in a pan.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12[146].

### DEEMED MEASURE COST

The incremental capital cost for this measure is $2400[147].

### LOADSHAPE

N/A

### COINCIDENCE FACTOR

N/A

**Algorithm**

### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

N/A

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

### NATURAL GAS ENERGY SAVINGS

The annual natural gas energy savings from this measure is a deemed value equaling 1380 Therms[148].

### WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

[146]See 'Arkansas Deemed TRM Table for GasFoodService.xls' from v3.0 Arkansas Technical Reference Manual.
[147]Ibid.
[148] See 'Arkansas Deemed TRM Table for GasFoodService.xls' from v3.0 Arkansas Technical Reference Manual.

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-FSE-PCOK-V02-180101**

**REVIEW DEADLINE: 1/1/2024**

## 4.2.18 Rack Oven - Double Oven

### Description

This measure applies to natural gas fired high efficiency rack oven - double oven installed in a commercial kitchen.

This measure was developed to be applicable to the following program types: TOS. If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

To qualify for this measure the installed equipment must be a new natural gas rack oven –double oven with a baking efficiency ≥ 50% utilizing ASTM standard 2093

### Definition of Baseline Equipment

The baseline equipment is an existing natural gas rack oven – double oven with a baking efficiency < 50%.

### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 12 years.[149]

### Deemed Measure Cost

The incremental capital cost for this measure is $3000.[150]

### Loadshape

N/A

### Coincidence Factor

N/A

**Algorithm**

### Calculation of Savings

### Electric Energy Savings

N/A

### Summer Coincident Peak Demand Savings

N/A

### Natural Gas Energy Savings

Custom calculation below, otherwise use deemed value of 1930 therms based on default values.[151]

$$\Delta Therms = InputRate * (BakingEfficiency_{EE} - BakingEfficiency_{Base}) * Duty * Hours * \frac{1}{100{,}000}$$

Where:

[149] Lifecycle determined from Food Service Technology Center Gas Rack Oven Life-Cycle Cost Calculator and from FSTC Oven Technology Assessment

[150] See ‘Arkansas Deemed TRM Table for GasFoodService.xls’ from v3.0 Arkansas Technical Reference Manual.

[151] Assumptions derived from Food Service Technology Center Gas Rack Oven Life-Cycle Cost Calculator, FSTC Oven Technology Assessment, Section 7: Ovens, and from FSTC Gas Double Rack Oven Test Reports.

| | |
|---|---|
| InputRate | = Input energy rate of rack oven – double oven |
| | = Custom or if unknown, 275,000 Btu/hr[152] |
| $BakingEfficiency_{EE}$ | = Baking efficiency of energy efficiency rack oven – double oven |
| | = Custom or if unknown, use 55%[153] |
| $BakingEfficiency_{Base}$ | = Baking efficiency of baseline rack oven – double oven |
| | = Custom or if unknown, 30% |
| Duty | = Duty cycle of double rack oven (%) |
| | = Custom or if unknown, use 75%[154] |
| Hours | = Average daily hours of operation |
| | = Custom or if unknown, use 3,744 hours[155] |
| 100,000 | = Btu to therms conversion factor |

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE CI-FSE-RKOV-VO2-180101**

**REVIEW DEADLINE: 1/1/2024**

[152] Median rated energy input for rack ovens from FSTC Oven Technology Assessment, Section 7: Ovens.
[153] Average baking efficiency of double rack oven from FSTC Gas Double Rack Oven Test Reports.
[154] Duty cycle from FSTC Gas Double Rack Oven Test Reports on various double rack ovens.
[155] Typical operating hours based on oven operating schedule of 12 hours per day, 6 days per week, 52 weeks per year, provided in FSTC Gas Double Rack Oven Test Reports on various double rack ovens.

## 4.2.19 ENERGY STAR Electric Convection Oven

### Description

Commercial convection ovens that are ENERGY STAR certified have higher heavy load cooking efficiencies, and lower idle energy rates, making them on average about 20 percent more efficient than standard models. Energy savings estimates are for ovens using full size (18" x 36") sheet pans.

This measure was developed to be applicable to the following program types; TOS.

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

The efficient equipment is assumed to be an ENERGY STAR qualified electric convection oven.

### Definition of Baseline Equipment

The baseline equipment is assumed to be a standard convection oven with a heavy load efficiency of 65%.

### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 12 years.[156]

### Deemed Measure Cost

The incremental cost for this measure is assumed to be $800 for half size units and $1000 for full size[157]

### Loadshape

Loadshape C01 - Commercial Electric Cooking

### Coincidence Factor

Summer Peak Coincidence Factor for measure is provided below for different building type[158]:

| Location | CF |
|---|---|
| Fast Food Limited Menu | 0.32 |
| Fast Food Expanded Menu | 0.41 |
| Pizza | 0.46 |
| Full Service Limited Menu | 0.51 |
| Full Service Expanded Menu | 0.36 |
| Cafeteria | 0.39 |
| Unknown | 0.41 |

[156] Food Service Technology Center (FSTC). Default value from life cycle cost calculator for electric ovens.
[157] Based on data from the Regional Technical Forum for the Northwest Council (Commercial Cooking Convection Oven Calculator, UES Measure Workbook) using actual list prices for 23 units from 2012, see "ComCookingConvectionOven_v2_0.xlsm".
[158]Values taken from Minnesota Technical Reference Manual (Version 2.2, effective May 2, 2018), 'Electric Oven and Range' measure and are based upon "Project on Restaurant Energy Performance-End-Use Monitoring and Analysis", Appendixes I and II, Claar, et. al., May 1985Unknown is an average of other location types.

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

$\Delta kWh = kWH_{base} - kWh_{eff}$

$kWh = [(LB * E_{FOOD}/EFF) + (IDLE * (HOURS_{DAY} – LB/PC – PRE_{TIME}/60)) + PRE_{ENERGY}] * DAYS$

Where:

$kWH_{base}$ = the annual energy usage of the baseline equipment calculated using baseline values

$kWH_{eff}$ = the annual energy usage of the efficient equipment calculated using efficient values

$HOURS_{DAY}$ = daily operating hours

= Actual, defaults:

| Type of Food Service | $HOURS_{DAY}$ [159] |
|---|---|
| Fast Food, limited menu | 4 |
| Fast Food, expanded menu | 5 |
| Pizza | 8 |
| Full Service, limited menu | 8 |
| Full Service, expanded menu | 7 |
| Cafeteria | 6 |
| Unknown | 6 |
| Custom | Varies |

DAYS = Days per year of operation

= Actual, default = 365[160]

$PRE_{TIME}$ = Preheat time (min/day), the amount of time it takes a steamer to reach operating temperature when turned on
= 15 min/day[161]

$E_{FOOD}$ = ASTM Energy to Food (kWh/lb); the amount of energy absorbed by the food during cooking, per pound of food

= 0.0732[162]

LB = pounds of food cooked per day (lb/day)

= Actual, default = 100[163]

EFF = Heavy load cooking energy efficiency (%). See table below.

IDLE = Idle energy rate. See table below.

PC = Production capacity (lbs/hr). See table below.

$PRE_{ENERGY}$ = Preheat energy (kWh/day). See table below.

---

159 Ibid.
160 Food Service Technology Center (FSTC). Default value from life cycle cost calculator for electric ovens.
161 Food Service Technology Center (2002). *Commercial Cooking Appliance Technology Assessment*. Prepared by Don Fisher. Chapter 7: Ovens
162 American Society for Testing and Materials. Industry standard for Commercial Ovens
163 Food Service Technology Center (FSTC). Default value from life cycle cost calculator for electric ovens.

Performance Metrics: Baseline and Efficient Values

| Metric | Baseline Model [164] | Energy Efficient Model [165] |
|---|---|---|
| $PRE_{ENERGY}$ (kWh) | 1.5 | 1 |
| IDLE (kW) | 2 | Actual, default = 1.0 |
| EFF | 65% | Actual, default = 74% |
| PC (lb/hr) | 70 | Actual, default = 79 |

**EXAMPLE**

Using defaults provided above, the savings for a ENERGY STAR Electric Convection Oven in unknown location are:

$kWH_{base}$ = [(100 * 0.0732/0.65) + (2 * (6 – 100/70 – 15/60)) + 1.5] * 365

= 7,813 kWh

$kWh_{eff}$ = [(100 * 0.0732/0.74) + (1 * (6 – 100/79 – 15/60)) + 1.0] * 365

= 5,612 kWh

ΔkWh = $kWH_{base}$ - $kWh_{eff}$

= 7,813 – 5,612

= 2200 kWh

### Summer Coincident Peak Demand Savings

$$\Delta kW = (\Delta kWh / (HOURS_{DAY} * DAYS)) * CF$$

Where:

ΔkWh = Annual energy savings (kWh)

CF = Summer Peak Coincidence Factor for measure is provided below for different building type[166]:

| Location | CF |
|---|---|
| Fast Food Limited Menu | 0.32 |
| Fast Food Expanded Menu | 0.41 |
| Pizza | 0.46 |
| Full Service Limited Menu | 0.51 |
| Full Service Expanded Menu | 0.36 |
| Cafeteria | 0.39 |
| Unknown | 0.41 |

[164] Ibid.

[165] Average ratings of units on ENERGY STAR qualified list as of 10/2014. Preheat energy is not provided so default is provided based on FSTC life cycle cost calculator.

[166] Minnesota 2012 Technical Reference Manual, version 1.3, Commercial Food Service - Electric Oven and Range, page 138. Unknown is an average of other location types

**EXAMPLE**

Using defaults provided above, the savings for a ENERGY STAR Electric Convection Oven in unknown location are:

$$\Delta kW = (2200 / (6 * 365)) * 0.41$$
$$= 0.41$$

**FOSSIL FUEL IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE CI-FSE-ECON-V02-190101**

**REVIEW DEADLINE: 1/1/2022**

# 4.3 Hot Water

## 4.3.1 Storage Water Heater

### DESCRIPTION

This measure is for upgrading from minimum code to a high efficiency storage-type water heater. Storage water heaters are used to supply hot water for a variety of commercial building types. Storage capacities vary greatly depending on the application. Large consumers of hot water include (but not limited to) industries, hotels/motels and restaurants.

This measure was developed to be applicable to the following program types: TOS.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

The minimum specifications of the high efficiency equipment should be defined by the programs.

### DEFINITION OF BASELINE EQUIPMENT

The baseline condition is assumed to be a new standard water heater of same type as existing, meeting the Federal Standard for ≤75,000 Btuh units and IECC 2015 for all others. If existing type is unknown, assume Gas Storage Water Heater.

Note IECC 2018 is scheduled to become effective March 1, 2019 and will become baseline for all New Construction permits from that date.

| Equipment Type | Sub Category | Federal Standard – Uniform Energy Factor[167] |
|---|---|---|
| Gas Storage Water Heaters ≤ 75,000 Btu/h | ≤55 gallon tanks | 0.6483 – (0.0017 * Rated Storage Volume in Gallons) |
| | >55 gallon tanks | 0.7897 – (0.0004 * Rated Storage Volume in Gallons) |
| Gas Storage Water Heaters > 75,000 Btu/h | < 4000 Btu/h/gal | 0.6002 – (0.0011 * Rated Storage Volume in Gallons) |
| Electric Water Heaters ≤ 75,000 Btu/h | ≤55 gallon tanks | 0.9307 – (0.0002 * Rated Storage Volume in Gallons) |
| | >55 gallon tanks [168] | 2.1171 – (0.0011 * Rated Storage Volume in Gallons) |
| Electric Water Heaters > 75,000 Btu/h | ≤2 gal | 0.91 |
| | > 12kW and ≤58.6 kW and ≤2 gal | 0.80 |

V= Rated volume in gallons, Vm = measured volume in gallons.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 Years[169]

### DEEMED MEASURE COST

The full install cost and incremental cost assumptions are provided below. Actual costs should be used where available[170]:

[167] ≤75,000 Btu/h Storage Water Heater and <200,000 Btu/h Tankless Water Heater Federal Standard is DOE Standard 10 CFR 430.32(d). All other standards are from 10 CFR 431.110.
[168] It is assumed that tanks <75,000Btu/h and >55 gallons will not be eligible measures due to the high baseline.
[169] DEER 08, EUL_Summary_10-1-08.xls.
[170] Cost information is based upon data from "2010-2012 WA017 Ex Ante Measure Cost Study Draft Report", Itron, February 28, 2014. See "NR HW Heater_WA017_MCS Results Matrix - Volume I.xls" for more information.

| Equipment Type | Category | Install Cost | Incremental Cost |
|---|---|---|---|
| Gas Storage Water Heaters ≤ 75,000 Btu/h, ≤55 Gallons | Baseline | $616 | N/A |
| | Efficient | $1,055 | $440 |
| Gas Storage Water Heaters > 75,000 Btu/h | 0.80 Et | $4,886 | N/A |
| | 0.83 Et | $5,106 | $220 |
| | 0.84 Et | $5,299 | $413 |
| | 0.85 Et | $5,415 | $529 |
| | 0.86 Et | $5,532 | $646 |
| | 0.87 Et | $5,648 | $762 |
| | 0.88 Et | $5,765 | $879 |
| | 0.89 Et | $5,882 | $996 |
| | 0.90 Et | $6,021 | $1,135 |

For electric water heaters the incremental capital cost for this measure is assumed to be[171]

| Tank Size | Incremental Cost |
|---|---|
| 50 gallons | $1050 |
| 80 gallons | $1050 |
| 100 gallons | $1950 |

### LOADSHAPE

For electric hot water heaters, use Loadshape C02 - Non-Residential Electric DHW.

### COINCIDENCE FACTOR

The coincidence factor is assumed to be 0.925 [172].

## Algorithm

### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

Electric energy savings are calculated for electric storage water heaters per the equations given below.

Electric units ≤12 kW:

$$\Delta kWh = \frac{(T_{out} - T_{in}) * HotWaterUse_{Gallon} * \gamma Water * 1 * \left(\frac{1}{UEF_{elecbase}} - \frac{1}{UEF_{Eff}}\right)}{3412}$$

Where:

$T_{OUT}$ = Tank temperature

= 125°F

$T_{IN}$ = Incoming water temperature from well or municiple system

= 54°F[173]

[171] Act on Energy Commercial Technical Reference Manual, Table 9.6.1-4
[172] Coincidence factor based on Average W in peak period/Max W from Itron eShape data for Missouri, calibrated to Illinois loads,
[173] US DOE Building America Program, Building America Analysis Spreadsheet (for Chicago, IL), Office of Energy Efficiency & Renewable Energy.

$HotWaterUse_{Gallon}$ = Estimated annual hot water consumption (gallons)

= Actual if possible to provide reasonable custom estimate. If not, two methodologies are provided to develop an estimate:

1. Consumption per usable storage tank capacity
   = Capacity * Consumption/cap

   Where:

   Capacity = Usable capacity of hot water storage tank in gallons

   = Actual

   Consumption/cap = Estimate of consumption per gallon of usable tank capacity, based on building type:[174]

| Building Type[175] | Consumption/Cap |
|---|---|
| Convenience | 528 |
| Education | 568 |
| Grocery | 528 |
| Health | 788 |
| Large Office | 511 |
| Large Retail | 528 |
| Lodging | 715 |
| Other Commercial | 341 |
| Restaurant | 622 |
| Small Office | 511 |
| Small Retail | 528 |
| Warehouse | 341 |
| Nursing | 672 |
| Multi-Family | 894 |

2. Consumption per unit area by building type
   = (Area/1000) * Consumption/1,000 sq.ft.

   Where:

   Area = Area in sq.ft that is served by DHW boiler

   = Actual

   Consumption/1,000 sq.ft. = Estimate of DHW consumption per 1,000 sq.ft. based on building type:[176]

[174] Methodology based on Cadmus analysis. Annual hot water usage in gallons based on CBECS (2012) and RECS (2009) consumption data of East North Central (removed outliers of 1,000 kBtuh or less) to calculate hot water usage. Annual hot water gallons per tank size gallons based on the tank sizing methodology found in ASHRAE 2011 HVAC Applications. Chapter 50 Service Water Heating. Demand assumptions (gallons per day) for each building type based on ASHRAE Chapter 50 and to LBNL White Paper. LBL-37398 Technology Data Characterizing Water Heating in Commercial Buildings: Application to End Use Forecasting. Assumes hot water heater efficiency of 80%.

[175] According to CBECS 2012 "Lodging" buildings include Dormitories, Hotels, Motel or Inns and other Lodging and "Nursing" buildings include Assisted Living and Nursing Homes.

[176] Methodology based on Cadmus analysis. Annual hot water usage in gallons based on CBECS (2012) and RECS (2009) consumption data of East North Central (removed outliers of 1,000 kBtuh or less) to calculate hot water usage. Annual hot water gallons per tank size gallons based on the tank sizing methodology found in ASHRAE 2011 HVAC Applications. Chapter 50 Service Water Heating. Demand assumptions (gallons per day) for each building type based on ASHRAE Chapter 50 and to LBNL

| Building Type[177] | Consumption/1,000 sq.ft. |
|---|---|
| Convenience | 4,594 |
| Education | 7,285 |
| Grocery | 697 |
| Health | 24,540 |
| Large Office | 1,818 |
| Large Retail | 1,354 |
| Lodging | 29,548 |
| Other Commercial | 3,941 |
| Restaurant | 44,439 |
| Small Office | 1,540 |
| Small Retail | 6,111 |
| Warehouse | 1,239 |
| Nursing | 30,503 |
| Multi-Family | 15,434 |

γWater = Specific weight capacity of water (lb/gal)

= 8.33 lbs/gal

1 = Specific heat of water (Btu/lb.°F)

$EF_{elecbase}$ = Rated efficiency of baseline water heater expressed as Uniform Energy Factor (UEF);

| Equipment Type | Sub Category | Federal Standard – Uniform Energy Factor [178] |
|---|---|---|
| Electric Water Heaters ≤ 75,000 Btu/h | ≤55 gallon tanks | 0.9307 – (0.0002 * Rated Storage Volume in Gallons) |
| | >55 gallon tanks [179] | 2.1171 – (0.0011 * Rated Storage Volume in Gallons) |
| Electric Water Heaters > 75,000 Btu/h | ≤2 gal | 0.91 |
| | > 12kW and ≤58.6 kW and ≤2 gal | 0.80 |

$EF_{eff}$ = Rated efficiency of efficient water heater expressed as Uniform Energy Factor (UEF)

= Actual

3412 = Converts Btu to kWh

For example, for a 200,000 Btu/h, 150 gallon, 90% UEF storage unit with rated standby loss of 1029 BTU/h installed in a 1500 ft$^2$ restaurant:

ΔkWh = ((125 – 54) * ((1,500/1,000) * 44,439) * 8.33 * 1 * (1/0.8 - 1/0.9))/3412

= 1,605 kWh

Electric units > 12kW:

White Paper. LBL-37398 Technology Data Characterizing Water Heating in Commercial Buildings: Application to End Use Forecasting. Assumes hot water heater efficiency of 80%.

[177] According to CBECS 2012 "Lodging" buildings include Dormitories, Hotels, Motel or Inns and other Lodging and "Nursing" buildings include Assisted Living and Nursing Homes.

[178] ≤75,000 Btu/h Storage Water Heater and <200,000 Btu/h Tankless Water Heater Federal Standard is DOE Standard 10 CFR 430.32(d). All other standards are from 10 CFR 431.110.

[179] It is assumed that tanks <75,000Btu/h and >55 gallons will not be eligible measures due to the high baseline.

$$\Delta kWh = \frac{\left((T_{out} - T_{air}) * V * \gamma Water * 1 * \left(SL_{elecbase} - SL_{eff}\right)\right) * 8766}{3412}$$

$T_{air}$ = Ambient Air Temperature

= 70°F

V = Rated tank volume in gallons

= Actual

$SL_{elecbase}$ = Standby loss of electric baseline unit (%/hr)

= 0.30 + 27/V

$SL_{eff}$ = Nameplate standby loss of new water heater, in BTU/h

8766 = Hours per year

For example, >12kW, 100 gallon storage unit with rated standby loss of 0.5 %/hr:

SLbase = 0.3 + (27 / 100)

= 0.57%/hr

ΔkWh = (((125 – 70) * 100 * 8.33 * 1 * (0.57- 0.5)) * 8766)/3412

= 8,239 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$$\Delta kW = \frac{\Delta kWh}{Hours} * CF$$

Where:

Hours = Full load hours of water heater

= 6461 [180]

CF = Summer Peak Coincidence Factor for measure

= 0.925 [181]

For example, >12kW, 100 gallon storage unit with rated standby loss of 0.5 %/hr:

ΔkW = 8,239 / 6,461 * 0.925

= 1.18 kW

**NATURAL GAS ENERGY SAVINGS**

Natural gas  energy savings are calculated for natural gas storage water heaters per the equations given below.

$$\Delta Therms = \frac{(T_{out} - T_{in}) \ * \ HotWaterUse_{Gallon} * \gamma Water * 1 * \left(\frac{1}{UEF_{gasbase}} - \frac{1}{UEF_{Eff}}\right)}{100{,}000}$$

Where:

100,000 = Converts Btu to Therms

$UEF_{gasbase}$ = Rated efficiency of baseline water heater expressed as Uniform Energy Factor (UEF)

[180] Full load hours assumption based on Wh/Max W Ratio from Itron eShape data for Missouri, calibrated to Illinois loads,

[181] Coincidence factor based on Average W in peak period/Max W from Itron eShape data for Missouri, calibrated to Illinois loads,

| Equipment Type | Sub Category | Federal Standard – Uniform Energy Factor [182] |
|---|---|---|
| Gas Storage Water Heaters ≤ 75,000 Btu/h | ≤55 gallon tanks | 0.6483 – (0.0017 * Rated Storage Volume in Gallons) |
| | >55 gallon tanks | 0.7897 – (0.0004 * Rated Storage Volume in Gallons) |
| Gas Storage Water Heaters > 75,000 Btu/h | < 4000 Btu/h/gal | 0.6002 – (0.0011 * Rated Storage Volume in Gallons) |

**Additional Standby Loss Savings**

Gas Storage Water Heaters >75,000 Btu/h can claim additional savings due to lower standby losses.

$$\Delta Therms_{Standby} = \frac{(SL_{gasbase} - SL_{eff}) * 8766}{100{,}000}$$

Where:

$SL_{gasbase}$ = Standby loss of gas baseline unit (Btu/h)

$= Q/800 + 110\sqrt{V}$

Q =Nameplate input rating in Btu/h

V = Rated volume in gallons

$SL_{eff}$ = Nameplate standby loss of new water heater, in Btu/h

8766 = Hours per year

For example, for a 200,000 Btu/h, 150 gallon, 90% UEF storage unit with rated standby loss of 1029 BTU/h installed in a 1500 $ft^2$ restaurant:

ΔTherms = ((125 – 54) * ((1,500/1,000) * 44,439) * 8.33 * 1 * (1/0.8 - 1/0.9))/100,000

= 54.8 Therms

$\Delta Therms_{Standby}$ = (((200000/800 + 110 * √150) – 1029) * 8766)/100,000

= 49.8 Therms

ΔThermsTotal = 54.8 + 49.8

= 104.6 Therms

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-HWE-STWH-V03-190101**

**REVIEW DEADLINE: 1/1/2022**

[182] ≤75,000 Btu/h Storage Water Heater and <200,000 Btu/h Tankless Water Heater Federal Standard is DOE Standard 10 CFR 430.32(d). All other standards are from 10 CFR 431.110.

## 4.3.2 Low Flow Faucet Aerators

### DESCRIPTION

This measure relates to the direct installation of a low flow faucet aerator in a commercial building. Expected applications include small business, office, restaurant, or motel. Health care-specific inputs are defined for Laminar Flow Restrictor (LFR) devices. For multifamily or senior housing, the residential low flow faucet aerator should be used.

This measure was developed to be applicable to the following program types, DI.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed equipment must be an energy efficient faucet aerator, for bathrooms rated at 1.5 gallons per minute (GPM) or less, or for kitchens rated at 2.2 GPM or less. For LFR devices, the installed equipment must be a device rated at 2.2 GPM or less. Savings are calculated on an average savings per faucet fixture basis.

### DEFINITION OF BASELINE EQUIPMENT

The baseline condition is assumed to be a standard bathroom faucet aerator rated at 2.25 GPM or more, or a standard kitchen faucet aerator rated at 2.75 GPM or more. For LFR devices, the baseline condition is assumed to be no aerator at all, due to the contamination risk caused by faucet aerators in health care facilities and the baseline flow rate is assumed to be 3.74 GPM[183]. Note if flow rates are measured, for example through a Direct Install program, then actual baseline flow rates should be used as opposed to the deemed values.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 10 years.[184]

### DEEMED MEASURE COST

The full install cost (including labor) for this measure is $8[185] or program actual. For LFRs, The incremental cost is $14.27[186] or program actual.

### LOADSHAPE

Loadshape C02 - Commercial Electric DHW

### COINCIDENCE FACTOR

The coincidence factor for this measure is dependent on building type as presented below.

[183] Workpaper WPSCGNRWH150827A, Laminar Flow Restrictors For Hospitals and Health Care Facilities.
[184] As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.
[185] Direct-install price per faucet assumes cost of aerator and install time. (2011, Market research average of $3 and assess and install time of $5 (20min @ $15/hr)
[186] Direct install price per faucet assumes cost of LFR ($7.27) and install time ($7) (Southern California Gas Company, Workpaper WPSCGNRWH150827A Revision #0, September, 2015).

**Algorithm**

**‘CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

**NOTE THESE SAVINGS ARE *PER* FAUCET RETROFITTED[187].**

ΔkWh = %ElectricDHW * ((GPM_base - GPM_low)/GPM_base) * Usage * EPG_electric * ISR

Where:

%ElectricDHW = proportion of water heating supplied by electric resistance heating

| DHW fuel | %Electric_DHW |
|---|---|
| Electric | 100% |
| Fossil Fuel | 0% |

GPM_base = Average flow rate, in gallons per minute, of the baseline faucet “as-used”

= 1.39[188] or custom based on metering studies[189] or if measured during DI:

= Measured full throttle flow * 0.83 throttling factor[190]

Baseline for LFRs[191]: = 3.74 * 0.83 = 3.10

GPM_low = Average flow rate, in gallons per minute, of the low-flow faucet aerator “as-used”

= 0.94[192] or custom based on metering studies[193] or if measured during DI:

= Rated full throttle flow * 0.95 throttling factor[194]

For LFRs[195]: = 2.2 * 0.95 = 2.09

[187] This algorithm calculates the amount of energy saved per aerator by determining the fraction of water consumption savings for the upgraded fixture. Due to the distribution of water consumption by fixture type, as well as the different number of fixtures in a building, several variables must be incorporated.

[188] DeOreo, B., and P. Mayer. Residential End Uses of Water Study Update. Forthcoming. ©2015 Water Research Foundation. Reprinted With Permission.

[189] Measurement should be based on actual average flow consumed over a period of time rather than a onetime spot measurement for maximum flow. Studies have shown maximum flow rates do not correspond well to average flow rate due to occupant behavior which does not always use maximum flow.

[190] 2008, Schultdt, Marc, and Debra Tachibana. Energy related Water Fixture Measurements: Securing the Baseline for Northwest Single Family Homes. 2008 ACEEE Summer Study on Energy Efficiency in Buildings. Page 1-265.

[191] Using measured flow rate assumption from Workpaper WPSCGNRWH150827A, Laminar Flow Restrictors For Hospitals and Health Care Facilities.

[192] Average retrofit flow rate for kitchen and bathroom faucet aerators from sources 2, 4, 5, and 7. This accounts for all throttling and differences from rated flow rates. Assumes all kitchen aerators at 2.2 gpm or less and all bathroom aerators at 1.5 gpm or less. The most comprehensive available studies did not disaggregate kitchen use from bathroom use, but instead looked at total flow and length of use for all faucets. This makes it difficult to reliably separate kitchen water use from bathroom water use. It is possible that programs installing low flow aerators lower than the 2.2 gpm for kitchens and 1.5 gpm for bathrooms will see a lower overall average retrofit flow rate.

[193] Measurement should be based on actual average flow consumed over a period of time rather than a onetime spot measurement for maximum flow. Studies have shown maximum flow rates do not correspond well to average flow rate due to occupant behavior which does not always use maximum flow.

[194] 2008, Schultdt, Marc, and Debra Tachibana. Energy related Water Fixture Measurements: Securing the Baseline for Northwest Single Family Homes. 2008 ACEEE Summer Study on Energy Efficiency in Buildings. Page 1-265.

[195] Using measured flow rate assumption from Workpaper WPSCGNRWH150827A, Laminar Flow Restrictors For Hospitals and Health Care Facilities.

Usage = Estimated usage of mixed water (mixture of hot water from water heater line and cold water line) per faucet (gallons per year)

= If data is available to provide a reasonable custom estimate it should be used, if not use the following defaults (or substitute custom information in to the calculation):

| Building Type | Gallons hot water per unit per day[196] (A) | Unit | Estimated % hot water from Faucets [197] (B) | Multiplier [198] (C) | Unit | Days per year (D) | Annual gallons mixed water per faucet (A*B*C*D) |
|---|---|---|---|---|---|---|---|
| Small Office | 1 | person | 100% | 10 | employees per faucet | 250 | 2,500 |
| Large Office | 1 | person | 100% | 45 | employees per faucet | 250 | 11,250 |
| Fast Food Rest | 0.7 | meal/day | 50% | 75 | meals per faucet | 365 | 9,581 |
| Sit-Down Rest | 2.4 | meal/day | 50% | 36 | meals per faucet | 365 | 15,768 |
| Retail | 2 | employee | 100% | 5 | employees per faucet | 365 | 3,650 |
| Grocery | 2 | employee | 100% | 5 | employees per faucet | 365 | 3,650 |
| Warehouse | 2 | employee | 100% | 5 | employees per faucet | 250 | 2,500 |
| Elementary School | 0.6 | person | 50% | 50 | students per faucet | 200 | 3,000 |
| Jr High/High School | 1.8 | person | 50% | 50 | students per faucet | 200 | 9,000 |
| Health | 90 | patient | 25% | 2 | Patients per faucet | 365 | 16,425 |
| Motel | 20 | room | 25% | 1 | faucet per room | 365 | 1,825 |
| Hotel | 14 | room | 25% | 1 | faucet per room | 365 | 1,278 |
| Other | 1 | employee | 100% | 20 | employees per faucet | 250 | 5,000 |

EPG_electric = Energy per gallon of mixed water used by faucet (electric water heater)

= (8.33 * 1.0 * (WaterTemp - SupplyTemp)) / (RE_electric * 3412)

= 0.0795 kWh/gal for Bath, 0.0969 kWh/gal for Kitchen, 0.139 kWh/gal for LFRs, 0.0919 kWh/gal for unknown

8.33 = Specific weight of water (lbs/gallon)

1.0 = Heat Capacity of water (btu/lb-°F)

WaterTemp = Assumed temperature of mixed water

= 86F for Bath, 93F for Kitchen 91F for Unknown[199], 110F for health care facilities[200]

SupplyTemp = Assumed temperature of water entering building

= 54.1°F [201]

[196] Table 2-45 Chapter 49, Service Water Heating, 2007 ASHRAE Handbook, HVAC Applications.

[197] Estimated based on data provided in Appendix E; "Waste Not, Want Not: The Potential for Urban Water Conservation in California", Pacific Institute, November 2003.

[198] Based on review of the Illinois plumbing code (Employees and students per faucet). Retail, grocery, warehouse and health are estimates. Meals per faucet estimated as 4 bathroom and 3 kitchen faucets and average meals per day of 250 (based on California study above) – 250/7 = 36. Fast food assumption estimated.

[199] Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group. If the aerator location is unknown an average of 91% should be used which is based on the assumption that 70% of household water runs through the kitchen faucet and 30% through the bathroom (0.7*93)+(0.3*86)=0.91.

[200] Southern California Gas Company, Workpaper WPSCGNRWH150827A Revision #0, September, 2015

[201] US DOE Building America Program, Building America Analysis Spreadsheet (for Chicago, IL), Office of Energy Efficiency & Renewable Energy.

RE_electric = Recovery efficiency of electric water heater

= 98% [202]

3412 = Converts Btu to kWh (Btu/kWh)

ISR = In service rate of faucet aerators dependant on install method as listed in table below[203]

| Selection | ISR |
|---|---|
| Direct Install - Deemed | 0.95 |

**EXAMPLE**

For example, a direct installed kitchen faucet in a large office with electric DHW:

ΔkWh = 1 * ((1.39 – 0.94)/1.39) * 11,250 * 0.0969 * 0.95

= 335.3 kWh

For example, a direct installed bathroom faucet in an Elementary School with electric DHW:

ΔkWh = 1 * ((1.39 – 0.94)/1.39) * 3,000 * 0.0795 * 0.95

= 73.4 kWh

Secondary kWh Savings for Water Supply and Wastewater Treatment

The following savings should be included in the total savings for this measure, but should not be included in TRC tests to avoid double counting the economic benefit of water savings.

$$\Delta kWh_{water} = \Delta Water\ (gallons) / 1{,}000{,}000 * E_{water\ total}$$

Where

$E_{water\ total}$ = IL Total Water Energy Factor (kWh/Million Gallons)

=5,010[204]

**EXAMPLE**

For example, a direct installed faucet in a large office:

ΔWater (gallons) = ((1.39 – 0.94)/1.39) * 11,250 * 0.95

= 3,640 gallons

$\Delta kWh_{water}$ = 3,640/1,000,000*5,010

= 18 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = (ΔkWh / Hours) * CF

Where:

ΔkWh = calculated value above on a per faucet basis.Note do not include the secondary savings in this calculation.

[202] Electric water heaters have recovery efficiency of 98%, as sourced from available products on the AHRI Certification Directory.

[203] ComEd Energy Efficiency/Demand Response Plan: Plan Year 2 (6/1/2009-5/31/2010) Evaluation Report: All Electric Single Family Home Energy Performance Tune-Up Program, December 21, 2010, Table 3-8.

[204] This factor include 2571 kWh/MG for water supply based on Illinois energy intensity data from a 2012 ISAWWA study and 2439 kWh/MG for wastewater treatment based on national energy intensity use estimates. For more information please review Elevate Energy's 'IL TRM: Energy per Gallon Factor, May 2018 paper'.

Hours = Annual electric DHW recovery hours for faucet use

= (Usage * 0.545[205] )/GPH

= Calculate if usage is custom, if using default usage use:

| Building Type | Annual Recovery Hours |
|---|---|
| Small Office | 24 |
| Large Office | 109 |
| Fast Food Rest | 93 |
| Sit-Down Rest | 153 |
| Retail | 36 |
| Grocery | 36 |
| Warehouse | 24 |
| Elementary School | 29 |
| Jr High/High School | 88 |
| Health | 160 |
| Motel | 18 |
| Hotel | 12 |
| Other | 49 |

Where:

GPH = Gallons per hour recovery of electric water heater calculated for 85.9F temp rise (140-54.1), 98% recovery efficiency, and typical 12kW electric resistance storage tank.

= 56

CF = Coincidence Factor for electric load reduction

= Dependent on building type[206]

| Building Type | Coincidence Factor |
|---|---|
| Small Office | 0.0064 |
| Large Office | 0.0288 |
| Fast Food Rest | 0.0084 |
| Sit-Down Rest | 0.0184 |
| Retail | 0.0043 |
| Grocery | 0.0043 |
| Warehouse | 0.0064 |
| Elementary School | 0.0096 |
| Jr High/High School | 0.0288 |
| Health | 0.0144 |
| Motel | 0.0006 |
| Hotel | 0.0004 |
| Other | 0.0128 |

[205] 54.5% is the proportion of hot 120F water mixed with 54.1F supply water to give 90°F mixed faucet water.
[206] Calculated as follows: Assumptions for percentage of usage during peak period (1-5pm) were made and then multiplied by 65/365 (65 being the number of days in peak period) and by the number of total annual recovery hours to give an estimate of the number of hours of recovery during peak periods. There are 260 hours in the peak period so the probability you will see savings during the peak period is calculated as the number of hours of recovery during peak divided by 260. See 'C&I Faucet Aerator.xls' for details.

**EXAMPLE**

For example, a direct installed kitchen faucet in a large office with electric DHW:

ΔkW = 335.3/109 * 0.0288

= 0.0886 kW

For example, a direct installed bathroom faucet in an Elementary School with electric DHW:

ΔkW = 73.4/29 * 0.0096

= 0.0243 kW

### FOSSIL FUEL IMPACT DESCRIPTIONS AND CALCULATION

ΔTherms = %FossilDHW * ((GPM_base - GPM_low)/GPM_base) * Usage * EPG_gas * ISR

Where:

%FossilDHW = proportion of water heating supplied by fossil fuel heating

| DHW fuel | %Fossil_DHW |
|---|---|
| Electric | 0% |
| Fossil Fuel | 100% |

EPG_gas = Energy per gallon of mixed water used by faucet (gas water heater)

= (8.33 * 1.0 * (WaterTemp - SupplyTemp)) / (RE_gas * 100,000)

= 0.00397 Therm/gal for Bath, 0.00484 Therm/gal for Kitchen, 0.00695 Therm/gal for LFRs, 0.00459 Therm/gal for unknown

Where:

RE_gas = Recovery efficiency of gas water heater

` = 67% [207]

100,000 = Converts Btus to Therms (Btu/Therm)

Other variables as defined above.

**EXAMPLE**

For example, a direct installed kitchen faucet in a large office with gas DHW:

ΔTherms = 1 * ((1.39 – 0.94)/1.39) * 11,250 * 0.00484 * 0.95

= 16.7 Therms

For example, a direct installed bathroom faucet in an Elementary School with gas DHW:

ΔTherms = 1 * ((1.39 – 0.94)/1.39) * 3,000 * 0.00397 * 0.95

= 3.66 Therms

### WATER IMPACT DESCRIPTIONS AND CALCULATION

ΔWater (gallons) = ((GPM_base - GPM_low)/GPM_base) * Usage * ISR

[207] Review of AHRI Directory suggests range of recovery efficiency ratings for new Gas DHW units of 70-87%. Average of existing units is estimated at 75%. Commercial properties are more similar to MF homes than SF homes. MF hot water is often provided by a larger commercial boiler. This suggests that the average recovery efficiency is somewhere between a typical central boiler efficiency of .59 and the .75 for single family home. An average is used for this analysis by default.

Variables as defined above

**EXAMPLE**

For example, a direct installed faucet in a large office:

ΔWater (gallons) = ((1.39 – 0.94)/1.39) * 11,250 * 0.95

= 3,640 gallons

For example, a direct installed faucet in a Elementary School:

ΔWater (gallons) = ((1.39 – 0.94)/1.39) * 3,000 * 0.95

= 971 gallons

## DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

## SOURCES USED FOR GPM ASSUMPTIONS

| Source ID | Reference |
|---|---|
| 1 | 2011, DeOreo, William. California Single Family Water Use Efficiency Study. April 20, 2011. |
| 2 | 2000, Mayer, Peter, William DeOreo, and David Lewis. Seattle Home Water Conservation Study. December 2000. |
| 3 | 1999, Mayer, Peter, William DeOreo. Residential End Uses of Water. Published by AWWA Research Foundation and American Water Works Association. 1999. |
| 4 | 2003, Mayer, Peter, William DeOreo. Residential Indoor Water Conservation Study. Aquacraft, Inc. Water Engineering and Management. Prepared for East Bay Municipal Utility District and the US EPA. July 2003. |
| 5 | 2011, DeOreo, William. Analysis of Water Use in New Single Family Homes. By Aquacraft. For Salt Lake City Corporation and US EPA. July 20, 2011. |
| 6 | 2011, Aquacraft. Albuquerque Single Family Water Use Efficiency and Retrofit Study. For Albuquerque Bernalillo County Water Utility Authority. December 1, 2011. |
| 7 | 2008, Schultdt, Marc, and Debra Tachibana. Energy related Water Fixture Measurements: Securing the Baseline for Northwest Single Family Homes. 2008 ACEEE Summer Study on Energy Efficiency in Buildings. |

## MEASURE CODE: CI-HWE-LFFA-V08-190101

## REVIEW DEADLINE: 1/1/2023

## 4.3.3 Low Flow Showerheads

### DESCRIPTION

This measure relates to the direct installation of a low flow showerhead in a commercial building. Expected applications include small business, office, restaurant, or small motel. For multifamily or senior housing, the residential low flow showerhead should be used.

This measure was developed to be applicable to the following program types: DI.

If applied to other program types, the measure savings should be verified

### DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed equipment must be an energy efficient showerhead rated at 2.0 gallons per minute (GPM) or less. Savings are calculated on a per showerhead fixture basis.

### DEFINITION OF BASELINE EQUIPMENT

The baseline condition is assumed to be a standard showerhead rated at 2.5 GPM.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 10 years.[208]

### DEEMED MEASURE COST

The full install cost (including labor) for this measure is $12[209] or program actual.

### LOADSHAPE

Loadshape C02 - Commercial Electric DHW

### COINCIDENCE FACTOR

The coincidence factor for this measure is assumed to be 2.78%[210].

**Algorithm**

### CALCULATION OF SAVINGS [211]

### ELECTRIC ENERGY SAVINGS

Note these savings are per showerhead fixture

ΔkWh =

%ElectricDHW * ((GPM_base * L_base - GPM_low * L_low) * NSPD * 365.25) * EPG_electric * ISR

---

[208] Table C-6, Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. Evaluations indicate that consumer dissatisfaction may lead to reductions in persistence, particularly in Multi-Family.

[209] Direct-install price per showerhead assumes cost of showerhead (Market research average of $7 and assess and install time of $5 (20min @ $15/hr)

[210] Calculated as follows: Assume 11% showers take place during peak hours (as sourced from "Analysis of Water Use in New Single Family Homes, Aquacraft Water Engineering and Management, January 2011). There are 65 days in the summer peak period, so the percentage of total annual aerator use in peak period is 0.11*65/365 = 1.96%. The number of hours of recovery during peak periods is therefore assumed to be 1.96% * 369 = 7.23 hours of recovery during peak period. There are 260 hours in the peak period so the probability you will see savings during the peak period is 7,23/260 = 0..0278

[211] Based on excel spreadsheet 120911.xls …on SharePoint

Where:

%ElectricDHW = proportion of water heating supplied by electric resistance heating

= 1 if electric DHW, 0 if fuel DHW, if unknown assume 16% [212]

GPM_base = Flow rate of the baseline showerhead

= 2.67 for Direct-install programs[213]

GPM_low = As-used flow rate of the low-flow showerhead, which may, as a result of measurements of program evaulations deviate from rated flows, see table below:

| Rated Flow |
|---|
| 2.0 GPM |
| 1.75 GPM |
| 1.5 GPM |
| Custom or Actual[214] |

L_base = Shower length in minutes with baseline showerhead

= 8.20 min[215]

L_low = Shower length in minutes with low-flow showerhead

= 8.20 min[216]

365.25 = Days per year, on average.

NSPD = Estimated number of showers taken per day for one showerhead

EPG_electric = Energy per gallon of hot water supplied by electric

= (8.33 * 1.0 * (ShowerTemp - SupplyTemp)) / (RE_electric * 3412)

= (8.33 * 1.0 * (105 – 54.1)) / (0.98 * 3412)

= 0.127 kWh/gal

8.33 = Specific weight of water (lbs/gallon)

1.0 = Heat Capacity of water (btu/lb-°F)

ShowerTemp = Assumed temperature of water

= 105°F [217]

SupplyTemp = Assumed temperature of water entering house

= 54.1°F [218]

---

[212] Table HC8.9. Water Heating in U.S. Homes in Midwest Region, Divisions, and States, 2009 (RECS)

[213] Based on measured data from Ameren IL EM&V of Direct-Install program. Program targets showers that are rated 2.5 GPM or above.

[214] Note that actual values may be either a) program-specific minimum flow rate, or b) program-specific evaluation-based value of actual effective flow-rate due to increased duration or temperatures. The latter increases in likelihood as the rated flow drops and may become significant at or below rated flows of 1.5 GPM. The impact can be viewed as the inverse of the throttling described in the footnote for baseline flowrate.

[215] Representative value from sources 1, 2, 3, 4, 5, and 6 (See Source Table at end of measure section)

[216] Set equal to L_base.

[217] Shower temperature cited from SBW Consulting, Evaluation for the Bonneville Power Authority, 1994.

[218] US DOE Building America Program, Building America Analysis Spreadsheet (for Chicago, IL), Office of Energy Efficiency & Renewable Energy.

RE_electric = Recovery efficiency of electric water heater

= 98% [219]

3412 = Converts Btu to kWh (btu/kWh)

ISR = In service rate of showerhead

= Dependant on program delivery method as listed in table below

| Selection | ISR[220] |
|---|---|
| Direct Install - Deemed | 0.98 |

**EXAMPLE**

For example, a direct-installed 1.5 GPM showerhead in an office with electric DHW where the number of showers is estimated at 3 per day:

$\Delta$kWh = 1 * ((2.67*8.20)- (1.5*8.20)) * 3*365.25) *0.127 * 0.98

= 1308.4 kWh

<u>Secondary kWh Savings for Water Supply and Wastewater Treatment</u>

The following savings should be included in the total savings for this measure, but should not be included in TRC tests to avoid double counting the economic benefit of water savings.

$$\Delta kWh_{water} = \Delta Water\ (gallons) / 1{,}000{,}000 * E_{water\ total}$$

Where

$E_{water\ total}$ = IL Total Water Energy Factor (kWh/Million Gallons)

=5,010[221]

**EXAMPLE**

For example, a direct-installed 1.5 GPM showerhead in an office with where the number of showers is estimated at 3 per day:

$\Delta$Water (gallons) = ((2.67 * 8.20)-(1.5 * 8.20)) * 3 * 365.25 * 0.98

= 10,302 gallons

$\Delta kWh_{water}$ = 10,302/1,000,000*5,010

= 52 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$$\Delta kW = \Delta kWh/Hours * CF$$

Where:

$\Delta$kWh = calculated value above. Note do not include the secondary savings in this calculation.

[219] Electric water heaters have recovery efficiency of 98%, as sourced from available products on the AHRI Certification Directory.

[220] Deemed values are from ComEd Energy Efficiency/ Demand Response Plan: Plan Year 2 (6/1/2009-5/31/2010) Evaluation Report: All Electric Single Family Home Energy Performance Tune-Up Program Table 3-8. Alternative ISRs may be developed for program delivery methods based on evaluation results.

[221] This factor include 2571 kWh/MG for water supply based on Illinois energy intensity data from a 2012 ISAWWA study and 2439 kWh/MG for wastewater treatment based on national energy intensity use estimates. For more information please review Elevate Energy's 'IL TRM: Energy per Gallon Factor, May 2018 paper'.

Hours = Annual electric DHW recovery hours for showerhead use

= ((GPM_base * L_base) *NSPD * 365.25 ) * 0.773[222] / GPH

Where:

GPH = Gallons per hour recovery of electric water heater calculated for 65.9F temp rise (120-54.1), 98% recovery efficiency, and typical 4.5kW electric resistance storage tank.

= 27.51

CF = Coincidence Factor for electric load reduction

= 0.0278[223]

**EXAMPLE**

For example, a direct-installed 1.5 GPM showerhead in an office with electric DHW where the number of showers is estimated at 3 per day:

ΔkW = (1308.4 / 674.1)*0.0278

= 0.054 kW

**FOSSIL FUEL IMPACT DESCRIPTIONS AND CALCULATION**

ΔTherms = %FossilDHW * ((GPM_base * L_base - GPM_low * L_low) * NSPD* 365.25) * EPG_gas * ISR

Where:

%FossilDHW = proportion of water heating supplied by fossil fuel heating

| DHW fuel | %Fossil_DHW |
|---|---|
| Electric | 0% |
| Fossil Fuel | 100% |
| Unknown | 84%[224] |

EPG_gas = Energy per gallon of Hot water supplied by gas

= (8.33 * 1.0 * (ShowerTemp - SupplyTemp)) / (RE_gas * 100,000)

= 0.0063 Therm/gal

Where:

RE_gas = Recovery efficiency of gas water heater

[222] 77.3% is the proportion of hot 120F water mixed with 54.1°F supply water to give 105°F shower water

[223] Calculated as follows: Assume 11% showers take place during peak hours (as sourced from “Analysis of Water Use in New Single Family Homes, Aquacraft Water Engineering and Management, January 2011). There are 65 days in the summer peak period, so the percentage of total annual aerator use in peak period is 0.11*65/365.25 = 1.96%. The number of hours of recovery during peak periods is therefore assumed to be 1.96% * 369 = 7.23 hours of recovery during peak period where 369 equals the average annual electric DHW recovery hours for showerhead use including SF and MF homes with Direct Install and Retrofit/TOS measures. There are 260 hours in the peak period so the probability you will see savings during the peak period is 7.23/260 = 0.0278

[224] Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IL. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used

= 67% [225]

100,000 = Converts Btus to Therms (btu/Therm)

Other variables as defined above.

**EXAMPLE**

For example, a direct-installed 1.5 GPM showerhead in an office with gas DHW where the number of showers is estimated at 3 per day:

ΔTherms = 1.0 * (( 2.67 *8.2) – (1.5 * 8.2)) * 3 * 365.25 * 0.0063 * 0.98

= 64.9 therms

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

ΔWater (gallons) = ((GPM_base * L_base - GPM_low * L_low) * NSPD * 365.25 * ISR

Variables as defined above

**EXAMPLE**

For example, a direct-installed 1.5 GPM showerhead in an office with where the number of showers is estimated at 3 per day:

ΔWater (gallons) = ((2.67 * 8.20)-(1.5 * 8.20)) * 3 * 365.25 * 0.98

= 10,302 gallons

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**SOURCES**

| Source ID | Reference |
|---|---|
| 1 | 2011, DeOreo, William. California Single Family Water Use Efficiency Study. April 20, 2011. |
| 2 | 2000, Mayer, Peter, William DeOreo, and David Lewis. Seattle Home Water Conservation Study. December 2000. |
| 3 | 1999, Mayer, Peter, William DeOreo. Residential End Uses of Water. Published by AWWA Research Foundation and American Water Works Association. 1999. |
| 4 | 2003, Mayer, Peter, William DeOreo. Residential Indoor Water Conservation Study. Aquacraft, Inc. Water Engineering and Management. Prepared for East Bay Municipal Utility District and the US EPA. July 2003. |
| 5 | 2011, DeOreo, William. Analysis of Water Use in New Single Family Homes. By Aquacraft. For Salt Lake City Corporation and US EPA. July 20, 2011. |
| 6 | 2011, Aquacraft. Albuquerque Single Family Water Use Efficiency and Retrofit Study. For Albuquerque Bernalillo County Water Utility Authority. December 1, 2011. |
| 7 | 2008, Schultdt, Marc, and Debra Tachibana. Energy related Water Fixture Measurements: Securing the Baseline for Northwest Single Family Homes. 2008 ACEEE Summer Study on Energy Efficiency in Buildings. |

[225] Review of AHRI Directory suggests range of recovery efficiency ratings for new Gas DHW units of 70-87%. Average of existing units is estimated at 75%. Commercial properties are more similar to MF homes than SF homes. MF hot water is often provided by a larger commercial boiler. This suggests that the average recovery efficiency is somewhere between a typical central boiler efficiency of .59 and the .75 for single family home. An average is used for this analysis by default.

**MEASURE CODE: CI-HWE-LFSH-V05-190101**

**REVIEW DEADLINE: 1/1/2020**

### 4.3.4 Commercial Pool Covers

**DESCRIPTION**

This measure refers to the installation of covers on commercial use pools that are heated with gas-fired equipment located either indoors or outdoors. By installing pool covers, the heating load on the pool boiler will be reduced by reducing the heat loss from the water to the environment and the amount of actual water lost due to evaporation (which then requires additional heated water to make up for it).

The main source of energy loss in pools is through evaporation. This is particularly true of outdoor pools where wind plays a larger role. The point of installing pool covers is threefold. First, it will reduce convective losses due to the wind by shielding the water surface. Second, it will insulate the water from the colder surrounding air. And third, it will reduce radiative losses to the night sky. In doing so, evaporative losses will also be minimized, and the boiler will not need to work as hard in replenishing the pool with hot water to keep the desired temperature.

This measure can be used for pools that (1) currently do not have pool covers, (2) have pool covers that are past the useful life of the existing cover, or (3) have pool covers that are past their warranty period and have failed.

**DEFINITION OF EFFICIENT EQUIPMENT**

For indoor pools, the efficient case is the installation of an indoor pool cover with a 5 year warranty on an indoor pool that operates all year.

For outdoor pools, the efficient case is the installation of an outdoor pool cover with a 5 year warranty on an outdoor pool that is open through the summer season.

**DEFINITION OF BASELINE EQUIPMENT**

For indoor pools, the base case is an uncovered indoor pool that operates all year.

For outdoor pools, the base case is an outdoor pool that is uncovered and is open through the summer season.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The useful life of this measure is assumed to be 6 years [226]

**DEEMED MEASURE COST**

The table below shows the costs for the various options and cover sizes. Since this measure covers a mix of various sizes, the average cost of these options is taken to be the incremental measure cost. [227].

| Cover Size | Edge Style | |
|---|---|---|
| | Hemmed (indoor) | Weighted (outdoor) |
| 1000-1,999 sq. ft. | $2.19 | $2.24 |
| 2,000-2,999 sq. ft. | $2.01 | $2.06 |
| 3,000+ sq. ft. | $1.80 | $1.83 |
| Average | $2.00 | $2.04 |

**LOADSHAPE**

N/A

[226] The effective useful life of a pool cover is typically one year longer than its warranty period. SolaPool Covers. Pool Covers Website, FAQ- "How long will my SolaPool cover blanket last?". Pool covers are typically offered with 3 and 5 year warranties with at least one company offering a 6 year warranty. Conversation with Trade Ally. Knorr Systems

[227] Pool Cover Costs: Lincoln Commercial Pool Equipment online catalog. Accessed 8/26/11.

### COINCIDENCE FACTOR

N/A

## Algorithm

### CALCULATION OF ENERGY SAVINGS

### ELECTRIC ENERGY SAVINGS

Secondary kWh Savings for Water Supply and Wastewater Treatment

The following savings should be included in the total savings for this measure, but should not be included in TRC tests to avoid double counting the economic benefit of water savings.

$$\Delta kWh_{water} = \Delta Water\ (gallons) / 1{,}000{,}000 * E_{water\ supply}$$

Where

$E_{water\ supply}$ = Water Supply Energy Factor (kWh/Million Gallons)

= 2,571[228]

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

### NATURAL GAS SAVINGS

The calculations are based on modeling runs using RSPEC! Energy Smart Pools Software that was created by the U.S. Department of Energy. [229]

$$\Delta Therms = SavingFactor \times Size\ of\ Pool$$

Where

Savings factor = dependant on pool location and listed in table below[230]

| Location | Therm / sq-ft |
|---|---|
| Indoor | 2.61 |
| Outdoor | 1.01 |

Size of Pool = custom input

### WATER IMPACT DESCRIPTIONS AND CALCULATION

$$\Delta Water\ (gallons) = WaterSavingFactor \times Size\ of\ Pool$$

Where

WaterSavingFactor = Water savings for this measure dependant on pool location and listed in table below.[231].

[228] This factor include 2571 kWh/MG for water supply based on Illinois energy intensity data from a 2012 ISAWWA study. For more information please review Elevate Energy's 'IL TRM: Energy per Gallon Factor, May 2018 paper'. Note since the water loss associated with this measure is due to evaporation and does not discharge into the wastewater system, only the water supply factor is used here.

[229] Full method and supporting information found in reference document: IL TRM - Business Pool Covers WorkPaper.docx. Note that the savings estimates are based upon Chicago weather data.

[230] Business Pool Covers.xlsx

[231] Ibid.

| Location | Annual Savings Gal / sq-ft |
|---|---|
| Indoor | 15.28 |
| Outdoor | 8.94 |

Size of Pool = Custom input

**DEEMED O&M COST ADJUSTMENT CALCULATION**

There are no O&M cost adjustments for this measure.

**MEASURE CODE: CI-HWE-PLCV-V02-190101**

**REVIEW DEADLINE: 1/1/2020**

## 4.3.5 Tankless Water Heater

### DESCRIPTION

This measure covers the installation of on-demand or instantaneous tankless water heaters. Tankless water heaters function similar to standard hot water heaters except they do not have a storage tank. When there is a call for hot water, the water is heated instantaneously as it passes through the heating element and then proceeds to the user or appliance calling for hot water. Tankless water heaters achieve savings by eliminating the standby losses that occur in stand-alone or tank-type water heaters and by being more efficient than the baseline storage hot water heater.

This measure was developed to be applicable to the following program types: TOS, RF, ER.

If applied to other program types, the measure savings should be verified.

Note IECC 2018 is scheduled to become effective March 1, 2019 and will become baseline for all New Construction permits from that date.

### DEFINITION OF EFFICIENT EQUIPMENT

| Electric | Gas |
|---|---|
| To qualify for this measure, the tankless water heater shall be a new electric powered tankless hot water heater with an energy factor greater than or equal to 0.98 with an output greater than or equal to 5 GPM output at 70° F temperature rise. | To qualify for this measure, the tankless water heater shall meet or exceed the efficiency requirements for tankless hot water heaters mandated by the International Energy Conservation Code (IECC) 2012/2015/2018, Table C404.2. |

### DEFINITION OF BASELINE EQUIPMENT

| Electric | Gas |
|---|---|
| The baseline condition is assumed to be an electric commercial-grade tanked water heater 50 or more gallon storage capacity with an energy factor less than or equal to 0.9 or the water heater is five or more years old. | The baseline condition is assumed to be a gas-fired tank-type water heater meeting the efficiency requirements mandated by the International Energy conservation Code (IECC) 2012/2015/2018, Table C404.2. The Federal Standard applies to units with input ≤75,000 Btu/hr, consistent with the baseline definitions of 4.3.1 Storage Water Heater. |

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

| Electric | Gas |
|---|---|
| The expected measure life is assumed to be 5 years[232]. | The expected measure life is assumed to be 20 years[233] |

### DEEMED MEASURE COST

The incremental capital cost for an electric tankless heater this measure is assumed to be[234]

| Output (gpm) at delta T 70 | Incremental Cost |
|---|---|
| 5 | $1050 |
| 10 | $1050 |
| 15 | $1950 |

232 Ohio Technical Reference Manual 8/2/2010 referencing CenterPoint Energy-Triennial CIP/DSM Plan 2010-2012 Report; Additional reference stating >20 years is soured from the US DOE Energy Savers for Tankless or Demand-Type Water Heaters.
233 Ibid.
234 Act on Energy Technical Reference Manual, Table 9.6.2-3

The incremental capital cost for a gas fired tankless heater is as follows:

| Program | Capital Cost, $ per unit |
|---|---|
| Retrofit | $3,255[235] |
| Time of Sale or New Construction | $2,526[236] |

#### DEEMED O&M COST ADJUSTMENTS

$100[237]

#### LOADSHAPE

Loadshape C02 - Commercial Electric DHW

#### COINCIDENCE FACTOR

The measure has deemed kW savings therefor a coincidence factor is not applied

## Algorithm

#### CALCULATION OF ENERGY SAVINGS

#### ELECTRIC ENERGY SAVINGS [238]

The annual electric savings from an electric tankless heater is a deemed value and assumed to be:

| Output (gpm) at delta T 70 | Savings (kWh) |
|---|---|
| 5.0 | 2,992 |
| 10.0 | 7,905 |
| 15.0 | 12,879 |

#### SUMMER COINCIDENT PEAK DEMAND SAVINGS[239]

The annual kW savings from an electric tankless heater is a deemed value and assumed to be:

| Output (gpm) at delta T 70 | Savings (kW) |
|---|---|
| 5.0 | 0.34 |
| 10.0 | 0.90 |
| 15.0 | 1.47 |

---

[235] Based on AOE historical average installation data of 42 tankless gas hot water heaters

[236]Minnesota Center for Energy and Environment, Low contractor estimate used to reflect less labor required in new construction of venting.

[237] Water heaters (WH) require annual maintenance. There are different levels of effort for annual maintenance depending if the unit is gas or electric, tanked or tankless. Electric and gas tank water heater manufacturers recommend an annual tank drain to clear sediments. Also recommended are "periodic" inspections by qualified service professionals of operating controls, heating element and wiring for electric WHs and thermostat, burner, relief valve internal flue-way and venting systems for gas WHs. Tankless WH require annual maintenance by licensed professionals to clean control compartments, burners, venting system and heat exchangers. This information is from WH manufacturer product brochures including GE, Rennai, Rheem, Takagi and Kenmore. References for incremental O&M costs were not found. Therefore the incremental cost of the additional annual maintenance for tankless WH is estimated at $100.

[238] Act on Energy Technical Reference Manual, Table 9.6.2-3

[239] Ibid.

**NATURAL GAS SAVINGS**

ΔTherms =[[Wgal x 8.33 x 1 x (Tout - Tin) x [(1/Eff base) - (1/Eff ee)]]/100,000] +[[(SL x 8,766)/Eff base]] / 100,000 Btu/Therms]

Where:

Wgal = Annual water use for equipment in gallons

= custom, otherwise assume 21,915 gallons [240]

8.33 lbm/gal = weight in pounds of one gallon of water

1 Btu/lbm°F = Specific heat of water: 1 Btu/lbm/°F

8,766 hr/yr = hours a year

Tout = Unmixed Outlet Water Temperature

= custom, otherwise assume 130 °F[241]

Tin = Inlet Water Temperature

= custom, otherwise assume 54.1 °F[242]

Eff base = Rated efficiency of baseline water heater expressed as Energy Factor (EF) or Thermal Efficiency (Et); see table below[243]

| Input Btu/hr of existing, tanked water heater | Eff base | Units |
|---|---|---|
| Size: ≤ 75,000 Btu/hr, ≥20 gal and ≤55 gal | 0.675 -0.0015*Tank Volume | Energy Factor |
| Size: ≤ 75,000 Btu/hr, >55 gal and ≤100 gal | 0.8012 -0.00078*Tank Volume | Energy Factor |
| Size: >75,000 Btu/hr and ≤ 155,000 Btu/hr | 80% | Thermal Efficiency |
| Size: >155,000 Btu/hr | 80% | Thermal Efficiency |

Where:

Tank Volume = custom input, if unknown assume 60 gallons for Size: ≤ 75,000 Btu/hr

Please note: Units in base case must match units in efficient case. If Energy Factor used in base case, Energy Factor to be used in efficient case. If Themal Efficiency is used in base case, Thermal Efficiency must be used in efficient case.

Eff ee = Rated efficiency of efficient water heater expressed as Energy Factor (EF) or Thermal Efficiency (Eff t)

---

[240] 21,915 gallons is an estimate of 60 gal/day for 365.25 days/yr. If building type is known, reference 2007 ASHRAE Handbook HVAC Applications p. 49.14 Table 7 Hot Water Demands and Use for Various Types of Buildings to help estimate hot water consumption.

[241] Based on 2010 Ohio Techical Reference Manual and NAHB Research Center, (2002) Performance Comparison of Residential hot Water Systems. Prepared for National Renewable Energy Laboratory, Golden, Colorado.

[242] August 31, 2011 Memo of Savings for Hot Water Savings Measures to Nicor Gas from Navigant states that 54.1°F was calculated from the weighted average of monthly water mains temperatures reported in the 2010 Building America Benchmark Study for Chicago-Waukegan, Illinois.

[243] International Energy Conservation Code (IECC) 2012/2015, Table C404.2, Minimum Performance of Water-Heating Equipment. Units less than or equal to 75,000 Btu/hr input are governed by the most recent Code of Federal Regulation rulings, consistent with baseline definitions of 4.3.1 Storage Water Heater.

= custom input, if unknown assume 0.84[244]

SL = Stand-by Loss in Base Case Btu/hr

= custom input based on formula in table below, if unknown assume unit size in table below[245]

| Input Btu/h of new, tankless water heater | Standby Loss (SL) |
|---|---|
| Size: ≤ 75,000 Btu/hr | 0 |
| Size: >75,000 Btu/hr | (Input rating/800)+(110*√Tank Volume))* |

**Note: IECC2018 does not specify standby performance.*

Where:

Tank Volume = custom input, if unknown assume, 60 gallons for <75,000 Btu/hr, 75 gallons for >75,000 Btu/hr and ≤ 155,000 Btu/hr and 150 for Size >155,000 Btu/hr

Input Rating = nameplate Btu/hr rating of water heater

**EXAMPLE**

For example, a 75,000 Btu/hr tankless unit using 21,915 gal/yr with outlet temperature at 130.0 and inlet temperature at 54.1, replacing a baseline unit with 0.8 thermal efficiency and standby losses of 1008.3 btu/hr:

ΔTherms =[[(21,915 x 8.33x 1 x (130 – 54.1) x [(1/.8) - (1/.84)]/100,000] +[(1008.3 x 8,766)/.8]] / 100,000

=115 Therms

### WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

### DEEMED O&M COST ADJUSTMENT CALCULATION

The deemed O&M cost adjustment for a gas fired tankless heater is $100

### REFERENCE TABLES

Minimum Performance Water Heating Equipment[246]

[244] Specifications of energy efficient tankless water heater. Reference Consortium for Energy Efficiency (CEE) which maintains a list of high efficiency tankless water heaters which currently have Energy Factors up to .96. Ameren currently requires minimum .82 energy factor.

[245] Stand-by loss is provided in 2012/2015 IECC, Table C404.2, Minimum Performance of Water-Heating Equipment

[246] International Energy Conservation Code (IECC)2012/2015

TABLE C404.2
MINIMUM PERFORMANCE OF WATER-HEATING EQUIPMENT

| EQUIPMENT TYPE | SIZE CATEGORY (input) | SUBCATEGORY OR RATING CONDITION | PERFORMANCE REQUIRED[a, b] | TEST PROCEDURE |
|---|---|---|---|---|
| Water heaters, electric | ≤ 12 kW | Resistance | 0.97 - 0.00 132 $V$, EF | DOE 10 CFR Part 430 |
| | > 12 kW | Resistance | 1.73 $V$ + 155 SL, Btu/h | ANSI Z21.10.3 |
| | ≤ 24 amps and ≤ 250 volts | Heat pump | 0.93 - 0.00 132 $V$, EF | DOE 10 CFR Part 430 |
| Storage water heaters, gas | [redacted] | | | |
| | > 75,000 Btu/h and ≤ 155,000 Btu/h | < 4,000 Btu/h/gal | 80% $E_t$ $(Q/800 + 110\sqrt{V})$ SL, Btu/h | ANSI Z21.10.3 |
| | > 155,000 Btu/h | < 4,000 Btu/h/gal | 80% $E_t$ $(Q/800 + 110\sqrt{V})$ SL, Btu/h | |
| Instantaneous water heaters, gas | > 50,000 Btu/h and < 200,000 Btu/h[c] | ≥ 4,000 (Btu/h)/gal and < 2 gal | 0.62 - 0.00 19 $V$, EF | DOE 10 CFR Part 430 |
| | ≥ 200,000 Btu/h | ≥ 4,000 Btu/h/gal and < 10 gal | 80% $E_t$ | ANSI Z21.10.3 |
| | ≥ 200,000 Btu/h | ≥ 4,000 Btu/h/gal and ≥ 10 gal | 80% $E_t$ $(Q/800 + 110\sqrt{V})$ SL, Btu/h | |
| Storage water heaters, oil | ≤ 105,000 Btu/h | ≥ 20 gal | 0.59 - 0.0019 $V$, EF | DOE 10 CFR Part 430 |
| | ≥ 105,000 Btu/h | < 4,000 Btu/h/gal | 78% $E_t$ $(Q/800 + 110\sqrt{V})$ SL, Btu/h | ANSI Z21.10.3 |
| Instantaneous water heaters, oil | ≤ 210,000 Btu/h | ≥ 4,000 Btu/h/gal and < 2 gal | 0.59 - 0.0019V, EF | DOE 10 CFR Part 430 |
| | > 210,000 Btu/h | ≥ 4,000 Btu/h/gal and < 10 gal | 80% $E_t$ | ANSI Z21.10.3 |
| | > 210,000 Btu/h | ≥ 4,000 Btu/h/gal and ≥ 10 gal | 78% $E_t$ $(Q/800 + 110\sqrt{V})$ SL, Btu/h | |
| Hot water supply boilers, gas and oil | ≥ 300,000 Btu/h and < 12,500,000 Btu/h | ≥ 4,000 Btu/h/gal and < 10 gal | 80% $E_t$ | ANSI Z21.10.3 |
| Hot water supply boilers, gas | ≥ 300,000 Btu/h and < 12,500,000 Btu/h | ≥ 4,000 Btu/h/gal and ≥ 10 gal | 80% $E_t$ $(Q/800 + 110\sqrt{V})$ SL, Btu/h | |
| Hot water supply boilers, oil | > 300,000 Btu/h and < 12,500,000 Btu/h | > 4,000 Btu/h/gal and > 10 gal | 78% $E_t$ $(Q/800 + 110\sqrt{V})$ SL, Btu/h | |
| Pool heaters, gas and oil | All | — | 78% $E_t$ | ASHRAE 146 |
| Heat pump pool heaters | All | — | 4.0 COP | AHRI 1160 |
| Unfired storage tanks | All | — | Minimum insulation requirement R-12.5 $(h \cdot ft^2 \cdot {}^\circ F)/Btu$ | (none) |

For SI: °C = [(°F) - 32]/1.8, 1 British thermal unit per hour = 0.2931 W, 1 gallon = 3.785 L, 1 British thermal unit per hour per gallon = 0.078 W/L.

a. Energy factor (EF) and thermal efficiency ($E_t$) are minimum requirements. In the EF equation, $V$ is the rated volume in gallons.

b. Standby loss (SL) is the maximum Btu/h based on a nominal 70°F temperature difference between stored water and ambient requirements. In the SL equation, $Q$ is the nameplate input rate in Btu/h. In the SL equation for electric water heaters, $V$ is the rated volume in gallons. In the SL equation for oil and gas water heaters and boilers, $V$ is the rated volume in gallons.

c. Instantaneous water heaters with input rates below 200,000 Btu/h must comply with these requirements if the water heater is designed to heat water to temperatures 180°F or higher.

**IECC 2018 :**

TABLE C404.2
MINIMUM PERFORMANCE OF WATER-HEATING EQUIPMENT

| EQUIPMENT TYPE | SIZE CATEGORY (input) | SUBCATEGORY OR RATING CONDITION | PERFORMANCE REQUIRED[a, b] | TEST PROCEDURE |
|---|---|---|---|---|
| Water heaters, electric | ≤ 12 kW[d] | Tabletop[e], ≥ 20 gallons and ≤ 120 gallons | 0.93 - 0.00132*V*, EF | DOE 10 CFR Part 430 |
| | | Resistance ≥ 20 gallons and ≤ 55 gallons | 0.960 - 0.0003*V*, EF | |
| | | Grid-enabled[f] > 75 gallons and ≤ 120 gallons | 1.061 - 0.00168V, EF | |
| | > 12 kW | Resistance | $(0.3 + 27/V_m)$, %/h | ANSI Z21.10.3 |
| | ≤ 24 amps and ≤ 250 volts | Heat pump > 55 gallons and ≤ 120 gallons | 2.057 - 0.00113V, EF | DOE 10 CFR Part 430 |
| Storage water heaters, gas | [redacted] | | | |
| | > 75,000 Btu/h and ≤ 155,000 Btu/h | < 4,000 Btu/h/gal | 80% $E_t$ | ANSI Z21.10.3 |
| | > 155,000 Btu/h | < 4,000 Btu/h/gal | 80% $E_t$ | |
| Instantaneous water heaters, gas | > 50,000 Btu/h and < 200,000 Btu/h[c] | ≥ 4,000 (Btu/h)/gal and < 2 gal | 0.82 - 0.00 19V, EF | DOE 10 CFR Part 430 |
| | ≥ 200,000 Btu/h | ≥ 4,000 Btu/h/gal and < 10 gal | 80% $E_t$ | ANSI Z21.10.3 |
| | ≥ 200,000 Btu/h | ≥ 4,000 Btu/h/gal and ≥ 10 gal | 80% $E_t$ | |
| Storage water heaters, oil | ≤ 105,000 Btu/h | ≥ 20 gal and ≤ 50 gallons | 0.68 - 0.0019V, EF | DOE 10 CFR Part 430 |
| | ≥ 105,000 Btu/h | < 4,000 Btu/h/gal | 80% $E_t$ | ANSI Z21.10.3 |
| Instantaneous water heaters, oil | ≤ 210,000 Btu/h | ≥ 4,000 Btu/h/gal and < 2 gal | 0.59 - 0.0019V, EF | DOE 10 CFR Part 430 |
| | > 210,000 Btu/h | ≥ 4,000 Btu/h/gal and < 10 gal | 80% $E_t$ | ANSI Z21.10.3 |
| | > 210,000 Btu/h | ≥ 4,000 Btu/h/gal and ≥ 10 gal | 78% $E_t$ | |
| Storage water heaters, oil | ≤ 105,000 Btu/h | ≥ 20 gal and ≤ 50 gallons | 0.68 - 0.0019V, EF | DOE 10 CFR Part 430 |
| | ≥ 105,000 Btu/h | < 4,000 Btu/h/gal | 80% $E_t$ | ANSI Z21.10.3 |
| Instantaneous water heaters, oil | ≤ 210,000 Btu/h | ≥ 4,000 Btu/h/gal and < 2 gal | 0.59 - 0.0019V, EF | DOE 10 CFR Part 430 |
| | > 210,000 Btu/h | ≥ 4,000 Btu/h/gal and < 10 gal | 80% $E_t$ | ANSI Z21.10.3 |
| | > 210,000 Btu/h | ≥ 4,000 Btu/h/gal and ≥ 10 gal | 78% $E_t$ | |
| Hot water supply boilers, gas and oil | ≥ 300,000 Btu/h and < 12,500,000 Btu/h | ≥ 4,000 Btu/h/gal and < 10 gal | 80% $E_t$ | ANSI Z21.10.3 |
| Hot water supply boilers, gas | ≥ 300,000 Btu/h and < 12,500,000 Btu/h | ≥ 4,000 Btu/h/gal and ≥ 10 gal | 80% $E_t$ | |
| Hot water supply boilers, oil | > 300,000 Btu/h and < 12,500,000 Btu/h | > 4,000 Btu/h/gal and > 10 gal | 78% $E_t$ | |
| Pool heaters, gas and oil | All | — | 82% $E_t$ | ASHRAE 146 |
| Heat pump pool heaters | All | — | 4.0 COP | AHRI 1160 |
| Unfired storage tanks | All | — | Minimum insulation requirement R-12.5 (h • ft² • °F)/Btu | (none) |

**MEASURE CODE: CI-HWE-TKWH-V04-190101**

**REVIEW DEADLINE: 1/1/2022**

## 4.3.6 Ozone Laundry

### DESCRIPTION

A new ozone laundry system(s) is added-on to new or existing commercial washing machine(s) using hot water heated with natural gas. The system generates ozone ($O_3$), a naturally occurring molecule, which helps clean fabrics by chemically reacting with soils in cold water. Adding an ozone laundry system(s) will reduce the amount of chemicals, detergents, and hot water needed to wash linens. Using ozone also reduces the total amount of water consumed, saving even more in energy.

Natural gas energy savings will be achieved at the hot water heater/boiler as they will be required to produce less hot water to wash each load of laundry. The decrease in hot water usage will increase cold water usage, but overall water usage at the facility will decrease.

Electric savings can be realized through reduced washer cycle length and reduced pumping load at the boiler feeding the commercial washers. The increased usage associated with operating the ozone system should also be accounted for when determining total kWh impact. Data reviewed for this measure characterization indicated that pumping savings should be accounted for, but washer savings and ozone generator consumption are comparatively so small that they can be ignored.

The reduced washer cycle length may decrease the dampness of the clothes when they move to the dryer. This can result in shorter runtimes which result in gas and electrical savings. However, at this time, there is inconclusive evidence that energy savings are achieved from reduced dryer runtimes so the resulting dryer effects are not included in this analysis. Additionally, there would be challenges verifying that dryer savings will be achieved throughout the life of the equipment.

This incentive only applies to the following facilities with on-premise laundry operations:

- Hotels/motels
- Fitness and recreational sports centers.
- Healthcare (excluding hospitals)
- Assisted living facilities

Ozone laundry system(s) could create significant energy savings opportunities at other larger facility types with on-premise laundry operations (such as correctional facilities, universities, and staff laundries), however, the results included in this analysis are based heavily on past project data for the applicable facility types listed above and may not apply to facilities outside of this list due to variances in number of loads and average pound (lbs.)-capacity per project site. Projects at these facilities should continue to be evaluated through custom programs and the applicable facility types and the resulting analysis should be updated based on new information.

This measure was developed to be applicable to the following program types: TOS, RF.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

A new ozone laundry system(s) is added-on to new or existing commercial washing machine(s) using hot water heated with natural gas. The ozone laundry system(s) must transfer ozone into the water through:

- Venturi Injection
- Bubble Diffusion
- Additional applications may be considered upon program review and approval on a case by case basis

### DEFINITION OF BASELINE EQUIPMENT

The base case equipment is a conventional washing machine system with no ozone generator installed. The washing machines are provided hot water from a gas-fired boiler.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure equipment effective useful life (EUL) is estimated at 10 years based on typical lifetime of the ozone generator's corona discharge unit.[247]

### DEEMED MEASURE COST

The actual measure costs should be used if available. If not a deemed value of $79.84 / lbs capacity should be used[248].

### LOADSHAPE

Loadshape C53 – Flat

### COINCIDENCE FACTOR

Past project documentation and data collection is not sufficient to determine a coincidence factor for this measure. Value should continue to be studied and monitored through additional studies due to limited data points used for this determination

## Algorithm

### CALCULATION OF ENERGY SAVINGS

### ELECTRIC ENERGY SAVINGS

Electric savings can be realized through reduced washer cycle length and reduced pumping load at the boiler feeding the commercial washers. There is also an increased usage associated with operating the ozone system. Data reviewed for this measure characterization indicated that while pumping savings is significant and should be accounted for, washer savings and ozone generator consumption are negligible, counter each other out and are well within the margin of error so these are not included to simplify the characterization[249].

$$\Delta kWh_{PUMP} = HP * HP_{CONVERSION} * Hours * \%water\_savings$$

Where:

$\Delta kWh_{PUMP}$ = Electric savings from reduced pumping load

HP = Brake horsepower of boiler feed water pump;

= Actual or use 5 HP if unknown[250]

$HP_{CONVERSION}$ = Conversion from Horsepower to Kilowatt

= 0.746

Hours = Actual associated boiler feed water pump hours

[247] Aligned with other national energy efficiency programs and confirmed with national vendors

[248] Average costs per unit of capacity were generated using data collected from existing ozone laundry projects that received incentives under the Non-Residential Retrofit Demand Reduction program (NRR-DR), as well as from the Nicor Custom Incentive Program, and the Nicor Emerging Technology Program (ETP). See referenced document Table 2 and RSMeans Mechanical Cost Data, 31st Annual Edition (2008)

[249] Washer savings were reviewed but were considered negligible and not included in the algorithm (0.00082 kWh / lbs-capacity, determined through site analysis through Nicor Emerging Technology Program (ETP) and confirmed with national vendors). Note that washer savings from Nicor's site analysis are smaller than those reported in a WI Focus on Energy case study (0.23kWh/100lbs, Hampton Inn Brookfield, November 2010). Electric impact of operating ozone generator (0.0021 kWh / lbs-capacity same source as washer savings) was also considered negligible and not included in calculations. Values should continue to be studied and monitored through additional studies due to limited data points used for this determination.

[250] Assumed average horsepower for boilers connected to applicable washer

= 800 hours if unknown[251]

%water_savings = water reduction factor: how much more efficient an ozone injection washing machine is compared to a typical conventional washing machine as a rate of hot and cold water reduction.

= 25%[252]

Using defaults above:

$\Delta kWh_{PUMP}$ = 5 * 0.746 * 800 * 0.25

= 746 kWh

Default per lb capacity: = $\Delta kWh_{PUMP}$ / lb capacity

Where:

Lbs-Capacity = Average Capacity in lbs of washer

=254.38[253]

$\Delta kWh_{PUMP}$ / lb capacity = 746/254.38

= 2.93 kWh/lb-capacity

Secondary kWh Savings for Water Supply and Wastewater Treatment

The following savings should be included in the total savings for this measure, but should not be included in TRC tests to avoid double counting the economic benefit of water savings.

$\Delta kWh_{water}$ = ΔWater (gallons) / 1,000,000 * $E_{water\ total}$

Where

$E_{water\ total}$ = IL Total Water Energy Factor (kWh/Million Gallons)

=5,010[254]

Deemed savings using defaults:

$\Delta kWh_{water}$ = 464,946/1,000,000*5,010

= 2,329 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

Past project documentation and data collection is not sufficient to determine summer coincident peak demand savings for this measure. Value should continue to be studied and monitored through additional studies due to

[251] Engineered estimate provided by CLEAResult review of Nicor custom projects. Machines spent approximately 7 minutes per hour filling with water and were in operation approximately 20 hours per day. Total pump time therefore estimated as 7/60 * 20 * 365 = 852 hours, and rounded down conservatively to 800 hours.

[252] Average water reduction factors were generated using data collected from existing ozone laundry projects that received incentives under the Non-Residential Retrofit Demand Reduction program (NRR-DR). Table 6 summarizes data gathered from several NRR-DR projects, Nicor Custom projects, and Nicor ETP projects. Nicor Savings Numbers are associated with ACEE_AWE_Ozone Laundry / From Gas Savings Calculations

[253] Average lbs-capacity per project site was generated using data collected from existing ozone laundry projects that received incentives under the Non-Residential Retrofit Demand Reduction program (NRR-DR), as well as from the Nicor Custom Incentive Program, and the Nicor Emerging Technology Program (ETP). See referenced document Table 2

[254] This factor include 2571 kWh/MG for water supply based on Illinois energy intensity data from a 2012 ISAWWA study and 2439 kWh/MG for wastewater treatment based on national energy intensity use estimates. For more information please review Elevate Energy's 'IL TRM: Energy per Gallon Factor, May 2018 paper'.

limited data points used for this determination. In absence of site-specific data, the summer coincident peak demand savings should be assumed to be zero.

$\Delta kW = 0$

**NATURAL GAS SAVINGS**

$\Delta Therm = Therm_{Baseline} * \%hot\_water\_savings$

Where:

ΔTherm = Gas savings resulting from a reduction in hot water use, in therm.

$Therm_{Baseline}$ = Annual Baseline Gas Consumption

= WHE * WUtiliz * WUsage_hot

Where:

WHE = water heating energy: energy required to heat the hot water used

= 0.00885 therm/gallon[255]

WUtiliz = washer utilitzation factor: the annual pounds of clothes washed per year

= actual, if unknown use 916,150 lbs laundry[256], approximately equivalent to 13 cycles/day

WUsage_hot = hot water usage factor: how much hot water a typical conventional washing machine utilizes, normalized per pounds of clothes washed

= 1.19 gallons/lbs laundry[257]

Using defaults above:

$Therm_{Baseline}$ = 0.00885 * 916,150 * 1.19

= 9,648 therms

Default per lb capacity:

$Therm_{Baseline}$ / lb capacity = 9,648 / 254.38

= 37.9 therms / lb-capacity

%hot_water_savings = hot water reduction factor: how much more efficient an ozone injection washing machine is, compared to a typical conventional washing machine, as a rate of hot water reduction

= 81%[258]

[255] Assuming boiler efficiency is the regulated minimum efficiency (80%), per Title 20 Appliance Standard of the California Energy Regulations (October 2007). The incoming municipal water temperature is assumed to be 55 °F with an average hot water supply temperature of 140°F, based on default test procedures on clothes washers set by the Department of Energy's Office of Energy Efficiency and Renewable Energy (Federal Register, Vol. 52, No. 166). Enthalpies for these temperatures (107 btu/lbs at 140F, 23.07 btu/lbs at 55F) were obtained from ASHRAE Fundamentals

[256] Average utilization factors were generated using data collected from existing ozone laundry projects that received incentives under the NRR-DR program. Table 3 summarizes data gathered from several NRR-DR projects, Nicor Custom projects, and Nicor ETP projects

[257] Average hot water usage factors were generated using data collected from existing ozone laundry projects that received incentives under the NRR-DR program. summarizes data gathered from several NRR-DR projects:

[258] Average hot water reduction factors were generated using data collected from existing ozone laundry projects that received incentives under the Non-Residential Retrofit Demand Reduction program (NRR-DR). Table 5 summarizes data gathered from

Savings using defaults above:

ΔTherm = $Therm_{Baseline}$ * %hot_water_savings

= 9648 * 0.81

= 7,815 therms

Default per lb capacity:

ΔTherm / lb-capacity = 7815 / 254.38

= 30.7 therms / lb-capacity

### WATER IMPACT DESCRIPTIONS AND CALCULATION

The water savings calculations listed here account for the combination of hot and cold water used. Savings calculations for this measure were based on the reduction in total water use from implementing an ozone washing system to the base case. There are three main components in obtaining this value:

ΔWater (gallons) = WUsage * WUtiliz * %water_savings

Where:

ΔWater (gallons) = reduction in total water use from implementing an ozone washing system to the base case

WUsage = water usage factor: how efficiently a typical conventional washing machine utilized hot and cold water normalized per unit of clothes washed

= 2.03 gallons/lbs laundry[259]

WUtiliz = washer utilitzation factor: the annual pounds of clothes washed per year

= actual, if unknown use 916,150 lbs laundry[260], approximately equivalent to 13 cycles/day

%water_savings = water reduction factor: how much more efficient an ozone injection washing machine is compared to a typical conventional washing machine as a rate of hot and cold water reduction.

= 25%[261]

Savings using defaults above:

ΔGallons = WUsage * WUtiliz * %water_savings

= 2.03 * 916,150 * 0.25

= 464,946 gallons

Default per lb capacity:

several NRR-DR projects, Nicor Custom projects, and Nicor ETP projects. Nicor Savings Numbers are associated with ACEE_AWE_Ozone Laundry / From Gas Savings Calculations

[259] Average water usage factors were generated using data collected from existing ozone laundry projects that received incentives under the NRR-DR program.  summarizes data gathered from several NRR-DR projects

[260] Average utilization factors were generated using data collected from existing ozone laundry projects that received incentives under the NRR-DR program. Table 3 summarizes data gathered from several NRR-DR projects, Nicor Custom projects, and Nicor ETP projects

[261] Average water reduction factors were generated using data collected from existing ozone laundry projects that received incentives under the Non-Residential Retrofit Demand Reduction program (NRR-DR). Table 6 summarizes data gathered from several NRR-DR projects, Nicor Custom projects, and Nicor ETP projects. Nicor Savings Numbers are associated with ACEE_AWE_Ozone Laundry / From Gas Savings Calculations

$\Delta$ Gallons / lb-capacity = 464,946 / 254.38

= 1,828 gallons / lb-capacity

### Deemed O&M Cost Adjustment Calculation

Maintenance is required for the following components annually:[262]

- Ozone Generator: filter replacement, check valve replacement, fuse replacement, reaction chamber inspection/cleaning, reaction chamber o-ring replacement
- Air Preparation – Heat Regenerative: replacement of two medias
- Air Preparation – Oxygen Concentrators: filter replacement, pressure relief valve replacement, compressor rebuild
- Venturi Injector: check valve replacement

Maintenance is expected to cost $0.79 / lbs capacity.

### References


1 "Lodging Report", December 2008, California Travel & Tourism Commission, http://tourism.visitcalifornia.com/media/uploads/files/editor/Research/CaliforniaTourism_200812.pdf

2 "Health, United States, 2008" Table 120, U.S. Department of Health & Human Services, Centers for Disease Control & Prevention, National Center for Health Statistics, http://www.cdc.gov/nchs/data/hus/hus08.pdf#120

3 Fourth Quarter 2008 Facts and Fictures, California Department of Corrections & Rehabilitation (CDCR), http://www.cdcr.ca.gov/Divisions_Boards/Adult_Operations/docs/Fourth_Quarter_2008_Facts_and_Figures.pdf

4 Jail Profile Survey (2008), California Department of Corrections & Rehabilitation (CDCR), http://www.cdcr.ca.gov/Divisions_Boards/CSA/FSO/Docs/2008_4th_Qtr_JPS_full_report.pdf

5 DEER2011_NTGR_2012-05-16.xls from DEER Database for Energy-Efficient Resources; Version 2011 4.01

Under: DEER2011 Update Documentation linked at: DEER2011 Update Net-To-Gross table Cells: T56 and U56

6 The Benefits of Ozone in Hospitality On-Premise Laundry Operations, PG&E Emerging Technologies Program, Application Assessment Report #0802, April 2009.

7 Federal Register, Vol. 52, No. 166

8 2009 ASHRAE Handbook – Fundamentals, Thermodynamic Properties of Water at Saturation, Section 1.1 (Table 3), 2009

9 Table 2 through 6: Excel file summarizing data collected from existing ozone laundry projects that received incentives under the NRR-DR program


### Measure Code CI-HWE-OZLD-V02-190101

### Review Deadline: 1/1/2020

[262] Confirmed through communications with national vendors and available references, via an online forum (The Ozone Laundry Blog – The Importance of Maintenance)

## 4.3.7 Multifamily Central Domestic Hot Water Plants

### Description

This measure covers multifamily central domestic hot water (DHW) plants with thermal efficiencies greater than or equal to 88%. This measure is applicable to any combination of boilers and storage tanks provided the thermal efficiency of the boilers is greater than 88%. Plants providing other than solely DHW are not applicable to this measure.

This measure was developed to be applicable to the following program types: TOS, NC, ER.

If applied to other program types, the measure savings should be verified.

Note IECC 2018 is scheduled to become effective March 1, 2019 and will become baseline for all New Construction permits from that date.

### Definition of Efficient Equipment

To qualify the boiler(s) must have a Thermal Efficiency of 88% or greater and supply domestic hot water to multi-family buildings.

### Definition of Baseline Equipment

For TOS the baseline boiler is assumed to have a Thermal Efficiency of 80%.[263]

For Early Replacement the savings are calculated between existing unit and efficient unit consumption during the remaining life of the existing unit, and between new baseline unit as above and efficient unit consumption for the remainder of the measure life.

### Deemed Lifetime of Efficient Equipment

The measure life for the domestic hot water boilers is 15 years.[264]

### Deemed Measure Cost

TOS: The actual install cost should be used for the efficient case, minus the baseline cost assumption provided below:

| Capacity Range | Baseline Installed Cost per kBtuh[265] |
|---|---|
| <300kBtuh | $65 per kBTUh |
| 300 – 2500 kBtuh | $38 per kBTUh |
| >2500 kBtuh | $32 per kBTUh |

### Loadshape

N/A

### Coincidence Factor

N/A

[263] International Energy Conservation Code (IECC) 2012/2015/2018, Table C404.2, Minimum Performance of Water-Heating Equipment
[264] Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562, May 27, 2011.
[265] Baseline install costs are based on data from the "2010-2012 WO017 Ex Ante Measure Cost Study", Itron, California Public Utilities Commission. The data is provided in a file named "MCS Results Matrix – Volume I".

**Algorithm**

### CALCULATION OF ENERGY SAVINGS

### ELECTRIC ENERGY SAVINGS

There are no anticipated electrical savings from this measure.

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

### NATURAL GAS SAVINGS

Time of Sale:

ΔTherms = Hot Water Savings + Standby Loss Savings

= [(MFHH * #Units * GPD * Days/yr * ყWater * (Tout – Tin) * (1/Eff_base – 1/Eff_ee)) / 100,000] + [((SL * Hours/yr * (1/Eff_base – 1/Eff_ee)) / 100,000]

Early Replacment[266]:

ΔTherms for remaining life of existing unit (1st 5 years):

= [(MFHH * #Units * GPD * Days/yr * ყWater * (Tout – Tin) * (1/Eff_exist – 1/Eff_ee)) / 100,000] + [((SL * Hours/yr * (1/Eff_exist – 1/Eff_ee)) / 100,000]

ΔTherms for remaining measure life (next 10 years):

= [(MFHH * #Units * GPD * Days/yr * ყWater * (Tout – Tin) * (1/Eff_base – 1/Eff_ee)) / 100,000] + [((SL * Hours/yr * (1/Eff_base – 1/Eff_ee)) / 100,000]

Where:

MFHH = number of people in Multi-Family House Hold

= Actual. If unknown assume 2.1 persons/unit[267]

#Units = Number of units served by hot water boiler

= Actual

GPD = Gallons of hot water used per person per day

= Actual. If unknown assume 17.6 gallons per person per day[268]

Days/yr = 365.25

ყWater = Specific Weight of Water

= 8.33 gal/lb

Tout = tank temperature of hot water

= 125°F or custom

[266] The two equations are provided to show how savings are determined during the initial phase of the measure (existing to efficient) and the remaining phase (new baseline to efficient). In practice, the screening tools used may either require a First Year savings (using the first equation) and then a "number of years to adjustment" and "savings adjustment" input which would be the (new base to efficient savings)/(existing to efficient savings).

[267] Navigant, ComEd PY3 Multi-Family Home Energy Savings Program Evaluation Report Final, May 16, 2012.

[268] Deoreo, B., and P. Mayer. Residential End Uses of Water Study Update. Forthcoming. ©2015 Water Research Foundation. Reprinted With Permission.

Tin = Incoming water temperature from well or municiple system

= 54°F[269]

Eff_base = thermal efficiency of base unit

= 80%[270]

Eff_ee = thermal efficiency of efficient unit complying with this measure

= Actual. If unknown assume 88%

Eff_exist = thermal efficiency of existing unit

= Actual. If unknown assume 73%[271]

SL = Standby Loss[272]

= (Input rating / 800) + (110 * √Tank Volume). Note: IECC2018 does not specify standby loss performance.

Input rating = Name plate input capacity in Btuh

Tank Volume = Rated volume of the tank in gallons

Hours / yr = 8766 hours

100,000 = btu/therm

[269] US DOE Building America Program, Building America Analysis Spreadsheet (for Chicago, IL), Office of Energy Efficiency & Renewable Energy.

[270] IECC 2012/2015, Table C404.2, Minimum Performance of Water-Heating Equipment

[271] Based upon DCEO data provided 10/2014; average age adjusted efficiency of existing units replaced through the program. Efficiency age adjustment of 0.5% per year based upon NREL "Building America Performance Analysis Procedures for Existing Homes".

[272] Stand-by loss is provided in IECC 2012/2015, Table C404.2, Minimum Performance of Water-Heating Equipment

**EXAMPLES**

Time of Sale:

For example, an 88% 1000 gallon boiler with 150,000 Btuh input rating installed serving 50 units.

ΔTherms = Hot Water Savings + Standby Loss Savings

= [(MFHH * #Units * GPD * Days/yr * γWater * (Tout – Tin) * (1/Eff_base – 1/Eff_ee)) / 100,000] + [((SL * Hours/yr * (1/Eff_base – 1/Eff_ee)) / 100,000]

=[(2.1 * 50 * 17.6 * 8.33 * 365.25 * 1.0 * (125-54) * (1/0.8 – 1/0.88)) / 100000] + [((150000/800 + (110 * √1000)) * 8766 * (1/0.8 – 1/0.88)) / 100000]

= 454 + 37

= 490 therms

Early Replacement:

For example, an 88% 1000 gallon boiler with 150,000 Btuh input rating installed serving 50 units replaces a working unit with unknown efficiency.

ΔTherms for remaining life of existing unit (1st 5 years):

=[(2.1 * 50 * 17.6 * 8.33 * 365.25 * 1.0 * (125-54) * (1/0.73 – 1/0.88)) / 100000] + [((150000/800 + (110 * √1000)) * 8766 * (1/0.73 – 1/0.88)) / 100000]

= 932 + 75

= 1007 therms

ΔTherms for remaining measure life (next 10 years):

= 454 + 37 (as above)

= 490 therms

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-HWE-MDHW-V03-190101**

**REVIEW DEADLINE: 1/1/2023**

## 4.3.8 Controls for Central Domestic Hot Water

### Description

Demand control recirculation pumps seek to reduce inefficiency by combining control via temperature and demand inputs, whereby the controller will not activate the recirculation pump unless both (a) the recirculation loop return water has dropped below a prescribed temperature (e.g. 100°F) and (b) a CDHW demand is sensed as water flow through the CDHW system.

This measure was developed to be applicable to the following program types: TOS, RF, NC. If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

Re-circulating pump shall cycle on based on (a) the recirculation loop return water dropping below a prescribed temperature (e.g. 100°F) and (b) a CDHW demand is sensed as water flow through the CDHW system.

### Definition of Baseline Equipment

The base case for this measure category are existing, un-controlled Recirculation Pumps on gas-fired Central Domestic Hot Water Systems.

### Deemed Lifetime of Efficient Equipment

The effective useful life is 15 years[273].

### Deemed Measure Cost

The average cost of the demand controller circulation kit is $1,608 with an installation cost of $400 for a total measure cost of $2,008.[274]

### Loadshape

Loadshape C02 - Non-Residential Electric DHW

### Coincidence Factor

N/A

**Algorithm**

### Calculation of Energy Savings

### Electric Energy Savings

Deemed at 656 kWh[275].

[273] Benningfield Group. (2009). *PY 2009 Monitoring Report: Demand Control for Multifamily Central Domestic Hot Water.* Folsom, CA: Prepared for Southern California Gas Company, October 30, 2009.

[274] The incremental costs were averaged based on the following multi-family and dormitory building studies-

- Gas Technology Institute. (2014). *1003: Demand-based domestic hot water recirculation Public project report.* Des Plaines, IL: Prepared for Nicor Gas, January 7, 2014.
- Studies performed in multiple dormitory buildings in the California region for Southern California Gas' PREPS Program, 2012.

[275] This value is the average kWh saved per pump based on results from Multi-Family buildings studied in Nicor Gas Emerging Technology Program study and Southern California Gas' study in multiple dormitory buildings. Note this value does not reflect

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

N/A

**NATURAL GAS SAVINGS**

Gas savings for this measure can be calculated by using site specific boiler size and boiler usage information or deemed values are provided based on number of rooms for Dormitories and number of apartments for Multi-Family buildings[276].

$$\Delta Therms = Boiler\ Input\ Capacity * (t_{normal\ occ} * R_{normal\ occ} + t_{low\ occ} * R_{low\ occ}) / 100,000$$

Where:

Boiler Input Capacity = Input capacity of the Domestic Hot Water boiler in BTU/hr.

= If the facility uses the same boiler for space heat and domestic hot water, estimate the boiler input capacity for only domestic hot water loads. If this cannot be estimated, use 22.75%[277] of total boiler input capacity for Multi-Family Buildings and 16.48%[278] of total boiler input capacity for Dormitories, as domestic hot water load.

= If unknown capcity use 4,938 BTU/hr per room for Dormitories[279] and 12,493 BTU/hr per apartment for Multi-Family Buildings[280]

$t_{normal\ occ}$ = Total operating hours of domestic hot water burner, when the facility has normal occupancy. If unknown, assume 1,688 hours for Dormitories[281] and 2,089 hours for Multi-Family buildings[282].

$t_{low\ occ}$ = Total operating hours of domestic hot water burner, when the facility has low occupancy[283]. If unknown, assume 520 hours for Dormitories and 0 hours for Multi-Family buildings.

---

savings from electric units but electrical savings from gas-fired units. See 'CDHW Controls Summary Calculations.xlsx' for more information.

[276] See 'CDHW Controls Summary Calculations.xlsx' for more information.

[277] This is an average number based on Residential Energy Consumption Survey (2009) data and Commercial Building Energy Consumption Survey (2012) data compiled by U.S. Energy Information Administration, for buildings with more than 5 apartments in Illinois and Nursing Home and Assisted Living facilties in Midwest.

[278] This is based on Commercial Building Energy Consumption Survey (2012) data compiled by U.S. Energy Information Administration, for Education facilities in East North Central.

[279] This is based on studies done in multiple university dormitory buildings in the California region, for Southern California Gas' PREPS Program, 2012. It closely matches the design guidelines outlined in 2007 ASHRAE Handbook, Chapter 49: Service Water Heating, Table 7, and assumes 1 to 2 students per dorm room based on typical dorm room layouts. This source provides the source for dormitory assumptions of Boiler Input Capacity, $t_{low\ occ}$, $R_{normal\ occ}$ and $R_{low\ occ}$,

[280] This is based on studies done at Multi-Family Buildings for the Nicor Gas Emerging Technology Program by Gas Technology Institute. It closely matches the design guidelines outlined in 2007 ASHRAE Handbook, Chapter 49: Service Water Heating, Table 9, and assumes 2.1 persons per apartment as per ComEd PY3 Multi-Family Home Energy Savings Program Evaluation Report Final, May 16, 2012 by Navigant. This source provides the source for dormitory assumptions of Boiler Input Capacity, $t_{low\ occ}$, $R_{normal\ occ}$ and $R_{low\ occ}$,

[281] Based on results of studies performed in multiple university dormitory buildings in the California region, for Southern California Gas' PREPS Program, 2012.

[282] Based on results of the studies done at Multi-Family Buildings for the Nicor Gas Emerging Technology Program:

- Gas Technology Institute. (2014). *1003: Demand-based domestic hot water recirculation Public project report.* Des Plaines, IL: Prepared for Nicor Gas, January 7, 2014.

[283] Low occupancy periods for dormitory buildings can be assumed as vacation day or holiday occupancy.

$R_{normal\ occ}$ = Reduction(%) in total operating hours of domestic hot water burner, due to installed central domestic hot water controls, during normal occupancy period.

= 22.44% for Dormitories

= 24.02% for Multi-Family Buildings

$R_{low\ occ}$ = Reduction(%) in total operating hours of domestic hot water burner, due to installed central domestic hot water controls, during low occupancy period.

= 44.57% for Dormitories

= 0% for Multi-Family Buildings

Based on defaults above:

ΔTherms = 30.1 * number of rooms (for Dormitories)

= 62.7 * number of apartments (for Multi-Family buildings)

**EXAMPLE**

For example, a dormitory building has a 400,000 BTU/hr boiler whose burner operates for an estimated 580 hours during vacation months and 1,300 hours during regular occupancy months. Savings from installing central domestic hot water controls in this building are -

ΔTherms = 400,000 BTU/hr * (1,300 * 0.2244 + 580 * 0.4457) / 100,000

= 2,200.9 therms

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-HWE-CDHW-V02-180101**

**REVIEW DEADLINE: 1/1/2022**

## 4.3.9 Heat Recovery Grease Trap Filter

### Description

A heat recovery grease trap filter combines grease filters and a heat exchanger to recover heat leaving kitchen hoods. As a direct replacement for conventional hood mounted filters in commercial kitchens, they are plumbed to the domestic hot water system to provide preheating energy to incoming water.

This measure was developed to be applicable to the following program types: TOS and RF. If applied to other program types, the measure savings should be verified. For NC projects, this measure may be applicable if code requirements are otherwise satisfied.

### Definition of Efficient Equipment

Grease filters with heat exchangers carrying domestic hot water in kitchen exhaust air ducts.

### Definition of Baseline Equipment

Kitchen exhaust air duct with constant air flow[284] and no heat recovery.

### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 15 years. 285

### Deemed Measure Cost

Full installation costs, including plumbing materials, labor and any associated contols, should be used for screening purposes.

### Loadshape

Loadshape C01 - Commercial Electric Cooking

### Coincidence Factor

Summer Peak Coincidence Factor for measure is provided below for different building type[286]:

| Location | CF |
|---|---|
| Fast Food Limited Menu | 0.32 |
| Fast Food Expanded Menu | 0.41 |
| Pizza | 0.46 |
| Full Service Limited Menu | 0.51 |
| Full Service Expanded Menu | 0.36 |
| Cafeteria | 0.36 |
| Unknown | 0.40 |

[284] Savings methodology factors are for a constant speed fan.
[285] Professional judgement, consistent with expected lifetime of kitchen demand ventilation controls and other kitchen equipment.
[286] Minnesota 2012 Technical Reference Manual, Electric Food Service_v03.2.xls

**Algorithm**

## CALCULATION OF ENERGY SAVINGS

### ELECTRIC ENERGY SAVINGS

For electric hot water heaters:

ΔkWh = [(Meal/Day * HW/Meal * Days/Year) * lbs/gal * BTU/lb.°F * (ΔT/filter * Qty_Filter) * 0.00293] /($\eta_{HeaterElec}$)

Where:

Meal/Day = Average number of meals served per day. If not directly available, see Table 1.

HW/Meal = Hot water required per meal

= 3 gal/meal[287]

Days/Year = Number of days kitchen operates per year. If not directly available, see Table 1.

Lbs/gal = weight of water

= 8.3 lbs/gal

BTU/lb.°F = Specific heat of water

= 1.0

ΔT/filter = Temperature difference of domestic water across each filter

= 5.8°F/filter[288]

Qty_Filter = Number of heat recovery grease trap filters installed. If not directly available, see Table 1.

**Commercial Kitchen Load based on Building Type**

| Building Type | Meals/Day[289] | Assumed days/Year | Number of Filters[290] |
|---|---|---|---|
| Primary School | 400 | 312 | 2 |
| Secondary School | 600 | 312 | 3 |
| Quick Service Restaurant | 800 | 312 | 5 |
| Full Service Restaurant | 780 | 312 | 4 |
| Large Hotel | 780 | 356 | 4 |
| Hospital | 800 | 356 | 4 |

$\eta_{HeaterElec}$ = Efficiency of the Electric water heater.

---

287 Average dishwashing and faucet water usage taken from Chapter 8, Table 8.3.3 Normalized Annual End Uses of Water in Select Restaurants in Western United States.

288 Average value based on case studies. Northwinds Sailing, Inc. and North Shore Sustainable Energy, LLC. *Angry Trout Café Kitchen Exhaust Heat Recovery.* Minnesota Department of Commerce, Division of Energy Resources, 2012.

289 Commercial Kitchen Loads for listed buildings in U.S. Department of Energy Commercial Reference Building Models of the National Building Stock, NREL

290 Each filter is 20 X 20 inches.

= Actual. If unknown, use the table C404.2 in IECC 2012 (or IECC 2015 if through new construction) to assume values based on code estimates

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = ΔkWh/Hours * CF

Where:

Hours = Hours of operation of kitchen exhaust air fan. If not directly available use:

| Building Type | Kitchen Exhaust Fan Annual Operating Hours[291] |
|---|---|
| Primary School | 4,056 |
| Secondary School | 4,056 |
| Quick Service Restaurant | 5,616 |
| Full Service Restaurant | 5,616 |
| Large Hotel | 5,340 |
| Hospital | 3,916 |

CF = Summer Peak Coincidence Factor for measure[292]:

| Location | CF |
|---|---|
| Fast Food Limited Menu | 0.32 |
| Fast Food Expanded Menu | 0.41 |
| Pizza | 0.46 |
| Full Service Limited Menu | 0.51 |
| Full Service Expanded Menu | 0.36 |
| Cafeteria | 0.36 |
| Unknown | 0.40 |

**NATURAL GAS SAVINGS**

For natural gas hot water heaters:

ΔTherm = [(Meal/Day * HW/Meal * Days/Year) * lbs/gal * BTU/lb .°F * (ΔT/filter * Qty_Filter] / ($\eta_{HeaterGas}$ * 100,000)

Where:

$\eta_{HeaterGas}$ = Efficiency of the Gas water heater. If not directly available, use:

= Actual. If unknown, use the table C404.2 in IECC 2012 (or IECC 2015 if through new construction) to assume values based on code estimates

Other variables as above

[291] Exhaust Fan Schedules for listed buildings in U.S. Department of Energy Commercial Reference Building Models of the National Building Stock, NREL

[292] Minnesota 2012 Technical Reference Manual, Electric Food Service_v03.2.xls.

## Water and Other Non-Energy Impact Descriptions and Calculation

N/A

## Deemed O&M Cost Adjustment Calculation

O&M savings may result from reduced filter and hood cleaning frequencies. More research should be done to understand any potential savings and the associated value.

**Measure Code: CI-HWE-GRTF-V01-160601**

**Review Deadline: 1/1/2024**

## 4.3.10 DHW Boiler Tune-up

### Description

Domestic hot water (DHW) boilers provide hot water for bathrooms, kitchens, tubs and other applicances. Several commercial and industrial facilities such as multi-family buildings, lodging and restaurants have a separate hot water boiler serving DHW loads. Unlike space heating boilers, DHW boilers operate year round, which means they have a greater need to be properly maintained and tuned up.

This measure calculates savings for tuning up a DHW boiler to improve its efficiency and reduce its consumption. A boiler tune-up involves cleaning/inspecting burners, burner nozzles and combustion chambers, adjusting air flow and burner gas input to reduce stack temperatures, and checking venting and safety controls. A pre- and post- tune up combustion efficiency ticket (from combustion analyzer) can be used to confirm the improvement in boiler efficiency.

Boilers that serve only a DHW load are eligible for this measure.

This measure was developed to be applicable to the following program types: RF. If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

To qualify for this measure the facility must, as applicable, complete the tune-up requirements[293] listed below, by approved technician:

- Measure combustion efficiency using an electronic flue gas analyzer
- Adjust airflow and reduce excessive stack temperatures
- Adjust burner and gas input, manual or motorized draft control
- Check for proper venting
- Complete visual inspection of system piping and insulation
- Check safety controls
- Check adequacy of combustion air intake
- Clean fireside surfaces.
- Inspect all refractory. Patch and wash coat as required.
- Inspect gaskets on front and rear doors and replace as necessary.
- Seal and close front and rear doors properly.
- Clean low and auxiliary low water cut-off controls, then re-install using new gaskets.
- Clean plugs in control piping.
- Remove all hand hole and man hole plates. Flush boiler with water to remove loose scale and sediment.
- Replace all hand hole and man hole plates with new gaskets.
- Open feedwater tank manway, inspect and clean as required. Replace manway plate with new gasket.
- Clean burner and burner pilot.
- Check pilot electrode and adjust or replace.
- Clean air damper and blower assembly.
- Clean motor starter contacts and check operation.
- Make necessary adjustments to burner for proper combustion.
- Perform all flame safeguard and safety trip checks.
- Check all hand hole plates and man hole plates for leaks at normal operating temperatures and pressures.
- Troubleshoot any boiler system problems as requested by on-site personnel

### Definition of Baseline Equipment

The baseline condition of this measure is a boiler that has not had a tune-up within the past 36 months.

[293] Act on Energy Commercial Technical Reference Manual No. 2010-4, 9.2.2 Gas Boiler Tune-up

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The life of this measure is 3 years.[294]

**DEEMED MEASURE COST**

The cost of this measure is $0.83/MBtu/hr per tune-up.[295]

**LOADSHAPE**

N/A

**COINCIDENCE FACTOR**

N/A

## Algorithm

**CALCULATION OF ENERGY SAVINGS**

**ELECTRIC ENERGY SAVINGS**

N/A

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

N/A

**NATURAL GAS SAVINGS**

$$\Delta Therms = ((T_{out} - T_{in}) * HotWaterUse_{Gallon} * \gamma_{water} * 1 * (1/Eff_{before} - 1/Eff_{after}))/100{,}000$$

Where:

$T_{OUT}$ = Hot water storage tank temperature

= 125°F

$T_{IN}$ = Incoming water temperature from well or municipal system

= 54°F[296]

$HotWaterUse_{Gallon}$ = Estimated annual hot water consumption (gallons)

= Actual if possible to provide reasonable custom estimate. If not, the following methods are provided to develop an estimate[297]:

1. Consumption per usable storage tank capacity

   = Capacity * Consumption/cap

[294] Act on Energy Commercial Technical Reference Manual No. 2010-4, 9.2.2 Gas Boiler Tune-up
[295] Work Paper – Tune up for Boilers serving Space Heating and Process Load by Resource Solutions Group, January 2012
[296] US DOE Building America Program, Building America Analysis Spreadsheet (for Chicago, IL), Office of Energy Efficiency & Renewable Energy
[297] Methodology based on Cadmus analysis. Annual hot water usage in gallons based on CBECS (2012) and RECS (2009) consumption data of East North Central (removed outliers of 1,000 kBtuh or less) to calculate hot water usage. Annual hot water gallons per tank size gallons based on the tank sizing methodology found in ASHRAE 2011 HVAC Applications. Chapter 50 Service Water Heating. Demand assumptions (gallons per day) for each building type based on ASHRAE Chapter 50 and to LBNL White Paper. LBL-37398 Technology Data Characterizing Water Heating in Commercial Buildings: Application to End Use Forecasting. Assumes hot water heater efficiency of 80%.

Where:

Capacity = Usable capacity of hot water storage tank in gallons

= Actual

Consumption/cap = Estimate of consumption per gallon of usable tank capacity, based on building type:

| Building Type[298] | Consumption/Cap |
|---|---|
| Convenience | 528 |
| Education | 568 |
| Grocery | 528 |
| Health | 788 |
| Large Office | 511 |
| Large Retail | 528 |
| Lodging | 715 |
| Other Commercial | 341 |
| Restaurant | 622 |
| Small Office | 511 |
| Small Retail | 528 |
| Warehouse | 341 |
| Nursing | 672 |
| Multi-Family | 894 |

2. Consumption per unit area by building type

= (Area/1000) * Consumption/1,000 sq.ft.

Where:

Area = Area in sq.ft that is served by DHW boiler

= Actual

Consumption/1,000 sq.ft. = Estimate of DHW consumption per 1,000 sq.ft. based on building type:

| Building Type | Consumption/1,000 sq.ft. |
|---|---|
| Convenience | 4,594 |
| Education | 7,285 |
| Grocery | 697 |
| Health | 24,540 |
| Large Office | 1,818 |
| Large Retail | 1,354 |
| Lodging | 29,548 |
| Other Commercial | 3,941 |
| Restaurant | 44,439 |
| Small Office | 1,540 |
| Small Retail | 6,111 |
| Warehouse | 1,239 |
| Nursing | 30,503 |
| Multi-Family | 15,434 |

[298] According to CBECS 2012 "Lodging" buildings include Dormitories, Hotels, Motel or Inns and other Lodging and "Nursing" buildings include Assisted Living and Nursing Homes.

$\gamma_{water}$ = Specific weight capacity of water (lb/gal)

= 8.33 lbs/gal

1 = Specific heat of water (Btu/lb.°F)

$Eff_{before}$ = Efficiency of the boiler before tune-up

$Eff_{after}$ = Efficiency of the boiler after tune-up

100,000 = Converts Btu to therms

*Note: Contractors should select a mid-level firing rate that appropriately represents the average building operating condition over the course of the year and take readings at a consistent firing rate for pre and post tune-up.*

**EXAMPLE**

Tune up of a DHW Boiler heating a 100 gallon storage tank in a nursing home, measuring 80% AFUE prior to tune up and 82.2% AFUE after.

$$\Delta Therms = ((T_{out} - T_{in}) * HotWaterUse_{Gallon} * \gamma_{water} * 1 * (1/Eff_{before} – 1/Eff_{after}))/100{,}000$$

$$= ((125 - 54) * (100 * 672) * 8.33 * 1 * (1/0.8 – 1/0.822))/100{,}000$$

$$= 13.3 \text{ therms}$$

### WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION

N/A

### DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

### MEASURE CODE: CI-HWE-DBTU-V01-180101

### REVIEW DEADLINE: 1/1/2024

## 4.4 HVAC End Use

Many of the commercial HVAC measures use equivalent full load hours (EFLH) to calculate heating and cooling savings. The tables with these values are included in this section and referenced in each measure.

To calculate the updated EFLHs by building type and climate zone provided below, a TAC Subcommittee utilized building energy models originally developed for ComEd[299], applying some adjustments and additions for new building type models and mechanical systems. Based on comparisons with available field data from Navigant[300], the EFLH calculation was finalized by the Subcommittee to be the annual total (heating or cooling) output (in Btu) divided by the 95th percentile hourly peak output (heating or cooling) demand (in Btu/hr). This calculation keeps EFLH independent of modeled systems efficiency (which is utilized in the TRM savings calculation) and buffers EFLH value from hourly variances in the modeling that are not representative of actual buildings. See "EFLH Description 2015-02-11.doc" for further explanation.

The building characteristics can be found in the reference table named "EFLH Building Descriptions Updated 2014-11-21.xlsx".

Note where a measure installation is within a building or application that does not fit with any of the defined building types below, the user should apply custom assumptions where it is reasonable to estimate them, else the building of best fit should be utilized.

| Building Type | Heating EFLH | | | | | Model Source |
|---|---|---|---|---|---|---|
| | Zone 1 (Rockford) | Zone 2 (Chicago) | Zone 3 (Springfield) | Zone 4 (Belleville) | Zone 5 (Marion) | |
| Assembly | 1,787 | 1,831 | 1,635 | 1,089 | 1,669 | eQuest |
| Assisted Living | 1,683 | 1,646 | 1,446 | 1,063 | 1,277 | eQuest |
| College | 1,530 | 1,430 | 1,276 | 709 | 849 | eQuest |
| Convenience Store | 1,481 | 1,368 | 1,214 | 871 | 973 | eQuest |
| Elementary School | 1,781 | 1,736 | 1,531 | 1,057 | 1,283 | eQuest |
| Garage | 985 | 969 | 852 | 680 | 752 | eQuest |
| Grocery | 1,608 | 1,602 | 1,404 | 876 | 1,047 | eQuest |
| Healthcare Clinic | 1,579 | 1,620 | 1,414 | 963 | 1,019 | eQuest |
| High School | 1,845 | 1,857 | 1,666 | 1,187 | 1,388 | eQuest |
| Hospital - CAV no econ[301] | 1,764 | 1,818 | 1,549 | 1,332 | 1,512 | eQuest |
| Hospital - CAV econ[302] | 1,788 | 1,853 | 1,580 | 1,369 | 1,555 | eQuest |
| Hospital - VAV econ[303] | 731 | 695 | 522 | 314 | 340 | eQuest |
| Hospital - FCU | 1,325 | 1,512 | 1,232 | 1,448 | 1,946 | eQuest |
| Hotel/Motel | 1,761 | 1,712 | 1,544 | 1,056 | 1,290 | eQuest |
| Hotel/Motel - Common | 1,601 | 1,626 | 1,548 | 1,260 | 1,323 | eQuest |
| Hotel/Motel - Guest | 1,758 | 1,702 | 1,521 | 1,018 | 1,252 | eQuest |
| Manufacturing Facility | 1,048 | 1,013 | 939 | 567 | 634 | eQuest |
| MF - High Rise | 1,526 | 1,506 | 1,373 | 1,169 | 1,172 | eQuest |
| MF - High Rise - Common | 1,815 | 1,762 | 1,580 | 1,089 | 1,406 | eQuest |
| MF - High Rise - Residential | 1,475 | 1,464 | 1,330 | 1,152 | 1,123 | eQuest |
| MF - Mid Rise | 1,742 | 1,704 | 1,498 | 1,208 | 1,429 | OpenStudio |
| Movie Theater | 1,916 | 1,905 | 1,718 | 1,288 | 1,538 | eQuest |

[299] A full description of the ComEd model development is found in "ComEd Portfolio Modeling Report. Energy Center of Wisconsin July 30, 2010"

[300] "Estimates of Heating Equivalent Full-Load Hours (EFLH) for the Illinois Technical Reference Manual (TRM)", Memorandum, Navigant

[301] Based on model with single duct reheat system with a fixed outdoor air volume.

[302] Based on model with single duct reheat system with airside economizer controls, with constant volume zone reheat boxes and single speed fan motors.

[303] Based on model with single duct reheat system with airside economizer controls, zone VAV reheat boxes and VFD fan motors.

| Building Type | Heating EFLH | | | | | Model Source |
|---|---|---|---|---|---|---|
| | Zone 1 (Rockford) | Zone 2 (Chicago) | Zone 3 (Springfield) | Zone 4 (Belleville) | Zone 5 (Marion) | |
| Office - High Rise - CAV no econ | 2,020 | 2,050 | 1,869 | 1,252 | 1,363 | eQuest |
| Office - High Rise - CAV econ | 2,089 | 2,132 | 1,960 | 1,351 | 1,487 | eQuest |
| Office - High Rise - VAV econ | 1,528 | 1,558 | 1,284 | 759 | 846 | eQuest |
| Office - High Rise - FCU | 1,118 | 1,102 | 952 | 505 | 530 | eQuest |
| Office - Low Rise | 1,428 | 1,425 | 1,132 | 692 | 793 | eQuest |
| Office - Mid Rise | 1,683 | 1,538 | 1,319 | 1,313 | 1,206 | OpenStudio |
| Religious Building | 1,603 | 1,504 | 1,440 | 1,054 | 1,205 | eQuest |
| Restaurant | 1,350 | 1,354 | 1,216 | 920 | 1,091 | eQuest |
| Retail - Department Store | 1,123 | 979 | 852 | 697 | 689 | OpenStudio |
| Retail - Strip Mall | 1,332 | 1,233 | 1,090 | 751 | 810 | eQuest |
| Warehouse | 1,338 | 1,098 | 976 | 771 | 810 | OpenStudio |
| Unknown | 1,553 | 1,539 | 1,369 | 982 | 1,139 | n/a |

Equivalent Full Load Hours for Cooling ($EFLH_{cooling}$) :

| Building Type | Cooling EFLH | | | | | Model Source |
|---|---|---|---|---|---|---|
| | Zone 1 (Rockford) | Zone 2 (Chicago) | Zone 3 (Springfield) | Zone 4 (Belleville) | Zone 5 (Marion) | |
| Assembly | 725 | 796 | 937 | 1,183 | 932 | eQuest |
| Assisted Living | 1,475 | 1,457 | 1,773 | 2,110 | 1,811 | eQuest |
| College | 475 | 481 | 662 | 746 | 806 | eQuest |
| Convenience Store | 1,088 | 1,067 | 1,368 | 1,541 | 1,371 | eQuest |
| Elementary School | 725 | 764 | 905 | 1,142 | 956 | eQuest |
| Garage | 934 | 974 | 1,226 | 1,582 | 1,383 | eQuest |
| Grocery | 1,033 | 1,000 | 1,236 | 1,499 | 1,286 | eQuest |
| Healthcare Clinic | 1,282 | 1,305 | 1,519 | 1,767 | 1,571 | eQuest |
| High School | 675 | 721 | 840 | 1,060 | 920 | eQuest |
| Hospital - CAV no econ | 4,166 | 4,275 | 4,319 | 4,692 | 4,445 | eQuest |
| Hospital - CAV econ | 1,751 | 1,814 | 2,120 | 2,411 | 2,112 | eQuest |
| Hospital - VAV econ | 1,531 | 1,592 | 1,853 | 2,163 | 1,876 | eQuest |
| Hospital - FCU | 3,245 | 3,291 | 3,451 | 4,128 | 3,806 | eQuest |
| Hotel/Motel | 1,233 | 1,186 | 1,436 | 1,274 | 1,616 | eQuest |
| Hotel/Motel - Common | 2,186 | 2,103 | 2,344 | 1,391 | 2,651 | eQuest |
| Hotel/Motel - Guest | 1,042 | 1,019 | 1,269 | 1,216 | 1,418 | eQuest |
| Manufacturing Facility | 1,010 | 1,055 | 1,209 | 1,453 | 1,273 | eQuest |
| MF - High Rise | 921 | 845 | 1,048 | 1,779 | 1,099 | eQuest |
| MF - High Rise - Common | 914 | 839 | 1,055 | 2,893 | 1,132 | eQuest |
| MF - High Rise - Residential | 899 | 831 | 1,011 | 1,569 | 1,055 | eQuest |
| MF - Mid Rise | 694 | 747 | 927 | 983 | 961 | OpenStudio |
| Movie Theater | 876 | 745 | 1,036 | 1,178 | 1,010 | eQuest |
| Office - High Rise - CAV no econ | 1,688 | 1,708 | 1,811 | 1,865 | 1,725 | eQuest |
| Office - High Rise - CAV econ | 1,454 | 1,452 | 1,551 | 1,568 | 1,416 | eQuest |
| Office - High Rise - VAV econ | 875 | 919 | 1,057 | 1,275 | 1,077 | eQuest |
| Office - High Rise - FCU | 1,117 | 1,170 | 1,277 | 1,642 | 1,412 | eQuest |
| Office - Low Rise | 949 | 1,010 | 1,182 | 1,452 | 1,281 | eQuest |
| Office - Mid Rise | 907 | 909 | 1083 | 1057 | 1060 | OpenStudio |
| Religious Building | 861 | 817 | 967 | 1,159 | 1,067 | eQuest |

| Building Type | Cooling EFLH | | | | | Model Source |
|---|---|---|---|---|---|---|
| | Zone 1 (Rockford) | Zone 2 (Chicago) | Zone 3 (Springfield) | Zone 4 (Belleville) | Zone 5 (Marion) | |
| Restaurant | 1,074 | 1,134 | 1,279 | 1,627 | 1,325 | eQuest |
| Retail - Department Store | 884 | 885 | 1076 | 1195 | 1108 | OpenStudio |
| Retail - Strip Mall | 950 | 919 | 1,149 | 1,351 | 1,215 | eQuest |
| Warehouse | 287 | 308 | 400 | 467 | 448 | OpenStudio |
| Unknown | 1,215 | 1,221 | 1,408 | 1,670 | 1,480 | n/a |

## 4.4.1 Air Conditioner Tune-up

### Description

An air conditioning system that is operating as designed saves energy and provides adequate cooling and comfort to the conditioned space

### Definition of Efficient Equipment

In order for this characterization to apply, the efficient equipment is assumed to be a unitary or split system air conditioner least 3 tons and preapproved by program. The measure requires that a certified technician performs the following items:

- Check refrigerant charge
- Identify and repair leaks if refrigerant charge is low
- Measure and record refrigerant pressures
- Measure and record temperature drop at indoor coil
- Clean condensate drain line
- Clean outdoor coil and straighten fins
- Clean indoor and outdoor fan blades
- Clean indoor coil with spray-on cleaner and straighten fins
- Repair damaged insulation – suction line
- Change air filter
- Measure and record blower amp draw

A copy of contractor invoices that detail the work performed to identify tune-up items, as well as additional labor and parts to improve/repair air conditioner performance must be submitted to the program

### Definition of Baseline Equipment

In order for this characterization to apply, the baseline condition is assumed to be an AC system that that does not have a standing maintenance contract or a tune up within in the past 36 months.

### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 3 years.[304]

### Deemed Measure Cost

The incremental capital cost for this measure is $35[305] per ton.

### Loadshape

Loadshape C03 - Commercial Cooling

### Coincidence Factor

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [306]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

---

[304] 3 years is given for "Clean Condenser Coils – Commercial" and "Clean Evaporator Coils". DEER2014 EUL Table.

[305] Act on Energy Commercial Technical Reference Manual No. 2010-4

[306] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility's peak hour is divided by the maximum AC load during the year.

= 47.8% [307]

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

ΔkWH = (kBtu/hr) * [(1/EERbefore) – (1/EERafter)] * EFLH

Where:

kBtu/hr = capacity of the cooling equipment actually installed in kBtu per hour (1 ton of cooling capacity equals 12 kBtu/hr).

=Actual

EERbefore = Energy Efficiency Ratio[308] of the baseline equipment prior to tune-up

=Actual

EERafter = Energy Efficiency Ratio of the baseline equipment after to tune-up

=Actual

EFLH = Equivalent Full Load Hours for cooling are provided in section 4.4 HVAC End Use

Where it is not possible or appropriate to perform Test in and Test out of the equipment, the following deemed methdology can be used:

ΔkWh = (kBtu/hr) / EERbefore * EFLH * %Savings

Where:

%Savings = Deemed percent savings per Tune-Up component. These are additive if condenser cleaning, evaporator cleaning and refrigerant charge correction are performed (totals provided below)[309]

| Tune-Up Component | % savings |
|---|---|
| Condenser Cleaning | 6.10% |
| Evaporator Cleaning | 0.22% |
| Refrig. Charge Off. <=20% | 0.68% |
| Refrig. Charge Off. >20% | 8.44% |
| Combined (Refrig. Charge Off. <=20%) | 7.00% |

[307]Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year

[308] In the context of this measure Energy Efficiency Ratio (EER) refers to field-measured steady-state rate of heat energy removal (e.g., cooling capacity) by the equipment in Btuh divided by the steady-state rate of energy input to the equipment in watts. This ratio is expressed in Btuh per watt (Btuh/watt). The cooling capacity may be derived using either refrigerant or air-side measurements. The measurement is performed at the outdoor and indoor environmental conditions that are present at the time the tune-up is being performed, and should be normalized using a correction function to the AHRI 210/240 Standard test conditions. The correction function should be developed based on manufacturer's performance data. Care must be taken to ensure the unit is fully loaded and operating at or near steady-state. Generally, this requires that the outside air temperature is at least 60°F, and that the unit runs with all stages of cooling enabled for 10 to 15 minutes prior to making measurements. For more information, please see "IL TRM_Normalizing to AHRI Conditions Method".

[309] Savings estimates are determined by applying the findings from DNV-GL "Impact Evaluation of 2013-2014 HVAC3 Commercial Quality Maintenance Programs", April 2016, to simulate the inefficient condition within select eQuest models and across climate zones. The percent savings were consistent enough across building types and climate zones that it was determined appropriate to apply a single set of assumptions for all. See 'eQuest C&I Tune up Analysis.xlsx' for more information.

| Tune-Up Component | % savings |
|---|---|
| Combined (Refrig. Charge Off. >20%) | 14.76% |

For example, a 12 EER 5-ton rooftop air conditioner on a department store in Rockford receives a tune-up that includes both condenser and evaporator cleaning:

$$\Delta kWh = (5*12) / 12 * 1{,}392 * 6.32\%$$
$$= 440 \text{ kWh}$$

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$$\Delta kW_{SSP} = (kBtu/hr * (1/EERbefore - 1/EERafter)) * CF_{SSP}$$

$$\Delta kW_{PJM} = (kBtu/hr * (1/ EERbefore - 1/EERafter)) * CF_{PJM}$$

Where:

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [310]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [311]

Where it is not possible or appropriate to perform Test in and Test out of the equipment, the following deemed methdology can be used:

$$\Delta kW = (kBtu/hr) / EERbefore * \%Savings * CF$$

**NATURAL GAS ENERGY SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-HVC-ACTU-V05-180101**

**REVIEW DEADLINE: 1/1/2021**

[310] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility's peak hour is divided by the maximum AC load during the year.
[311]Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year

## 4.4.2 Space Heating Boiler Tune-up

### DESCRIPTION

This measure is for a non-residential boiler that provides space heating. The tune-up will improve boiler efficiency by cleaning and/or inspecting burners, combustion chamber, and burner nozzles. Adjust air flow and reduce excessive stack temperatures, adjust burner and gas input. Check venting, safety controls, and adequacy of combustion air intake. Combustion efficiency should be measured before and after tune-up using an electronic flue gas analyzer.

### DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the facility must, as applicable, complete the tune-up requirements[312] listed below, by approved technician:

- Measure combustion efficiency using an electronic flue gas analyzer
- Adjust airflow and reduce excessive stack temperatures
- Adjust burner and gas input, manual or motorized draft control
- Check for proper venting
- Complete visual inspection of system piping and insulation
- Check safety controls
- Check adequacy of combustion air intake
- Clean fireside surfaces.
- Inspect all refractory. Patch and wash coat as required.
- Inspect gaskets on front and rear doors and replace as necessary.
- Seal and close front and rear doors properly.
- Clean low and auxiliary low water cut-off controls, then re-install using new gaskets.
- Clean plugs in control piping.
- Remove all hand hole and man hole plates. Flush boiler with water to remove loose scale and sediment.
- Replace all hand hole and man hole plates with new gaskets.
- Open feedwater tank manway, inspect and clean as required. Replace manway plate with new gasket.
- Clean burner and burner pilot.
- Check pilot electrode and adjust or replace.
- Clean air damper and blower assembly.
- Clean motor starter contacts and check operation.
- Make necessary adjustments to burner for proper combustion.
- Perform all flame safeguard and safety trip checks.
- Check all hand hole plates and man hole plates for leaks at normal operating temperatures and pressures.
- Troubleshoot any boiler system problems as requested by on-site personnel

### DEFINITION OF BASELINE EQUIPMENT

The baseline condition of this measure is a boiler that has not had a tune-up within the past 36 months

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The life of this measure is 3 years[313]

### DEEMED MEASURE COST

The cost of this measure is $0.83/MBtu/hr[314] per tune-up

---

[312] Act on Energy Commercial Technical Reference Manual No. 2010-4, 9.2.2 Gas Boiler Tune-up
[313] Act on Energy Commercial Technical Reference Manual No. 2010-4, 9.2.2 Gas Boiler Tune-up
[314]Work Paper – Tune up for Boilers serving Space Heating and Process Load by Resource Solutions Group, January 2012

**LOADSHAPE**

N/A

**COINCIDENCE FACTOR**

N/A

**Algorithm**

**CALCULATION OF ENERGY SAVINGS**

**ELECTRIC ENERGY SAVINGS**

N/A

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

N/A

**NATURAL GAS ENERGY SAVINGS**

$$\Delta Therms = (Capacity * EFLH * (((Effbefore + Ei)/ Effbefore) - 1)) / 100{,}000$$

Where:

Capacity = Boiler gas input size (Btu/hr)

= custom

EFLH = Equivalent Full Load Hours for heating are provided in section 4.4 HVAC End Use

Effbefore = Efficiency of the boiler before the tune-up

*Note: Contractors should select a mid-level firing rate that appropriately represents the average building operating condition over the course of the heating season and take readings at a consistent firing rate for pre and post tune-up.*

Ei = Efficiency Improvement of the boiler tune-up measure

100,000 = Converts Btu to therms

**EXAMPLE**

For example, a 1050 kBtu boiler in a Chicago high rise office records an efficiency prior to tune up of 82% AFUE and a 1.8% improvement in efficiency are tune up:

$$\Delta therms = (1{,}050{,}000 * 2050 * ((0.82 + 0.018)/ 0.82 - 1)) / 100{,}000$$

$$= 473 \text{ Therms}$$

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-HVC-BLRT-V06-160601**

**REVIEW DEADLINE: 1/1/2022**

## 4.4.3 Process Boiler Tune-up

### DESCRIPTION

This measure is for a non-residential boiler for process loads. For space heating, see measure 4.4.2. The tune-up will improve boiler efficiency by cleaning and/or inspecting burners, combustion chamber, and burner nozzles. Adjust air flow and reduce excessive stack temperatures, adjust burner and gas input. Check venting, safety controls, and adequacy of combustion air intake. Combustion efficiency should be measured before and after tune-up using an electronic flue gas analyzer.

### DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the facility must, as applicable, complete the tune-up requirements[315] by approved technician, as specified below:

- Measure combustion efficiency using an electronic flue gas analyzer
- Adjust airflow and reduce excessive stack temperatures
- Adjust burner and gas input, manual or motorized draft control
- Check for proper venting
- Complete visual inspection of system piping and insulation
- Check safety controls
- Check adequacy of combustion air intake
- Clean fireside surfaces
- Inspect all refractory. Patch and wash coat as required.
- Inspect gaskets on front and rear doors and replace as necessary.
- Seal and close front and rear doors properly.
- Clean low and auxiliary low water cut-off controls, then re-install using new gaskets.
- Clean plugs in control piping.
- Remove all hand hole and man hole plates. Flush boiler with water to remove loose scale and sediment.
- Replace all hand hole and man hole plates with new gaskets.
- Open feedwater tank manway, inspect and clean as required. Replace manway plate with new gasket.
- Clean burner and burner pilot.
- Check pilot electrode and adjust or replace.
- Clean air damper and blower assembly.
- Clean motor starter contacts and check operation.
- Make necessary adjustments to burner for proper combustion.
- Perform all flame safeguard and safety trip checks.
- Check all hand hole plates and man hole plates for leaks at normal operating temperatures and pressures.
- Troubleshoot any boiler system problems as reQuested by on-site personnel

### DEFINITION OF BASELINE EQUIPMENT

The baseline condition of this measure is a boiler that has not had a tune-up within the past 36 months

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The life of this measure is 3 years[316]

### DEEMED MEASURE COST

The cost of this measure is $0.83/MBtu/hr[317] per tune-up

[315] Act on Energy Commercial Technical Reference Manual No. 2010-4, 9.2.2 Gas Boiler Tune-up
[316] Act on Energy Commercial Technical Reference Manual No. 2010-4, 9.2.2 Gas Boiler Tune-up
[317] Work Paper – Tune up for Boilers serving Space Heating and Process Load by Resource Solutions Group, January 2012

**DEEMED O&M COST ADJUSTMENTS**

N/A

**LOADSHAPE**

N/A

**COINCIDENCE FACTOR**

N/A

## Algorithm

**CALCULATION OF ENERGY SAVINGS**

**ELECTRIC ENERGY SAVINGS**

N/A

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

N/A

**NATURAL GAS ENERGY SAVINGS**

$\Delta$Therms =((Ngi * 8766*UF)/100) * (1- ($Eff_{pre}$/$Eff_{measured}$))

Where:

Ngi = Boiler gas input size (kBtu/hr)

= custom

UF = Utilization Factor

= 41.9%[318] or custom

$Eff_{pre}$ = Boiler Combustion Efficiency Before Tune-Up

= Actual

*Note: Contractors should select a mid-level firing rate that appropriately represents the average building operating condition over the course of the heating season and take readings at a consistent firing rate for pre and post tune-up.*

$Eff_{measured}$ = Boiler Combustion Efficiency After Tune-Up

= Actual

100 =converstion from kBtu to therms

8766 = hours a year

**EXAMPLE**

For example, a 80% 1050 kBtu boiler is tuned-up resulting in final efficiency of 81.3%:

$\Delta$therms =((1050 * 8766*0.419)/100) * (1- (0.80/0.813))

= 617 therms

[318] Work Paper – Tune up for Boilers serving Space Heating and Process Load by Resource Solutions Group, January 2012

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-HVC-PBTU-V05-160601**

**REVIEW DEADLINE: 1/1/2022**

## 4.4.4 Boiler Lockout/Reset Controls

**DESCRIPTION**

This measure relates to improving combustion efficiency by adding controls to non-residential building heating boilers to vary the boiler entering water temperature relative to heating load as a function of the outdoor air temperature to save energy. Energy is saved by increasing the temperature difference between the water temperature entering the boiler in the boiler's heat exchanger and the boiler's burner flame temperature. The flame temperature remains the same while the water temperature leaving the boiler decreases with the decrease in heating load due to an increase in outside air temperature. A lockout temperature is also set to prevent the boiler from turning on when it is above a certain temperature outdoors.

This measure was developed to be applicable to the following program types: RF. If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

Natural gas customer adding boiler reset controls capable of resetting the boiler supply water temperature in an inverse linear fashion with outdoor air temperature. Boiler lockout temperatures should be set to 55 °F at this time as well, to turn the boiler off when the temperature goes above a certain setpoint.

**DEFINITION OF BASELINE EQUIPMENT**

Existing boiler without boiler reset controls, any size with constant hot water flow.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The life of this measure is 20 years[319]

**DEEMED MEASURE COST**

The cost of this measure is $612[320]

**LOADSHAPE**

N/A

**COINCIDENCE FACTOR**

N/A

### Algorithm

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

N/A

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

N/A

[319]CLEAResultreferences the Brooklyn Union Gas Company, High Efficiency Heating and Water and Controls, Gas Energy Efficiency Program Implementation Plan.
[320] Nexant. Questar DSM Market Characterization Report. August 9, 2006.

**NATURAL GAS ENERGY SAVINGS**

ΔTherms = Binput * SF * EFLH /( 100)

Where:

Binput = Boiler Input Capacity (kBtu/hr)

= custom

SF = Savings factor

= 8%[321] or custom

EFLH = Equivalent Full Load Hours for heating are provided in section 4.4 HVAC End Use

100 = conversion from kBtu to therms

**EXAMPLE**

For example, a 800 kBtu/hr boiler at a restaurant in Rockford, IL

ΔTherms = 800 * 0.08 * 1,350 / (100)

= 864 Therms

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-HVC-BLRC-V03-150601**

**REVIEW DEADLINE: 1/1/2021**

[321] Savings factor is the estimate of annual gas consumption that is saved due to adding boiler reset controls. The CLEAResultuses a boiler tuneup savings value derived from Xcel Energy "DSM Biennial Plan-Technical Assumptions," Colorado. Focus on Energy uses 8%, citing multiple sources. Vermont Energy Investment Corporation's boiler reset savings estimates for custom projects further indicate 8% savings estimate is better reflection of actual expected savings.

## 4.4.5 Condensing Unit Heaters

**DESCRIPTION**

This measure applies to a gas fired condensing unit heater installed in a commercial application.

This measure was developed to be applicable to the following program types: TOS, NC. If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

In order for this characterization to apply, the efficient equipment is assumed to be a condensing unit heater up to 300 MBH with a Thermal Efficiency > 90% and the heater must be vented, and condensate drained per manufacturer specifications. The unit must be replacing existing natural gas equipment.

**DEFINITION OF BASELINE EQUIPMENT**

In order for this characterization to apply, the baseline condition is assumed to be a non-condensing natural gas unit heater at end of life.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected measure life is assumed to be 12 years[322]

**DEEMED MEASURE COST**

The incremental capital cost for a unit heater is $676[323]

**LOADSHAPE**

N/A

**COINCIDENCE FACTOR**

N/A

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

N/A

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

N/A

**NATURAL GAS ENERGY SAVINGS**

The annual natural gas energy savings from this measure is a deemed value equaling 266 Therms.

[322] DEER 2008

[323] ENERGY STAR and CEE do not currently provide calculators for this type of equipment therefore deemed values from Nicor Gas were used. Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562, May 27, 2011

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-HVC-CUHT-V01-190101**

**REVIEW DEADLINE: 1/1/2022**

## 4.4.6 Electric Chiller

### DESCRIPTION

This measure relates to the installation of a new electric chiller meeting the efficiency standards presented below. This measure could relate to the replacement of an existing unit at the end of its useful life, or the installation of a new system in an existing building (i.e. time of sale). Only single-chiller applications should be assessed with this methodology. The characterization is not suited for multiple chillers projects or chillers equipped with variable speed drives (VSDs).

This measure was developed to be applicable to the following program types: TOS, NC. If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the efficient equipment is assumed to exceed the efficiency requirements defined by the program.

### DEFINITION OF BASELINE EQUIPMENT

In order for this characterization to apply, the baseline equipment is assumed to meet the efficiency requirements within Table 403.2.3(7) of either the 2012 or the 2015 IECC (applicable from 01/01/2016), depending on the IECC in effect on the date of the building permit (if unknown assume IECC 2015).

Note IECC 2018 is scheduled to become effective March 1, 2019 and will become baseline for all New Construction permits from that date.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 23 years [324].

### DEEMED MEASURE COST

The incremental capital cost for this measure is provided below.

| Equipment Type | Size Category | Incremental Cost ($/ton) |
|---|---|---|
| Air cooled, electrically operated | All capacities | $127/ton [325] |
| Water cooled, electrically operated, positive displacement (reciprocating) | All capacities | $22/ton [326] |
| Water cooled, electrically operated, positive displacement (rotary screw and scroll) | < 150 tons | $351/ton [327] |
| | >= 150 tons and < 300 tons | $127/ton |
| | >= 300 tons | $87/ton |

### LOADSHAPE

Loadshape C03 - Commercial Cooling

---

[324] As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.
(http://deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls)

[325] 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Cost Values and Summary Documentation", California Public Utilities Commission, December 16, 2008. Calculated as the simple average of screw and reciprocating air-cooled chiller incremental costs from DEER2008. This assumes that baseline shift from IECC 2012 to IECC 2015 carries the same incremental costs. Values should be verified during evaluation

[326] 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Cost Values and Summary Documentation"

[327] Incremental costs for water-cooled, electrically operated, positive displacement (rotary screw and scroll) from the "2010-2012 WO017 Ex Ante Measure Cost Study", Itron, May 2014 (submitted to CPUC). The data is provided in a file named "MCS Results Matrix – Volume I".

### COINCIDENCE FACTOR

The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the *average* savings over the defined summer peak period, and is presented so that savings can be bid into PJM's Forward Capacity Market. Both values provided are based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren.

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [328]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [329]

**Algorithm**

### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

ΔkWH = TONS * ((IPLVbase) – (IPLVee)) * EFLH

Where:

TONS = chiller nominal cooling capacity in tons (note: 1 ton = 12,000 Btu/hr)

= Actual installed

IPLVbase = efficiency of baseline equipment expressed as Integrated Part Load Value(kW/ton). Chiller units are dependent on chiller type. See Chiller Units, Convertion Values and Baseline Efficiency Values by Chiller Type and Capacity in the Reference Tables section.

IPLVee[330] = efficiency of high efficiency equipment expressed as Integrated Part Load Value (kW/ton)[331]

= Actual installed

EFLH = Equivalent Full Load Hours for cooling are provided in section 4.4 HVAC End Use.

> For example, a 100 ton air-cooled electrically operated chiller with IPLV of 14 EER (0.86 kW/ton) and baseline EER of 12.5 (0.96 kW/ton) ,in a low-rise office building in Rockford with a building permit dated on 1/1/2015 would save:
>
> ΔkWH = 100 * ((0.96) – (0.86)) * 949
>
> = 9,490 kWh

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta kW_{SSP}$ = TONS * ((PEbase) – (PEee)) * $CF_{SSP}$

328 Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility's peak hour is divided by the maximum AC load during the year.

329 Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year

330 Integrated Part Load Value is a seasonal average efficiency rating calculated in accordance with ARI Standard 550/590. It may be calculated using any measure of efficiency (EER, kW/ton, COP), but for consistency with IECC 2012, it is expressed in terms of IPLV here.

331 Can determine IPLV from standard testing or looking at engineering specs for design conditions. Standard data is available from AHRI online Certification Directory.

$\Delta kW_{PJM}$ = TONS * ((PEbase) – (PEee)) * $CF_{PJM}$

Where:

PEbase = Peak efficiency of baseline equipment expressed as Full Load (kW/ton)

PEee = Peak efficiency of high efficiency equipment expressed as Full Load (kW/ton)

= Actual installed

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3%

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8%

For example, a 100 ton air-cooled electrically operated chiller with a peak efficiency of 1.05 kW/ton and a baseline peak efficiency of 1.2 kW/ton would save:

$\Delta kW_{SSP}$ = 100 * (1.2 – 1.05) * 0.913

= 13.7 kW

**NATURAL GAS ENERGY SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**REFERENCE TABLES**

Chillers Ratings- Chillers are rated with different units depending on equipment type as shown below

| Equipment Type | Unit |
|---|---|
| Air cooled, electrically operated | EER |
| Water cooled, electrically operated, positive displacement (reciprocating) | kW/ton |
| Water cooled, electrically operated, positive displacement (rotary screw and scroll) | kW/ton |

In order to convert chiller equipment ratings to IPLV the following relationships are provided

kW/ton = 12 / EER

kW/ton = 12 / (COP x 3.412)

COP = EER / 3.412

COP = 12 / (kW/ton) / 3.412

EER = 12 / kW/ton

EER = COP x 3.412

2012 IECC Baseline Efficiency Values by Chiller Type and Capacity

**TABLE C403.2.3(7)**
**MINIMUM EFFICIENCY REQUIREMENTS:**
**WATER CHILLING PACKAGES[a]**

| EQUIPMENT TYPE | SIZE CATEGORY | UNITS | BEFORE 1/1/2010 | | AS OF 1/1/2010[b] | | | | TEST PROCEDURE[c] |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | PATH A | | PATH B | | |
| | | | FULL LOAD | IPLV | FULL LOAD | IPLV | FULL LOAD | IPLV | |
| Air-cooled chillers | < 150 tons | EER | ≥ 9.562 | ≥ 10.416 | ≥ 9.562 | ≥ 12.500 | NA | NA | AHRI 550/590 |
| | ≥ 150 tons | EER | | | ≥ 9.562 | ≥ 12.750 | NA | NA | |
| Air cooled without condenser, electrical operated | All capacities | EER | ≥ 10.586 | ≥ 11.782 | Air-cooled chillers without condensers shall be rated with matching condensers and comply with the air-cooled chiller efficiency requirements | | | | |
| Water cooled, electrically operated, reciprocating | All capacities | kW/ton | ≤ 0.837 | ≤ 0.696 | Reciprocating units shall comply with water cooled positive displacement efficiency requirements | | | | |
| Water cooled, electrically operated, positive displacement | < 75 tons | kW/ton | ≤ 0.790 | ≤ 0.676 | ≤ 0.780 | ≤ 0.630 | ≤ 0.800 | ≤ 0.600 | |
| | ≥ 75 tons and < 150 tons | kW/ton | | | ≤ 0.775 | ≤ 0.615 | ≤ 0.790 | ≤ 0.586 | |
| | ≥ 150 tons and < 300 tons | kW/ton | ≤ 0.717 | ≤ 0.627 | ≤ 0.680 | ≤ 0.580 | ≤ 0.718 | ≤ 0.540 | |
| | ≥ 300 tons | kW/ton | ≤ 0.639 | ≤ 0.571 | ≤ 0.620 | ≤ 0.540 | ≤ 0.639 | ≤ 0.490 | |
| Water cooled, electrically operated, centrifugal | < 150 tons | kW/ton | ≤ 0.703 | ≤ 0.669 | ≤ 0.634 | ≤ 0.596 | ≤ 0.639 | ≤ 0.450 | |
| | ≥ 150 tons and < 300 tons | kW/ton | ≤ 0.634 | ≤ 0.596 | | | | | |
| | ≥ 300 tons and < 600 tons | kW/ton | ≤ 0.576 | ≤ 0.549 | ≤ 0.576 | ≤ 0.549 | ≤ 0.600 | ≤ 0.400 | |
| | ≥ 600 tons | kW/ton | ≤ 0.576 | ≤ 0.549 | ≤ 0.570 | ≤ 0.539 | ≤ 0.590 | ≤ 0.400 | |
| Air cooled, absorption single effect | All capacities | COP | ≥ 0.600 | NR | ≥ 0.600 | NR | NA | NA | AHRI 560 |
| Water cooled, absorption single effect | All capacities | COP | ≥ 0.700 | NR | ≥ 0.700 | NR | NA | NA | |
| Absorption double effect, indirect fired | All capacities | COP | ≥ 1.000 | ≥ 1.050 | ≥ 1.000 | ≥ 1.050 | NA | NA | |
| Absorption double effect, direct fired | All capacities | COP | ≥ 1.000 | ≥ 1.000 | ≥ 1.000 | ≥ 1.000 | NA | NA | |

For SI: 1 ton = 3517 W, 1 British thermal unit per hour = 0.2931 W, °C = [(°F) - 32]/1.8.
NA = Not applicable, not to be used for compliance; NR = No requirement.

a. The centrifugal chiller equipment requirements, after adjustment in accordance with Section C403.2.3.1 or Section C403.2.3.2, do not apply to chillers used in low-temperature applications where the design leaving fluid temperature is less than 36°F. The requirements do not apply to positive displacement chillers with leaving fluid temperatures less than or equal to 32°F. The requirements do not apply to absorption chillers with design leaving fluid temperatures less than 40°F.

b. Compliance with this standard can be obtained by meeting the minimum requirements of Path A or B. However, both the full load and IPLV shall be met to fulfill the requirements of Path A or B.

c. Chapter 6 of the referenced standard contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.

2015 IECC Baseline Efficiency Values by Chiller Type and Capacity

**TABLE C403.2.3(7)**
**WATER CHILLING PACKAGES – EFFICIENCY REQUIREMENTS[a, b, d]**

| EQUIPMENT TYPE | SIZE CATEGORY | UNITS | BEFORE 1/1/2015 | | AS OF 1/1/2015 | | TEST PROCEDURE[c] |
|---|---|---|---|---|---|---|---|
| | | | Path A | Path B | Path A | Path B | |
| Air-cooled chillers | < 150 Tons | EER (Btu/W) | ≥ 9.562 FL | NA[c] | ≥ 10.100 FL | ≥ 9.700 FL | AHRI 550/590 |
| | | | ≥ 12.500 IPLV | | ≥ 13.700 IPLV | ≥ 15.800 IPLV | |
| | ≥ 150 Tons | | ≥ 9.562 FL | NA[c] | ≥ 10.100 FL | ≥ 9.700 FL | |
| | | | ≥ 12.500 IPLV | | ≥ 14.000 IPLV | ≥ 16.100 IPLV | |
| Air cooled without condenser, electrically operated | All capacities | EER (Btu/W) | Air-cooled chillers without condenser shall be rated with matching condensers and complying with air-cooled chiller efficiency requirements. | | | | |
| Water cooled, electrically operated positive displacement | < 75 Tons | kW/ton | ≤ 0.780 FL | ≤ 0.800 FL | ≤ 0.750 FL | ≤ 0.780 FL | |
| | | | ≤ 0.630 IPLV | ≤ 0.600 IPLV | ≤ 0.600 IPLV | ≤ 0.500 IPLV | |
| | ≥ 75 tons and < 150 tons | | ≤ 0.775 FL | ≤ 0.790 FL | ≤ 0.720 FL | ≤ 0.750 FL | |
| | | | ≤ 0.615 IPLV | ≤ 0.586 IPLV | ≤ 0.560 IPLV | ≤ 0.490 IPLV | |
| | ≥ 150 tons and < 300 tons | | ≤ 0.680 FL | ≤ 0.718 FL | ≤ 0.660 FL | ≤ 0.680 FL | |
| | | | ≤ 0.580 IPLV | ≤ 0.540 IPLV | ≤ 0.540 IPLV | ≤ 0.440 IPLV | |
| | ≥ 300 tons and < 600 tons | | ≤ 0.620 FL | ≤ 0.639 FL | ≤ 0.610 FL | ≤ 0.625 FL | |
| | | | ≤ 0.540 IPLV | ≤ 0.490 IPLV | ≤ 0.520 IPLV | ≤ 0.410 IPLV | |
| | ≥ 600 tons | | ≤ 0.620 FL | ≤ 0.639 FL | ≤ 0.560 FL | ≤ 0.585 FL | |
| | | | ≤ 0.540 IPLV | ≤ 0.490 IPLV | ≤ 0.500 IPLV | ≤ 0.380 IPLV | |
| Water cooled, electrically operated centrifugal | < 150 Tons | kW/ton | ≤ 0.634 FL | ≤ 0.639 FL | ≤ 0.610 FL | ≤ 0.695 FL | |
| | | | ≤ 0.596 IPLV | ≤ 0.450 IPLV | ≤ 0.550 IPLV | ≤ 0.440 IPLV | |
| | ≥ 150 tons and < 300 tons | | ≤ 0.634 FL | ≤ 0.639 FL | ≤ 0.610 FL | ≤ 0.635 FL | |
| | | | ≤ 0.596 IPLV | ≤ 0.450 IPLV | ≤ 0.550 IPLV | ≤ 0.400 IPLV | |
| | ≥ 300 tons and < 400 tons | | ≤ 0.576 FL | ≤ 0.600 FL | ≤ 0.560 FL | ≤ 0.595 FL | |
| | | | ≤ 0.549 IPLV | ≤ 0.400 IPLV | ≤ 0.520 IPLV | ≤ 0.390 IPLV | |
| | ≥ 400 tons and < 600 tons | | ≤ 0.576 FL | ≤ 0.600 FL | ≤ 0.560 FL | ≤ 0.585 FL | |
| | | | ≤ 0.549 IPLV | ≤ 0.400 IPLV | ≤ 0.500 IPLV | ≤ 0.380 IPLV | |
| | ≥ 600 Tons | | ≤ 0.570 FL | ≤ 0.590 FL | ≤ 0.560 FL | ≤ 0.585 FL | |
| | | | ≤ 0.539 IPLV | ≤ 0.400 IPLV | ≤ 0.500 IPLV | ≤ 0.380 IPLV | |
| Air cooled, absorption, single effect | All capacities | COP | ≥ 0.600 FL | NA[c] | ≥ 0.600 FL | NA[c] | AHRI 560 |
| Water cooled absorption, single effect | All capacities | COP | ≥ 0.700 FL | NA[c] | ≥ 0.700 FL | NA[c] | |
| Absorption, double effect, indirect fired | All capacities | COP | ≥ 1.000 FL | NA[c] | ≥ 1.000 FL | NA[c] | |
| | | | ≥ 1.050 IPLV | | ≥ 1.050 IPLV | | |
| Absorption double effect direct fired | All capacities | COP | ≥ 1.000 FL | NA[c] | ≥ 1.000 FL | NA[c] | |
| | | | ≥ 1.000 IPLV | | ≥ 1.050 IPLV | | |

a. The requirements for centrifugal chiller shall be adjusted for nonstandard rating conditions in accordance with Section C403.2.3.1 and are only applicable for the range of conditions listed in Section C403.2.3.1. The requirements for air-cooled, water-cooled positive displacement and absorption chillers are at standard rating conditions defined in the reference test procedure.

b. Both the full-load and IPLV requirements shall be met or exceeded to comply with this standard. Where there is a Path B, compliance can be with either Path A or Path B for any application.

c. NA means the requirements are not applicable for Path B and only Path A can be used for compliance.

d. FL represents the full-load performance requirements and IPLV the part-load performance requirements.

2018 IECC Baseline Efficiency Values by Chiller Type and Capacity

TABLE C403.3.2(7)
WATER CHILLING PACKAGES — EFFICIENCY REQUIREMENTS[a, b, d]

| EQUIPMENT TYPE | SIZE CATEGORY | UNITS | BEFORE 1/1/2015 | | AS OF 1/1/2015 | | TEST PROCEDURE[e] |
|---|---|---|---|---|---|---|---|
| | | | Path A | Path B | Path A | Path B | |
| Air-cooled chillers | < 150 Tons | EER (Btu/W) | ≥ 9.562 FL | NA[c] | ≥ 10.100 FL | ≥ 9.700 FL | AHRI 550/590 |
| | | | ≥ 12.500 IPLV | | ≥ 13.700 IPLV | ≥ 15,800 IPLV | |
| | ≥ 150 Tons | | ≥ 9.562 FL | NA[c] | ≥ 10.100 FL | ≥ 9.700 FL | |
| | | | ≥ 12.500 IPLV | | ≥ 14.000 IPLV | ≥ 16.100 IPLV | |
| Air cooled without condenser, electrically operated | All capacities | EER (Btu/W) | Air-cooled chillers without condenser shall be rated with matching condensers and complying with air-cooled chiller efficiency requirements. | | | | |
| Water cooled, electrically operated positive displacement | < 75 Tons | kW/ton | ≤ 0.780 FL | ≤ 0.800 FL | ≤ 0.750 FL | ≤ 0.780 FL | |
| | | | ≤ 0.630 IPLV | ≤ 0.600 IPLV | ≤ 0.600 IPLV | ≤ 0.500 IPLV | |
| | ≥ 75 tons and < 150 tons | | ≤ 0.775 FL | ≤ 0.790 FL | ≤ 0.720 FL | ≤ 0.750 FL | |
| | | | ≤ 0.615 IPLV | ≤ 0.586 IPLV | ≤ 0.560 IPLV | ≤ 0.490 IPLV | |
| | ≥ 150 tons and < 300 tons | | ≥ 0.680 FL | ≥ 0.718 FL | ≥ 0.660 FL | ≥ 0.680 FL | |
| | | | ≥ 0.580 IPLV | ≥ 0.540 IPLV | ≥ 0.540 IPLV | ≥ 0.440 IPLV | |
| | ≥ 300 tons and < 600 tons | | ≤ 0.620 FL | ≤ 0.639 FL | ≤ 0.610 FL | ≤ 0.625 FL | |
| | | | ≤ 0.540 IPLV | ≤ 0.490 IPLV | ≤ 0.520 IPLV | ≤ 0.410 IPLV | |
| | ≥ 600 tons | | ≤ 0.620 FL | ≤ 0.639 FL | ≤ 0.560 FL | ≤ 0.585 FL | |
| | | | ≤ 0.540 IPLV | ≤ 0.490 IPLV | ≤ 0.500 IPLV | ≤ 0.380 IPLV | |
| Water cooled, electrically operated centrifugal | < 150 Tons | kW/ton | ≤ 0.634 FL | ≤ 0.639 FL | ≤ 0.610 FL | ≤ 0.695 FL | |
| | | | ≤ 0.596 IPLV | ≤ 0.450 IPLV | ≤ 0.550 IPLV | ≤ 0.440 IPLV | |
| | ≥ 150 tons and < 300 tons | | ≤ 0.634 FL | ≤ 0.639 FL | ≤ 0.610 FL | ≤ 0.635 FL | |
| | | | ≤ 0.596 IPLV | ≤ 0.450 IPLV | ≤ 0.550 IPLV | ≤ 0.400 IPLV | |
| | ≥ 300 tons and < 400 tons | | ≤ 0.576 FL | ≤ 0.600 FL | ≤ 0.560 FL | ≤ 0.595 FL | |
| | | | ≤ 0.549 IPLV | ≤ 0.400 IPLV | ≤ 0.520 IPLV | ≤ 0.390 IPLV | |
| | ≥ 400 tons and < 600 tons | | ≤ 0.576 FL | ≤ 0.600 FL | ≤ 0.560 FL | ≤ 0.585 FL | |
| | | | ≤ 0.549 IPLV | ≤ 0.400 IPLV | ≤ 0.500 IPLV | ≤ 0.380 IPLV | |
| | ≥ 600 Tons | | ≤ 0.570 FL | ≤ 0.590 FL | ≤ 0.560 FL | ≤ 0.585 FL | |
| | | | ≤ 0.539 IPLV | ≤ 0.400 IPLV | ≤ 0.500 IPLV | ≤ 0.380 IPLV | |
| Air cooled, absorption, single effect | All capacities | COP | ≥ 0.600 FL | NA[c] | ≥ 0.600 FL | NA[c] | AHRI 560 |
| Water cooled absorption, single effect | All capacities | COP | ≥ 0.700 FL | NA[c] | ≥ 0.700 FL | NA[c] | |
| Absorption, double effect, indirect fired | All capacities | COP | ≥ 1.000 FL | NA[c] | ≥ 1.000 FL | NA[c] | |
| | | | ≥ 1.050 IPLV | | ≥ 1.050 IPLV | | |
| Absorption double effect direct fired | All capacities | COP | ≥ 1.000 FL | NA[c] | ≥ 1.000 FL | NA[c] | |
| | | | ≥ 1.000 IPLV | | ≥ 1.050 IPLV | | |

a. The requirements for centrifugal chiller shall be adjusted for nonstandard rating conditions in accordance with Section C403.3.2.1 and are only applicable for the range of conditions listed in Section C403.3.2.1. The requirements for air-cooled, water-cooled positive displacement and absorption chillers are at standard rating conditions defined in the reference test procedure.

b. Both the full-load and IPLV requirements shall be met or exceeded to comply with this standard. Where there is a Path B, compliance can be with either Path A or Path B for any application.

c. NA means the requirements are not applicable for Path B and only Path A can be used for compliance.

d. FL represents the full-load performance requirements and IPLV the part-load performance requirements.

**MEASURE CODE: CI-HVC-CHIL-V06-190101**

**REVIEW DEADLINE: 1/1/2022**

## 4.4.7 ENERGY STAR and CEE Super Efficient Room Air Conditioner

### DESCRIPTION

This measure relates to the purchase and installation of a room air conditioning unit that meets either the ENERGY STAR or CEE Super Efficient minimum qualifying efficiency specifications, in place of a baseline unit meeting minimum Federal Standard efficiency ratings presented below:[332]

<table>
<tr><th>Product Class (Btu/H)</th><th>Federal Standard CEER, with louvered sides</th><th>Federal Standard CEER, without louvered sides</th><th>ENERGY STAR CEER, with louvered sides</th><th>ENERGY STAR CEER, without louvered sides</th><th>CEE Super Efficient CEER</th></tr>
<tr><td>< 8,000</td><td>11.0</td><td>10.0</td><td>12.1</td><td>11.0</td><td>12.7</td></tr>
<tr><td>8,000 to 10,999</td><td rowspan="2">10.9</td><td>9.6</td><td rowspan="2">12.0</td><td>10.6</td><td rowspan="2">12.5</td></tr>
<tr><td>11,000 to 13,999</td><td>9.5</td><td>10.5</td></tr>
<tr><td>14,000 to 19,999</td><td>10.7</td><td>9.3</td><td>11.8</td><td>10.2</td><td>12.3</td></tr>
<tr><td>20,000 to 27,999</td><td>9.4</td><td rowspan="2">9.4</td><td>10.3</td><td rowspan="2">10.3</td><td>10.8</td></tr>
<tr><td>>= 28,000</td><td>9.0</td><td>9.9</td><td>10.4</td></tr>
</table>

| Casement | Federal Standard (CEER) | ENERGY STAR (CEER) |
|---|---|---|
| Casement-only | 9.5 | 10.5 |
| Casement-slider | 10.4 | 11.4 |

| Reverse Cycle - Product Class (Btu/H) | Federal Standard CEER, with louvered sides | Federal Standard CEER, without louvered sides | ENERGY STAR CEER, with louvered sides | ENERGY STAR CEER, without louvered sides |
|---|---|---|---|---|
| < 14,000 | N/A | 9.3 | N/A | 10.2 |
| >= 14,000 | N/A | 8.7 | N/A | 9.6 |
| < 20,000 | 9.8 | N/A | 10.8 | N/A |
| >= 20,000 | 9.3 | N/A | 10.2 | N/A |

This measure was developed to be applicable to the following program types: TOS. If applied to other program types, the measure savings should be verified.

[332] Federal Baselines defined by Code of Federal Regulations §430.32(d). ENERGY STAR specification defined by Version 4.0 Room Air Conditioners. CEE specification defined by Room Air Conditioner Specification effective January 31, 2017.
Side louvers that extend from a room air conditioner model in order to position the unit in a window. A model without louvered sides is placed in a built-in wall sleeve and are commonly referred to as "through-the-wall" or "built-in" models.
Casement-only refers to a room air conditioner designed for mounting in a casement window of a specific size.
Casement-slider refers to a room air conditioner with an encased assembly designed for mounting in a sliding or casement window of a specific size.
Reverse cycle refers to the heating function found in certain room air conditioner models.

### Definition of Efficient Equipment

To qualify for this measure the new room air conditioning unit must meet the ENERGY STAR efficiency standards presented above.

### Definition of Baseline Equipment

The baseline assumption is a new room air conditioning unit that meets the current minimum federal efficiency standards presented above.

### Deemed Lifetime of Efficient Equipment

The measure life is assumed to be 9 years.[333]

### Deemed Measure Cost

The incremental cost for this measure is assumed to be $40 for an ENERGY STAR unit and $80 for a CEE Super Efficient unit.[334]

### Loadshape

Loadshape C03 - Commercial Cooling

### Coincidence Factor

The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the *average* savings over the defined summer peak period, and is presented so that savings can be bid into PJM's Forward Capacity Market. Both values provided are based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren.

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [335]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [336]

## Algorithm

### Calculation of Savings

### Energy Savings

$$\Delta kWh = (FLH_{RoomAC} * Btu/H * (1/CEERbase - 1/CEERee))/1000$$

Where:

$FLH_{RoomAC}$ = Full Load Hours of room air conditioning unit

[333] Energy Star Room Air Conditioner Savings Calculator, Life Cycle Cost Estimate for ENERGY STAR Qualified Room Air Conditioners

[334] Based on field study conducted by Efficiency Vermont

[335] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility's peak hour is divided by the maximum AC load during the year.

[336] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year

= dependent on location:[337]

| Zone | FLHRoomAC |
|---|---|
| 1 (Rockford) | 253 |
| 2-(Chicago) | 254 |
| 3 (Springfield) | 310 |
| 4-(Belleville) | 391 |
| 5-(Marion) | 254 |

Btu/H = Size of unit

= Actual. If unknown assume 8500 Btu/hr [338]

CEERbase = Combined Energy Efficiency Ratio of baseline unit

= As provided in tables above

CEERee = Combined Energy Efficiency Ratio of ENERGY STAR or CEE Super Efficient unit

= Actual. If unknown assume minimum qualifying standard as provided in tables above

For example for an 8,500 Btu/H capacity ENERGY STAR unit, with louvered sides, in Rockford:

$\Delta kWH_{ENERGY\ STAR}$ = (253 * 8500 * (1/10.9 – 1/12.0)) / 1000

= 18.1 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = Btu/H * ((1/CEERbase - 1/CEERee))/1000) * CF

Where:

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [339]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8%[340]

Other variable as defined above

For example for an 8,500 Btu/H capacity ENERGY STAR unit, with louvered sides, in Rockford during system peak

$\Delta kW_{ENERGY\ STAR}$ = (8500 * (1/10.9 – 1/12.0)) / 1000 * 0.913

= 0.065 kW

[337] Full load hours for room AC is significantly lower than for central AC. The average ratio of FLH for Room AC (provided in RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008)) to FLH for Central Cooling for the same location (detailed in the Energy Star Room Air Conditioner Savings Calculator) is 31%. This ratio has been applied to the FLH from the unitary and split system air conditioning measure.

[338] Based on maximum capacity average from the RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008

[339] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility's peak hour is divided by the maximum AC load during the year.

[340] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year

### FOSSIL FUEL SAVINGS

N/A

### WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

### DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

**MEASURE CODE: CI-HVC-ESRA-V02-190101**

**REVIEW DEADLINE: 1/1/2022**

## 4.4.8 Guest Room Energy Management (PTAC & PTHP)

### Description

This measure applied to the installation of a temperature setback and lighting control system for individual guest rooms. The savings are achieved based on Guest Room Energy Management's (GREM's) ability to automatically adjust the guest room's set temperatures and control the HVAC unit for various occupancy modes.

This measure was developed to be applicable to the following program types: TOS, NC. If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

Guest room temperature set point must be controlled by automatic occupancy detectors or keycard that indicates the occupancy status of the room. During unoccupied periods the default setting for controlled units differs by at least 5 degrees from the operating set point. Theoretically, the control system may also be tied into other electric loads, such as lighting and plug loads to shut them off when occupancy is not sensed. This measure bases savings on improved HVAC controls. If system is connected to lighting and plug loads, additional savings would be realized. The incentive is per guestroom controlled, rather than per sensor, for multi-room suites. Replacement or upgrades of existing occupancy-based controls are not eligible for an incentive.

### Definition of Baseline Equipment

Guest room energy management thermostats replace manual heating/cooling temperature set-point and fan On/Off/Auto thermostat controls. Two possible baselines exist based on whether housekeeping staff are directed to set-back (or turn off) thermostats when rooms are not rented.

### Deemed Lifetime of Efficient Equipment

The measure life for GREM is 15 years[341].

### Deemed Measure Cost

$260/unit

The IMC documented for this measure is $260 per room HVAC controller, which is the cost difference between a non-programmable thermostat and a GREM[342].

### Deemed O&M Cost Adjustments

N/A

### Loadshape

Loadshape C03 - Commercial Cooling

### Coincidence Factor

A coincidence factor is not used in the determination of coincident peak kW savings.

**Algorithm**

### Calculation of Savings

Below are the annual kWh savings per installed EMS for different sizes and types of HVAC units. The savings are achieved based on GREM's ability to automatically adjust the guest room's set temperatures and control the HVAC

[341] DEER 2008 value for energy management systems
[342] This value was extracted from Smart Ideas projects in PY1 and PY2.

unit to maintain set temperatures for various occupancy modes. Note that care should be taken in selecting a value consistent with actual baseline conditions (e.g. whether housekeeping staff are directed to set-back/turn-off the thermostats when rooms are unrented). Different values are provided for Motels and Hotels since significant differences in shell performance, number of external walls per room and typical heating and cooling efficiencies result in significantly different savings estimates. Energy savings estimates are derived using a prototypical EnergyPlus simulation of a motel and a hotel[343]. Model outputs are normalized to the installed capacity and reported here as kWh/Ton, coincident peak kW/Ton and Therms/Ton.

**ELECTRIC ENERGY SAVINGS**

| Motel Electric Energy Savings | | | |
|---|---|---|---|
| Climate Zone (City based upon) | Heating Source | Baseline | Electric Savings (kWh/Ton) |
| 1 (Rockford) | PTAC w/ Electric Resistance Heating | Housekeeping Setback | 744 |
| | | No Housekeeping Setback | 1,786 |
| | PTAC w/ Gas Heating | Housekeeping Setback | 63 |
| | | No Housekeeping Setback | 155 |
| | PTHP | Housekeeping Setback | 385 |
| | | No Housekeeping Setback | 986 |
| 2 (Chicago) | PTAC w/ Electric Resistance Heating | Housekeeping Setback | 506 |
| | | No Housekeeping Setback | 1,582 |
| | PTAC w/ Gas Heating | Housekeeping Setback | 51 |
| | | No Housekeeping Setback | 163 |
| | PTHP | Housekeeping Setback | 211 |
| | | No Housekeeping Setback | 798 |
| 3 (Springfield) | PTAC w/ Electric Resistance Heating | Housekeeping Setback | 462 |
| | | No Housekeeping Setback | 1,382 |
| | PTAC w/ Gas Heating | Housekeeping Setback | 65 |
| | | No Housekeeping Setback | 198 |
| | PTHP | Housekeeping Setback | 202 |
| | | No Housekeeping Setback | 736 |
| 4 (Belleville) | PTAC w/ Electric Resistance Heating | Housekeeping Setback | 559 |
| | | No Housekeeping Setback | 1,877 |
| | PTAC w/ Gas Heating | Housekeeping Setback | 85 |
| | | No Housekeeping Setback | 287 |
| | PTHP | Housekeeping Setback | 260 |
| | | No Housekeeping Setback | 1,023 |
| 5 (Marion-Williamson) | PTAC w/ Electric Resistance Heating | Housekeeping Setback | 388 |
| | | No Housekeeping Setback | 1,339 |
| | PTAC w/ Gas Heating | Housekeeping Setback | 81 |
| | | No Housekeeping Setback | 274 |
| | PTHP | Housekeeping Setback | 174 |
| | | No Housekeeping Setback | 682 |

[343] For motels, see S. Keates, ADM Associates Workpaper: "Suggested Revisions to Guest Room Energy Management (PTAC & PTHP)", 11/14/2013 and spreadsheet summarizing the results: 'GREM Savings Summary_IL TRM_1_22_14.xlsx'. In 2014 the hotel models were also run to compile results, rather than by applying adjustment factors to the motel results as had been done in V3.0 of the TRM. The updated values can be found in 'GREM Savings Summary (Hotel)_IL TRM_10_16_14.xls'.

| Hotel Electric Energy Savings | | | |
|---|---|---|---|
| Climate Zone City based upon) | Heating Source | Baseline | Electric Savings (kWh/Ton) |
| 1 (Rockford) | PTAC w/ Electric Resistance Heating | Housekeeping Setback | 204 |
| | | No Housekeeping Setback | 345 |
| | PTAC w/ Gas Heating | Housekeeping Setback | 121 |
| | | No Housekeeping Setback | 197 |
| | PTHP | Housekeeping Setback | 152 |
| | | No Housekeeping Setback | 253 |
| | Central Hot Water Fan Coil w/ Electric Resistance Heating | Housekeeping Setback | 177 |
| | | No Housekeeping Setback | 296 |
| | Central Hot Water Fan Coil w/ Gas Heating | Housekeeping Setback | 94 |
| | | No Housekeeping Setback | 148 |
| 2 (Chicago) | PTAC w/ Electric Resistance Heating | Housekeeping Setback | 188 |
| | | No Housekeeping Setback | 342 |
| | PTAC w/ Gas Heating | Housekeeping Setback | 119 |
| | | No Housekeeping Setback | 195 |
| | PTHP | Housekeeping Setback | 145 |
| | | No Housekeeping Setback | 250 |
| | Central Hot Water Fan Coil w/ Electric Resistance Heating | Housekeeping Setback | 161 |
| | | No Housekeeping Setback | 294 |
| | Central Hot Water Fan Coil w/ Gas Heating | Housekeeping Setback | 92 |
| | | No Housekeeping Setback | 147 |
| 3 (Springfield) | PTAC w/ Electric Resistance Heating | Housekeeping Setback | 182 |
| | | No Housekeeping Setback | 291 |
| | PTAC w/ Gas Heating | Housekeeping Setback | 123 |
| | | No Housekeeping Setback | 197 |
| | PTHP | Housekeeping Setback | 145 |
| | | No Housekeeping Setback | 233 |
| | Central Hot Water Fan Coil w/ Electric Resistance Heating | Housekeeping Setback | 153 |
| | | No Housekeeping Setback | 240 |
| | Central Hot Water Fan Coil w/ Gas Heating | Housekeeping Setback | 94 |
| | | No Housekeeping Setback | 146 |
| 4 (Belleville) | PTAC w/ Electric Resistance Heating | Housekeeping Setback | 182 |
| | | No Housekeeping Setback | 308 |
| | PTAC w/ Gas Heating | Housekeeping Setback | 125 |
| | | No Housekeeping Setback | 199 |
| | PTHP | Housekeeping Setback | 146 |
| | | No Housekeeping Setback | 240 |
| | Central Hot Water Fan Coil w/ Electric Resistance Heating | Housekeeping Setback | 152 |
| | | No Housekeeping Setback | 255 |
| | Central Hot Water Fan Coil w/ Gas Heating | Housekeeping Setback | 95 |
| | | No Housekeeping Setback | 147 |
| 5 (Marion-Williamson) | PTAC w/ Electric Resistance Heating | Housekeeping Setback | 171 |
| | | No Housekeeping Setback | 295 |
| | PTAC w/ Gas Heating | Housekeeping Setback | 122 |
| | | No Housekeeping Setback | 199 |
| | PTHP | Housekeeping Setback | 140 |
| | | No Housekeeping Setback | 235 |
| | Central Hot Water Fan Coil w/ Electric Resistance Heating | Housekeeping Setback | 141 |

| Hotel Electric Energy Savings | | | |
|---|---|---|---|
| Climate Zone City based upon) | Heating Source | Baseline | Electric Savings (kWh/Ton) |
| | | No Housekeeping Setback | 243 |
| | Central Hot Water Fan Coil w/ Gas Heating | Housekeeping Setback | 92 |
| | | No Housekeeping Setback | 146 |

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

| Motel Coincident Peak Demand Savings | | | |
|---|---|---|---|
| Climate Zone (City based upon) | Heating Source | Baseline | Coincident Peak Demand Savings (kW/Ton) |
| 1 (Rockford) | PTAC w/ Electric Resistance Heating | Housekeeping Setback | 0.08 |
| | | No Housekeeping Setback | 0.17 |
| | PTAC w/ Gas Heating | Housekeeping Setback | 0.08 |
| | | No Housekeeping Setback | 0.17 |
| | PTHP | Housekeeping Setback | 0.08 |
| | | No Housekeeping Setback | 0.17 |
| 2 (Chicago) | PTAC w/ Electric Resistance Heating | Housekeeping Setback | 0.06 |
| | | No Housekeeping Setback | 0.17 |
| | PTAC w/ Gas Heating | Housekeeping Setback | 0.06 |
| | | No Housekeeping Setback | 0.17 |
| | PTHP | Housekeeping Setback | 0.06 |
| | | No Housekeeping Setback | 0.17 |
| 3 (Springfield) | PTAC w/ Electric Resistance Heating | Housekeeping Setback | 0.07 |
| | | No Housekeeping Setback | 0.17 |
| | PTAC w/ Gas Heating | Housekeeping Setback | 0.07 |
| | | No Housekeeping Setback | 0.17 |
| | PTHP | Housekeeping Setback | 0.07 |
| | | No Housekeeping Setback | 0.17 |
| 4 (Belleville) | PTAC w/ Electric Resistance Heating | Housekeeping Setback | 0.10 |
| | | No Housekeeping Setback | 0.28 |
| | PTAC w/ Gas Heating | Housekeeping Setback | 0.10 |
| | | No Housekeeping Setback | 0.28 |
| | PTHP | Housekeeping Setback | 0.10 |
| | | No Housekeeping Setback | 0.28 |
| 5 (Marion-Williamson) | PTAC w/ Electric Resistance Heating | Housekeeping Setback | 0.08 |
| | | No Housekeeping Setback | 0.21 |
| | PTAC w/ Gas Heating | Housekeeping Setback | 0.08 |
| | | No Housekeeping Setback | 0.21 |
| | PTHP | Housekeeping Setback | 0.08 |
| | | No Housekeeping Setback | 0.21 |

| Hotel Coincident Peak Demand Savings | | | |
|---|---|---|---|
| Climate Zone (City based upon) | Heating Source | Baseline | Coincident Peak Demand Savings (kW/Ton) |
| 1 (Rockford) | PTAC w/ Electric Resistance Heating | Housekeeping Setback | 0.08 |
| | | No Housekeeping Setback | 0.11 |
| | PTAC w/ Gas Heating | Housekeeping Setback | 0.08 |
| | | No Housekeeping Setback | 0.11 |
| | PTHP | Housekeeping Setback | 0.08 |
| | | No Housekeeping Setback | 0.11 |
| | Central Hot Water Fan Coil w/ Electric Resistance Heating | Housekeeping Setback | 0.05 |
| | | No Housekeeping Setback | 0.08 |
| | Central Hot Water Fan Coil w/ Gas Heating | Housekeeping Setback | 0.05 |
| | | No Housekeeping Setback | 0.08 |
| 2 (Chicago) | PTAC w/ Electric Resistance Heating | Housekeeping Setback | 0.07 |
| | | No Housekeeping Setback | 0.11 |
| | PTAC w/ Gas Heating | Housekeeping Setback | 0.07 |
| | | No Housekeeping Setback | 0.11 |
| | PTHP | Housekeeping Setback | 0.07 |
| | | No Housekeeping Setback | 0.11 |
| | Central Hot Water Fan Coil w/ Electric Resistance Heating | Housekeeping Setback | 0.05 |
| | | No Housekeeping Setback | 0.07 |
| | Central Hot Water Fan Coil w/ Gas Heating | Housekeeping Setback | 0.05 |
| | | No Housekeeping Setback | 0.07 |
| 3 (Springfield) | PTAC w/ Electric Resistance Heating | Housekeeping Setback | 0.08 |
| | | No Housekeeping Setback | 0.11 |
| | PTAC w/ Gas Heating | Housekeeping Setback | 0.08 |
| | | No Housekeeping Setback | 0.11 |
| | PTHP | Housekeeping Setback | 0.08 |
| | | No Housekeeping Setback | 0.11 |
| | Central Hot Water Fan Coil w/ Electric Resistance Heating | Housekeeping Setback | 0.05 |
| | | No Housekeeping Setback | 0.07 |
| | Central Hot Water Fan Coil w/ Gas Heating | Housekeeping Setback | 0.05 |
| | | No Housekeeping Setback | 0.07 |
| 4 (Belleville) | PTAC w/ Electric Resistance Heating | Housekeeping Setback | 0.08 |
| | | No Housekeeping Setback | 0.11 |
| | PTAC w/ Gas Heating | Housekeeping Setback | 0.08 |
| | | No Housekeeping Setback | 0.11 |
| | PTHP | Housekeeping Setback | 0.08 |
| | | No Housekeeping Setback | 0.11 |
| | Central Hot Water Fan Coil w/ Electric Resistance Heating | Housekeeping Setback | 0.05 |
| | | No Housekeeping Setback | 0.08 |
| | Central Hot Water Fan Coil w/ Gas Heating | Housekeeping Setback | 0.05 |
| | | No Housekeeping Setback | 0.08 |
| 5 (Marion-Williamson) | PTAC w/ Electric Resistance Heating | Housekeeping Setback | 0.08 |
| | | No Housekeeping Setback | 0.11 |
| | PTAC w/ Gas Heating | Housekeeping Setback | 0.08 |
| | | No Housekeeping Setback | 0.11 |
| | PTHP | Housekeeping Setback | 0.08 |
| | | No Housekeeping Setback | 0.11 |

| Hotel Coincident Peak Demand Savings | | | |
|---|---|---|---|
| Climate Zone (City based upon) | Heating Source | Baseline | Coincident Peak Demand Savings (kW/Ton) |
| | Central Hot Water Fan Coil w/ Electric Resistance Heating | Housekeeping Setback | 0.05 |
| | | No Housekeeping Setback | 0.08 |
| | Central Hot Water Fan Coil w/ Gas Heating | Housekeeping Setback | 0.05 |
| | | No Housekeeping Setback | 0.08 |

### NATURAL GAS ENERGY SAVINGS

For PTACs with gas heating:

| Motel Natural Gas Energy Savings | | |
|---|---|---|
| Climate Zone (City based upon) | Baseline | Gas Savings (Therms/Ton) |
| 1 (Rockford) | Housekeeping Setback | 30 |
| | No Housekeeping Setback | 71 |
| 2 (Chicago) | Housekeeping Setback | 20 |
| | No Housekeeping Setback | 62 |
| 3 (Springfield) | Housekeeping Setback | 17 |
| | No Housekeeping Setback | 52 |
| 4 (Belleville) | Housekeeping Setback | 21 |
| | No Housekeeping Setback | 70 |
| 5 (Marion-Williamson) | Housekeeping Setback | 13 |
| | No Housekeeping Setback | 47 |

| Hotel Natural Gas Energy Savings | | | |
|---|---|---|---|
| Climate Zone (City based upon) | Heating Source | Baseline | Gas Savings (Therms/Ton) |
| 1 (Rockford) | PTAC w/ Gas Heating | Housekeeping Setback | 3.6 |
| | | No Housekeeping Setback | 6.4 |
| | Central Hot Water Fan Coil w/ Gas Heating | Housekeeping Setback | 3.6 |
| | | No Housekeeping Setback | 6.4 |
| 2 (Chicago) | PTAC w/ Gas Heating | Housekeeping Setback | 3.0 |
| | | No Housekeeping Setback | 6.5 |
| | Central Hot Water Fan Coil w/ Gas Heating | Housekeeping Setback | 3.0 |
| | | No Housekeeping Setback | 6.5 |
| 3 (Springfield) | PTAC w/ Gas Heating | Housekeeping Setback | 2.6 |
| | | No Housekeeping Setback | 4.1 |
| | Central Hot Water Fan Coil w/ Gas Heating | Housekeeping Setback | 2.6 |
| | | No Housekeeping Setback | 4.1 |
| 4 (Belleville) | PTAC w/ Gas Heating | Housekeeping Setback | 2.5 |
| | | No Housekeeping Setback | 4.8 |
| | Central Hot Water Fan Coil w/ Gas Heating | Housekeeping Setback | 2.5 |
| | | No Housekeeping Setback | 4.8 |
| 5 (Marion-Williamson) | PTAC w/ Gas Heating | Housekeeping Setback | 2.1 |
| | | No Housekeeping Setback | 4.2 |
| | Central Hot Water Fan Coil w/ Gas Heating | Housekeeping Setback | 2.1 |

| Hotel Natural Gas Energy Savings | | | |
|---|---|---|---|
| Climate Zone (City based upon) | Heating Source | Baseline | Gas Savings (Therms/Ton) |
| | | No Housekeeping Setback | 4.2 |

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-HVC-GREM-V05-150601**

**REVIEW DEADLINE: 1/1/2022**

## 4.4.9 Air and Water Source Heat Pump Systems

### DESCRIPTION

This measure applies to the installation of high-efficiency air cooled and water source heat pump systems. This measure could apply to replacing an existing unit at the end of its useful life, or installation of a new unit in a new or existing building.

This measure was developed to be applicable to the following program types: TOS NC. If applied to other program types, the measure savings should be verified.

#### DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the efficient equipment is assumed to be a high-efficiency air cooled or water source, heat pump system that exceeds the baseline and meets program requirements.

### DEFINITION OF BASELINE EQUIPMENT

In order for this characterization to apply, the baseline equipment is assumed to be a standard-efficiency air cooled or water source heat pump system that meets the Code energy efficiency requirements (IECC or Code of Federal Regulations whichever is higher) in effect on the date of equipment purchase (if date unknown assume current Code minimum). The rating conditions for the baseline and efficient equipment efficiencies must be equivalent.

Note: IECC 2018 is scheduled to become effective March 1, 2019 will become baseline for all New Construction permits from that date.

Note: new Federal Standards affecting heat pumps become effective January 1, 2023.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years[344].

### DEEMED MEASURE COST

For analysis purposes, the incremental capital cost for this measure is assumed as $100 per ton for air-cooled units.[345] The incremental cost for all other equipment types should be determined on a site-specific basis.

### LOADSHAPE

Loadshape C05 - Commercial Electric Heating and Cooling

### COINCIDENCE FACTOR

The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the *average* savings over the defined summer peak period, and is presented so that savings can be bid into PJM's Forward Capacity Market. Both values provided are based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren.

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [346]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

---

[344] Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007.

[345] Based on a review of TRM incremental cost assumptions from Vermont, Wisconsin, and California.

[346] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility's peak hour is divided by the maximum AC load during the year.

= 47.8% [347]

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

For units with cooling capacities less than 65 kBtu/hr:

ΔkWh = Annual kWh $Savings_{cool}$ + Annual kWh $Savings_{heat}$

Annual kWh $Savings_{cool}$ = ($kBtu/hr_{cool}$) * [(1/SEERbase) – (1/SEERee)] * $EFLH_{cool}$

Annual kWh $Savings_{heat}$ = ($kBtu/hr_{heat}$) * [(1/HSPFbase) – (1/HSPFee)] * $EFLH_{heat}$

For units with cooling capacities equal to or greater than 65 kBtu/hr:

ΔkWh = Annual kWh $Savings_{cool}$ + Annual kWh $Savings_{heat}$

Annual kWh $Savings_{cool}$ = ($kBtu/hr_{cool}$) * [(1/EERbase) – (1/EERee)] * $EFLH_{cool}$

Annual kWh $Savings_{heat}$ = ($kBtu/hr_{heat}$)/3.412 * [(1/COPbase) – (1/COPee)] * $EFLH_{heat}$

Where:

$kBtu/hr_{cool}$ = capacity of the cooling equipment in kBtu per hour (1 ton of cooling capacity equals 12 kBtu/hr).

= Actual installed

SEERbase =Seasonal Energy Efficiency Ratio of the baseline equipment

= SEER from tables below, based on the applicable Code on the date of equipment purchase (if unknown assume current Code).

SEERee = Seasonal Energy Efficiency Ratio of the energy efficient equipment.

= Actual installed

$EFLH_{cool}$ = Equivalent Full Load Hours for cooling are provided in section 4.4 HVAC End Use.

HSPFbase = Heating Seasonal Performance Factor of the baseline equipment

= HSPF from tables below, based on the applicable Code on the date of equipment purchase (if unknown assume current Code).

HSPFee = Heating Seasonal Performance Factor of the energy efficient equipment.

= Actual installed. If rating is COP, HSPF = COP * 3.413

$EFLH_{heat}$ = heating mode equivalent full load hours are provided in section 4.4 HVAC End Use.

EERbase = Energy Efficiency Ratio of the baseline equipment

= EER from tables below, based on the applicable Code on the date of equipment purchase (if unknown assume current Code). For air-cooled units < 65 kBtu/hr, assume the following conversion from SEER to EER for calculation of peak savings:[348]

$$EER = (-0.02 * SEER^2) + (1.12 * SEER)$$

[347] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year

[348] Based on Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder. Note this is appropriate for single speed units only.

$EER_{ee}$ = Energy Efficiency Ratio of the energy efficient equipment. For air-cooled units < 65 kBtu/hr, if the actual $EER_{ee}$ is unknown, assume the conversion from SEER to EER as provided above.

= Actual installed

$kBtu/hr_{heat}$ = capacity of the heating equipment in kBtu per hour.

= Actual installed

3.412 = Btu per Wh.

$COP_{base}$ = coefficient of performance of the baseline equipment

= COP from tables below, based on the applicable Code on the date of equipment purchase (if unknown assume current Code). If rating is HSPF, COP = HSPF / 3.413

$COP_{ee}$ = coefficient of performance of the energy efficient equipment.

= Actual installed. If rating is HSPF, COP = HSPF / 3.413

**Code of Federal Redulations (baseline effective 1/1/2019):**

| Equipment type | Cooling capacity | Heating type | Cooling Efficiency level | Heating Efficiency level | Compliance date |
|---|---|---|---|---|---|
| Small Commercial Packaged Air Conditioning and Heating Equipment (Air-Cooled) | ≥65,000 Btu/h and <135,000 Btu/h | Electric Resistance Heating or No Heating | IEER = 12.2 | N/A | 1/1/2018 |
| | | All Other Types of Heating | IEER = 12.0 | COP = 3.3 | 1/1/2018 |
| Large Commercial Packaged Air Conditioning and Heating Equipment (Air-Cooled) | ≥135,000 Btu/h and <240,000 Btu/h | Electric Resistance Heating or No Heating | IEER = 11.6 | N/A | 1/1/2018 |
| | | All Other Types of Heating | IEER = 11.4 | COP = 3.2 | 1/1/2018 |
| Very Large Commercial Packaged Air Conditioning and Heating Equipment (Air-Cooled) | ≥240,000 Btu/h and <760,000 Btu/h | Electric Resistance Heating or No Heating | IEER = 10.6 | N/A | 1/1/2018 |
| | | All Other Types of Heating | IEER = 10.4 | COP = 3.2 | 1/1/2018 |
| Small Commercial Package Air-Conditioning and Heating Equipment (Air-Cooled, 3-Phase, Split-System) | <65,000 Btu/h | All | SEER = 14.0 | HSPF = 8.2 | 1/1/2017 |
| Small Commercial Package Air-Conditioning and Heating Equipment (Air-Cooled, 3-Phase, Single-Package) | <65,000Btu/h | All | SEER = 14.0 | HSPF = 8.0 | 1/1/2017 |
| Small Commercial Packaged Air-Conditioning and Heating Equipment (Water Source: Water-to-Air, Water-Loop) | <17,000 Btu/h | All | EER = 12.2 | COP = 4.3 | 10/9/2015 |
| | ≥17,000 Btu/h and <65,000 Btu/h | All | EER = 13.0 | COP = 4.3 | 10/9/2015 |
| | ≥65,000 Btu/h and <135,000Btu/h | All | EER = 13.0 | COP = 4.3 | 10/9/2015 |

Minimum Efficiency Requirements: 2012 IECC (baseline effective 1/1/2013)

**TABLE C403.2.3(2)**
**MINIMUM EFFICIENCY REQUIREMENTS:**
**ELECTRICALLY OPERATED UNITARY AND APPLIED HEAT PUMPS**

| EQUIPMENT TYPE | SIZE CATEGORY | HEATING SECTION TYPE | SUBCATEGORY OR RATING CONDITION | MINIMUM EFFICIENCY | TEST PROCEDURE[a] |
|---|---|---|---|---|---|
| Air cooled (cooling mode) | < 65,000 Btu/h[b] | All | Split System | 13.0 SEER | AHRI 210/240 |
| | | | Single Packaged | 13.0 SEER | |
| Through-the-wall, air cooled | ≤ 30,000 Btu/h[b] | All | Split System | 13.0 SEER | |
| | | | Single Packaged | 13.0 SEER | |
| Single-duct high-velocity air cooled | < 65,000 Btu/h[b] | All | Split System | 10.0 SEER | |
| Air cooled (cooling mode) | ≥ 65,000 Btu/h and < 135,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 11.0 EER<br>11.2 IEER | AHRI 340/360 |
| | | All other | Split System and Single Package | 10.8 EER<br>11.0 IEER | |
| | ≥ 135,000 Btu/h and < 240,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 10.6 EER<br>10.7 IEER | |
| | | All other | Split System and Single Package | 10.4 EER<br>10.5 IEER | |
| | ≥ 240,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 9.5 EER<br>9.6 IEER | |
| | | All other | Split System and Single Package | 9.3 EER<br>9.4 IEER | |
| Water source (cooling mode) | < 17,000 Btu/h | All | 86°F entering water | 11.2 EER | ISO 13256-1 |
| | ≥ 17,000 Btu/h and < 65,000 Btu/h | All | 86°F entering water | 12.0 EER | |
| | ≥ 65,000 Btu/h and < 135,000 Btu/h | All | 86°F entering water | 12.0 EER | |
| Ground water source (cooling mode) | < 135,000 Btu/h | All | 59°F entering water | 16.2 EER | |
| | | All | 77°F entering water | 13.4 EER | |
| Water-source water to water (cooling mode) | < 135,000 Btu/h | All | 86°F entering water | 10.6 EER | ISO 13256-2 |
| | | | 59°F entering water | 16.3 EER | |
| Ground water source Brine to water (cooling mode) | < 135,000 Btu/h | All | 77°F entering fluid | 12.1 EER | |
| Air cooled (heating mode) | < 65,000 Btu/h[b] | — | Split System | 7.7 HSPF | AHRI 210/240 |
| | | — | Single Package | 7.7 HSPF | |
| Through-the-wall, (air cooled, heating mode) | ≤ 30,000 Btu/h[b] (cooling capacity) | — | Split System | 7.4 HSPF | |
| | | — | Single Package | 7.4 HSPF | |
| Small-duct high velocity (air cooled, heating mode) | < 65,000 Btu/h[b] | — | Split System | 6.8 HSPF | |

*(continued)*

**TABLE C403.2.3(2)—continued**
**MINIMUM EFFICIENCY REQUIREMENTS:**
**ELECTRICALLY OPERATED UNITARY AND APPLIED HEAT PUMPS**

| EQUIPMENT TYPE | SIZE CATEGORY | HEATING SECTION TYPE | SUB-CATEGORY OR RATING CONDITION | MINIMUM EFFICIENCY | TEST PROCEDURE[a] |
|---|---|---|---|---|---|
| Air cooled (heating mode) | ≥ 65,000 Btu/h and < 135,000 Btu/h (cooling capacity) | — | 47°F db/43°F wb Outdoor Air | 3.3 COP | AHRI 340/360 |
| | | | 17°F db/15°F wb Outdoor Air | 2.25 COP | |
| | ≥ 135,000 Btu/h (cooling capacity) | — | 47°F db/43°F wb Outdoor Air | 3.2 COP | |
| | | | 17°F db/15°F wb Outdoor Air | 2.05 COP | |
| Water source (heating mode) | < 135,000 Btu/h (cooling capacity) | — | 68°F entering water | 4.2 COP | ISO 13256-1 |
| Ground water source (heating mode) | < 135,000 Btu/h (cooling capacity) | — | 50°F entering water | 3.6 COP | |
| Ground source (heating mode) | < 135,000 Btu/h (cooling capacity) | — | 32°F entering fluid | 3.1 COP | |
| Water-source water to water (heating mode) | < 135,000 Btu/h (cooling capacity) | — | 68°F entering water | 3.7 COP | ISO 13256-2 |
| | | — | 50°F entering water | 3.1 COP | |
| Ground source brine to water (heating mode) | < 135,000 Btu/h (cooling capacity) | — | 32°F entering fluid | 2.5 COP | |

For SI: 1 British thermal unit per hour = 0.2931 W, °C = [(°F) - 32]/1.8.

a. Chapter 6 of the referenced standard contains a complete specification of the referenced test procedure, including the reference year version of the test procedure.

b. Single-phase, air-cooled air conditioners less than 65,000 Btu/h are regulated by NAECA. SEER values are those set by NAECA.

Minimum Efficiency Requirements: 2015 IECC (baseline effective 1/1/2016)

**TABLE C403.2.3(2)
MINIMUM EFFICIENCY REQUIREMENTS:
ELECTRICALLY OPERATED UNITARY AND APPLIED HEAT PUMPS**

| EQUIPMENT TYPE | SIZE CATEGORY | HEATING SECTION TYPE | SUBCATEGORY OR RATING CONDITION | MINIMUM EFFICIENCY | | TEST PROCEDURE[a] |
|---|---|---|---|---|---|---|
| | | | | Before 1/1/2016 | As of 1/1/2016 | |
| Air cooled (cooling mode) | < 65,000 Btu/h[b] | All | Split System | 13.0 SEER[c] | 14.0 SEER[c] | AHRI 210/240 |
| | | | Single Package | 13.0 SEER[c] | 14.0 SEER[c] | |
| Through-the-wall, air cooled | ≤ 30,000 Btu/h[b] | All | Split System | 12.0 SEER | 12.0 SEER | |
| | | | Single Package | 12.0 SEER | 12.0 SEER | |
| Single-duct high-velocity air cooled | < 65,000 Btu/h[b] | All | Split System | 11.0 SEER | 11.0 SEER | |
| Air cooled (cooling mode) | ≥ 65,000 Btu/h and < 135,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 11.0 EER<br>11.2 IEER | 11.0 EER<br>12.0 IEER | AHRI 340/360 |
| | | All other | Split System and Single Package | 10.8 EER<br>11.0 IEER | 10.8 EER<br>11.8 IEER | |
| | ≥ 135,000 Btu/h and < 240,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 10.6 EER<br>10.7 IEER | 10.6 EER<br>11.6 IEER | |
| | | All other | Split System and Single Package | 10.4 EER<br>10.5 IEER | 10.4 EER<br>11.4 IEER | |
| | ≥ 240,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 9.5 EER<br>9.6 IEER | 9.5 EER<br>10.6 IEER | |
| | | All other | Split System and Single Package | 9.3 EER<br>9.4 IEER | 9.3 EER<br>9.4 IEER | |
| Water to Air: Water Loop (cooling mode) | < 17,000 Btu/h | All | 86°F entering water | 12.2 EER | 12.2 EER | ISO 13256-1 |
| | ≥ 17,000 Btu/h and < 65,000 Btu/h | All | 86°F entering water | 13.0 EER | 13.0 EER | |
| | ≥ 65,000 Btu/h and < 135,000 Btu/h | All | 86°F entering water | 13.0 EER | 13.0 EER | |
| Water to Air: Ground Water (cooling mode) | < 135,000 Btu/h | All | 59°F entering water | 18.0 EER | 18.0 EER | ISO 13256-1 |
| Brine to Air: Ground Loop (cooling mode) | < 135,000 Btu/h | All | 77°F entering water | 14.1 EER | 14.1 EER | ISO 13256-1 |
| Water to Water: WaterLoop (cooling mode) | < 135,000 Btu/h | All | 86°F entering water | 10.6 EER | 10.6 EER | ISO 13256-2 |
| Water to Water: Ground Water (cooling mode) | < 135,000 Btu/h | All | 59°F entering water | 16.3 EER | 16.3 EER | |
| Brine to Water: Ground Loop (cooling mode) | < 135,000 Btu/h | All | 77°F entering fluid | 12.1 EER | 12.1 EER | |

*(continued)*

**TABLE C403.2.3(2)—continued**
**MINIMUM EFFICIENCY REQUIREMENTS:**
**ELECTRICALLY OPERATED UNITARY AND APPLIED HEAT PUMPS**

| EQUIPMENT TYPE | SIZE CATEGORY | HEATING SECTION TYPE | SUBCATEGORY OR RATING CONDITION | MINIMUM EFFICIENCY | | TEST PROCEDURE[a] |
|---|---|---|---|---|---|---|
| | | | | Before 1/1/2016 | As of 1/1/2016 | |
| Air cooled (heating mode) | < 65,000 Btu/h[b] | — | Split System | 7.7 HSPF[c] | 8.2 HSPF[c] | AHRI 210/240 |
| | | — | Single Package | 7.7 HSPF[c] | 8.0 HSPF[c] | |
| Through-the-wall, (air cooled, heating mode) | ≤ 30,000 Btu/h[b] (cooling capacity) | — | Split System | 7.4 HSPF | 7.4 HSPF | |
| | | — | Single Package | 7.4 HSPF | 7.4 HSPF | |
| Small-duct high velocity (air cooled, heating mode) | < 65,000 Btu/h[b] | — | Split System | 6.8 HSPF | 6.8 HSPF | |
| Air cooled (heating mode) | ≥ 65,000 Btu/h and < 135,000 Btu/h (cooling capacity) | — | 47°F db/43°F wb outdoor air | 3.3 COP | 3.3 COP | AHRI 340/360 |
| | | | 17°F db/15°F wb outdoor air | 2.25 COP | 2.25 COP | |
| | ≥ 135,000 Btu/h (cooling capacity) | — | 47°F db/43°F wb outdoor air | 3.2 COP | 3.2 COP | |
| | | | 17°F db/15°F wb outdoor air | 2.05 COP | 2.05 COP | |
| Water to Air: Water Loop (heating mode) | < 135,000 Btu/h (cooling capacity) | — | 68°F entering water | 4.3 COP | 4.3 COP | ISO 13256-1 |
| Water to Air: Ground Water (heating mode) | < 135,000 Btu/h (cooling capacity) | — | 50°F entering water | 3.7 COP | 3.7 COP | |
| Brine to Air: Ground Loop (heating mode) | < 135,000 Btu/h (cooling capacity) | — | 32°F entering fluid | 3.2 COP | 3.2 COP | |
| Water to Water: Water Loop (heating mode) | < 135,000 Btu/h (cooling capacity) | — | 68°F entering water | 3.7 COP | 3.7 COP | ISO 13256-2 |
| Water to Water: Ground Water (heating mode) | < 135,000 Btu/h (cooling capacity) | — | 50°F entering water | 3.1 COP | 3.1 COP | |
| Brine to Water: Ground Loop (heating mode) | < 135,000 Btu/h (cooling capacity) | — | 32°F entering fluid | 2.5 COP | 2.5 COP | |

For SI: 1 British thermal unit per hour = 0.2931 W, °C = [(°F) - 32]/1.8.

a. Chapter 6 contains a complete specification of the referenced test procedure, including the reference year version of the test procedure.

b. Single-phase, air-cooled air conditioners less than 65,000 Btu/h are regulated by NAECA. SEER values are those set by NAECA.

c. Minimum efficiency as of January 1, 2015.

Minimum Efficiency Requirements: 2018 IECC (baseline effective 3/1/2019 for New Construction measures)

TABLE C403.3.2(2)
MINIMUM EFFICIENCY REQUIREMENTS: ELECTRICALLY OPERATED UNITARY AND APPLIED HEAT PUMPS

| EQUIPMENT TYPE | SIZE CATEGORY | HEATING SECTION TYPE | SUBCATEGORY OR RATING CONDITION | MINIMUM EFFICIENCY | TEST PROCEDURE[a] |
|---|---|---|---|---|---|
| Air cooled (cooling mode) | < 65,000 Btu/h[b] | All | Split System | 14.0 SEER | AHRI 210/240 |
| | | | Single Package | 14.0 SEER | |
| Through-the-wall, air cooled | ≤ 30,000 Btu/h[b] | All | Split System | 12.0 SEER | |
| | | | Single Package | 12.0 SEER | |
| Single-duct high-velocity air cooled | < 65,000 Btu/h[b] | All | Split System | 11.0 SEER | |
| Air cooled (cooling mode) | ≥ 65,000 Btu/h and < 135,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 11.0 EER 12.0 IEER | AHRI 340/360 |
| | | All other | Split System and Single Package | 10.8 EER 11.8 IEER | |
| | ≥ 135,000 Btu/h and < 240,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 10.6 EER 11.6 IEER | |
| | | All other | Split System and Single Package | 10.4 EER 11.4 IEER | |
| | ≥ 240,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 9.5 EER 10.6 IEER | |
| | | All other | Split System and Single Package | 9.3 EER 9.4 IEER | |
| Water to Air: Water Loop (cooling mode) | < 17,000 Btu/h | All | 86°F entering water | 12.2 EER | ISO 13256-1 |
| | ≥ 17,000 Btu/h and < 65,000 Btu/h | All | 86°F entering water | 13.0 EER | |
| | ≥ 65,000 Btu/h and < 135,000 Btu/h | All | 86°F entering water | 13.0 EER | |
| Water to Air: Ground Water (cooling mode) | < 135,000 Btu/h | All | 59°F entering water | 18.0 EER | ISO 13256-1 |
| Brine to Air: Ground Loop (cooling mode) | < 135,000 Btu/h | All | 77°F entering water | 14.1 EER | ISO 13256-1 |
| Water to Water: Water Loop (cooling mode) | < 135,000 Btu/h | All | 86°F entering water | 10.6 EER | ISO 13256-2 |
| Water to Water: Ground Water (cooling mode) | < 135,000 Btu/h | All | 59°F entering water | 16.3 EER | |
| Brine to Water: Ground Loop (cooling mode) | < 135,000 Btu/h | All | 77°F entering fluid | 12.1 EER | |

***IECC2018 Table C403.3.2(2) continued from previous page:***

| | | | | | |
|---|---|---|---|---|---|
| Air cooled (heating mode) | < 65,000 Btu/h[b] | — | Split System | 8.2 HSPF | AHRI 210/240 |
| | | — | Single Package | 8.0 HSPF | |
| Through-the-wall, (air cooled, heating mode) | ≤ 30,000 Btu/h[b] (cooling capacity) | — | Split System | 7.4 HSPF | |
| | | — | Single Package | 7.4 HSPF | |
| Small-duct high velocity (air cooled, heating mode) | < 65,000 Btu/h[b] | — | Split System | 6.8 HSPF | |
| Air cooled (heating mode) | ≥ 65,000 Btu/h and < 135,000 Btu/h (cooling capacity) | — | 47°F db/43°F wb outdoor air | 3.3 COP | AHRI 340/360 |
| | | | 17°Fdb/15°F wb outdoor air | 2.25 COP | |
| | ≥ 135,000 Btu/h (cooling capacity) | — | 47°F db/43°F wb outdoor air | 3.2 COP | |
| | | | 17°Fdb/15°F wb outdoor air | 2.05 COP | |
| Water to Air: Water Loop (heating mode) | < 135,000 Btu/h (cooling capacity) | — | 68°F entering water | 4.3 COP | ISO 13256-1 |
| Water to Air: Ground Water (heating mode) | < 135,000 Btu/h (cooling capacity) | — | 50°F entering water | 3.7 COP | |
| Brine to Air: Ground Loop (heating mode) | < 135,000 Btu/h (cooling capacity) | — | 32°F entering fluid | 3.2 COP | |
| Water to Water: Water Loop (heating mode) | < 135,000 Btu/h (cooling capacity) | — | 68°F entering water | 3.7 COP | ISO 13256-2 |
| Water to Water: Ground Water (heating mode) | < 135,000 Btu/h (cooling capacity) | — | 50°F entering water | 3.1 COP | |
| Brine to Water: Ground Loop (heating mode) | < 135,000 Btu/h (cooling capacity) | — | 32°F entering fluid | 2.5 COP | |

For SI: 1 British thermal unit per hour = 0.2931 W, °C = [(°F) - 32]/1.8.

a. Chapter 6 contains a complete specification of the referenced test procedure, including the reference year version of the test procedure.

b. Single-phase, air-cooled heat pumps less than 65,000 Btu/h are regulated by NAECA. SEER and HSPF values are those set by NAECA.

For example a 5 ton cooling unit with 60 kbtu heating, an efficient SEER of 16, and an efficient HSPF of 9.5, at a restaurant in Chicago with a building permit dated after 1/1/2016 saves:

$\Delta kWh = [(60) * [(1/14) – (1/16)] * 1134] + [(60) * [(1/8.2) – (1/9.5)] * 1354]$

$= 1963.2 \text{ kWh}$

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = ((kBtu/hr_{cool}) * (1/EERbase – 1/EERee)) * CF$$

Where CF value is chosen between:

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [349]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [350]

[349] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility's peak hour is divided by the maximum AC load during the year.

[350] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year

For example a 5 ton cooling unit with 60 kbtu heating, an efficient EER of 12.5 with a building permit dated after 1/1/2016 saves:

$$\Delta kW = (60 * (1/11 - 1/12.5)) * 0.913$$
$$= 0.598 \text{ kW}$$

**NATURAL GAS ENERGY SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-HVC-HPSY-V06-190101**

**REVIEW DEADLINE: 1/1/2022**

## 4.4.10 High Efficiency Boiler

### DESCRIPTION

To qualify for this measure the installed equipment must be replacement of an existing boiler at the end of its service life, in a commercial or multifamily space with a high efficiency, gas-fired steam or hot water boiler. High efficiency boilers achieve gas savings through the utilization of a sealed combustion chamber and multiple heat exchangers that remove a significant portion of the waste heat from flue gasses. Because multiple heat exchangers are used to remove waste heat from the escaping flue gasses, some of the flue gasses condense and must be drained.

This measure was developed to be applicable to the following program types: TOS, RF. If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed equipment must be a boiler used 80% or more for space heating, not process, and boiler AFUE, TE (thermal efficiency), or Ec (combustion efficiency) rating must be rated greater than or equal to 85% for hot water boilers and 81% for steam boilers.

### DEFINITION OF BASELINE EQUIPMENT

Dependent on when the unit is installed and whether the unit is hot water or steam. The baseline efficiency source is the Energy Independence and Security Act of 2007 with technical amendments from Federal Register, volume 73, Number 145, Monday, July 28, 2008 for boilers <300,000 Btu/hr and is Final Rule, Federal Register, volume 74, Number 139, Wednesday, July 22, 2009 for boiler ≥300,000 Btu/hr.

Note: a new Federal Standard, applicable only to gas-fired, natural draft steam packaged boilers, becomes effective March 2, 2022.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 20 years[351]

### DEEMED MEASURE COST

The incremental capital cost for this measure depends on efficiency as listed below[352]

| Measure Tier | Incr. Cost, per unit |
|---|---|
| ENERGY STAR® Minimum | $1,470 |
| AFUE 90% | $2,400 |
| AFUE 95% | $3,370 |
| AFUE ≥ 96% | $4,340 |
| Boilers > 300,000 Btu/hr with TE (thermal efficiency) rating | Custom |

### LOADSHAPE

N/A

[351] The technical support documents for federal residential appliance standards, per the US DOE Office of Energy Efficiency & Renewable Energy, 10 CFR 431.97(c). Note that this value is below the 20 years used by CA's DEER and the range of 20-40 year estimate made by the Consortium for Energy Efficiency in 2010

[352] Average of low and high incremental cost based on Nicor Gas program data for non-condensing and condensing boilers. Nicor Gas Energy Efficiency Plan 2011 - 2014, May 27, 2011 $1,470 for ≤ 300,000 Btu/hr for non-condensing hydronic boilers >85% AFUE & $3,365 for condensing boilers > 90% AFUE. The exception is $4,340 for AFUE ≥ 96% AFUE which was obtained from extrapolation above the size range that Nicor Gas Energy Efficiency Plan provided for incremental cost.

**COINCIDENCE FACTOR**

N/A

**Algorithm**

**CALCULATION OF ENERGY SAVINGS**

**ELECTRIC ENERGY SAVINGS**

N/A

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

N/A

**NATURAL GAS ENERGY SAVINGS**

ΔTherms = EFLH * Capacity * ((EfficiencyRating(actual) - EfficiencyRating(base)/ EfficiencyRating(base)) / 100,000

Where:

EFLH = Equivalent Full Load Hours for heating are provided in section 4.4 HVAC End Use

Capacity = Nominal Heating Input Capacity Boiler Size (Btu/hr) for efficient unit not existing unit

= custom Boiler input capacity in Btu/hr

EfficiencyRating(base) = Baseline Boiler Efficiency Rating, dependant on year and boiler type.

Hot water boiler baseline:

| Year | Efficiency |
|---|---|
| Hot Water <300,000 Btu/hr < June 1, 2013[353] | 80% AFUE |
| Hot Water <300,000 Btu/hr ≥ June 1, 2013 | 82% AFUE |
| Hot Water ≥300,000 & ≤2,500,000 Btu/hr | 80% TE |
| Hot Water >2,500,000 Btu/hr | 82% Ec |

Steam boiler baseline:

| Year | Efficiency |
|---|---|
| Steam <300,000 Btu/hr < June 1, 2013[354] | 75% AFUE |
| Steam <300,000 Btu/hr ≥June 1, 2013 | 80% AFUE |
| Steam - all except natural draft ≥300,000 & ≤2,500,000 Btu/hr | 79% TE |
| Steam - natural draft ≥300,000 & ≤2,500,000 Btu/hr | 77% TE |
| Steam - all except natural draft >2,500,000 Btu/hr | 79% TE |
| Steam - natural draft >2,500,000 Btu/hr | 77% TE |

EfficiencyRating(actual) = Efficent Boiler Efficiency Rating

=actual value, specified to one significant digit (i.e., 95.7%)

[353] The Federal baseline for boilers <300,000 btu/hr changes from 80% to 82% in September 2012. To prevent a change in baseline mid-program, the increase in efficiency is delayed until June 2013 when a new program year starts.
[354] Ibid.

**EXAMPLE**

For example, a 150,000 btu/hr water boiler meeting AFUE 90% in Rockford at a high rise office building , in the year 2012

ΔTherms = 2,089* 150,000 * (0.90-0.80)/0.80) / 100,000 Btu/Therm

= 392 Therms

### WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

### DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

### MEASURE CODE: CI-HVC-BOIL-V06-190101

### REVIEW DEADLINE: 1/1/2021

## 4.4.11 High Efficiency Furnace

### DESCRIPTION

This measure covers the installation of a high efficiency gas furnace in lieu of a standard efficiency gas furnace in a commercial or industrial space. High efficiency gas furnaces achieve savings through the utilization of a sealed, super insulated combustion chamber, more efficient burners, and multiple heat exchangers that remove a significant portion of the waste heat from the flue gasses. Because multiple heat exchangers are used to remove waste heat from the escaping flue gasses, most of the flue gasses condense and must be drained. Furnaces equipped with ECM fan motors can save additional electric energy

This measure was developed to be applicable to the following program types: TOS, RF and EREP. If applied to other program types, the measure savings should be verified.

Time of sale:

a. The installation of a new high efficiency, gas-fired condensing furnace in a commercial location. This could relate to the replacement of an existing unit at the end of its useful life, or the installation of a new system.

Early replacement:

Early Replacement determination will be based on meeting the following conditions:

- The existing unit is operational when replaced, or
- The existing unit requires minor repairs (<$528)[355].
- All other conditions will be considered Time of Sale.

The Baseline AFUE of the existing unit replaced:

- If the AFUE of the existing unit is known and <=75%, the Baseline AFUE is the actual AFUE value of the unit replaced. If the AFUE is >75%, the Baseline AFUE = 80%.
- If the AFUE of the existing unit is unknown, use assumptions in variable list below (AFUE(exist)).
- If the operational status or repair cost of the existing unit is unknown, use time of sale assumptions.

### DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed equipment must be a furnace with input energy less than 225,000 Btu/hr rated natural gas fired furnace with an Annual Fuel Utilization Efficiency (AFUE) rating and fan electrical efficiency exceeding the program requirements:

### DEFINITION OF BASELINE EQUIPMENT

Time of Sale: Although the current Federal Standard for gas furnaces is an AFUE rating of 78%, based upon review of available product in the AHRI database, the baseline efficiency for this characterization is assumed to be 80%. The baseline will be adjusted when the Federal Standard is updated.

Early replacement: The baseline for this measure is the efficiency of the existing equipment for the assumed remaining useful life of the unit and a new baseline unit for the remainder of the measure life. As discussed above we estimate that the new baseline unit that could be purchased in the year the existing unit would have needed replacing is 90%

Note: a new Federal Standard will become effective January 1, 2023 and be applicable to all gas furnaces.

[355] The Technical Advisory Committee agreed that if the cost of repair is less than 20% of the new baseline replacement cost it can be considered early replacement. Note the non-inflated cost is used as this would be a cost consideration in the program year.

### DEFINITION OF MEASURE LIFE

The expected measure life is assumed to be 16.5 years[356]

Remaining life of existing equipment is assumed to be 5.5 years[357].

### DEEMED MEASURE COST

Time of Sale: The incremental capital cost for this measure depends on efficiency as listed below[358]:

| AFUE | Installation Cost | Incremental Install Cost |
|---|---|---|
| 80% | $2011 | n/a |
| 90% | $2641 | $630 |
| 91% | $2727 | $716 |
| 92% | $2813 | $802 |
| 93% | $3049 | $1,038 |
| 94% | $3286 | $1,275 |
| 95% | $3522 | $1,511 |
| 96% | $3758 | $1,747 |

Early Replacement: The full installation cost is provided in the table above. The assumed deferred cost (after 5.5 years) of replacing existing equipment with a new baseline unit is assumed to be $2876[359]. This cost should be discounted to present value using the nominal discount rate.

### LOADSHAPE

N/A

### COINCIDENCE FACTOR

N/A

## Algorithm

### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

ΔkWh = Heating Savings + Cooling Savings + Shoulder Season Savings

Where:

Heating Savings = Brushless DC motor or Electronically commutated motor (ECM)
= 418 kWh[360]

Cooling Savings = Brushless DC motor or electronically commutated motor (ECM) savings during cooling season

[356] Average of 15-18 year lifetime estimate made by the Consortium for Energy Efficiency in 2010.
[357] Assumed to be one third of effective useful life
[358] Based on data from Appendix E of the US DOE Appliance Standards Technical Support Documents including equipment cost and installation labor. Where efficiency ratings are not provided, the values are interpolated from those that are.
[359] $2641 inflated using 1.91% rate.
[360] To estimate heating, cooling and shoulder season savings for Illinois, VEIC adapted results from a 2009 Focus on Energy study of BPM blower motor savings in Wisconsin. This study included effects of behavior change based on the efficiency of new motor greatly increasing the amount of people that run the fan continuously. The savings from the Wisconsin study were adjusted to account for different run hour assumptions (average values used) for Illinois. See: FOE to IL Blower Savings.xlsx.

If air conditioning = 263 kWh

If no air conditioning = 175 kWh

If unknown (weighted average)= 241 kWh[361]

Shoulder Season Savings = Brushless DC motor or electronically commutated motor (ECM) savings during shoulder seasons

= 51 kWh

**EXAMPLE**

For example, a blower motor in a low rise office building where air conditioning presence is unknown:

ΔkWh = Heating Savings + Cooling Savings + Shoulder Season Savings

= 418 +241 + 51

= 710 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

For units that have evaporator coils and condensing units and are cooling in the summer in addition to heating in the winter the summer coincident peak demand savings should be calculated. If the unit is not equipment with coils or condensing units, the summer peak demand savings will not apply.

ΔkW = (CoolingSavings/HOURSyear) * CF

Where:

HOURSyear = Actual hours per year if known, otherwise use hours from Table below for building type[362].

| Building Type | HOURSyear | Model source |
|---|---|---|
| Assembly | 2150 | eQuest |
| Assisted Living | 4373 | eQuest |
| College | 1605 | eQuest |
| Convenience Store | 2084 | eQuest |
| Elementary School | 3276 | eQuest |
| Garage | 2102 | eQuest |
| Grocery | 2096 | eQuest |
| Healthcare Clinic | 1987 | eQuest |
| High School | 3141 | eQuest |
| Hospital - VAV econ | 2788 | eQuest |
| Hospital - CAV econ | 2881 | eQuest |
| Hospital - CAV no econ | 8760 | eQuest |
| Hospital - FCU | 8729 | eQuest |
| Manufacturing Facility | 2805 | eQuest |
| MF - High Rise | 4237 | eQuest |
| MF - Mid Rise | 2899 | eQuest |
| Hotel/Motel – Guest | 4479 | eQuest |
| Hotel/Motel - Common | 8712 | eQuest |
| Movie Theater | 2120 | eQuest |

[361] The weighted average value is based on assumption that 75% of buildings installing BPM furnace blower motors have Central AC.

[362] Hours per year are estimated using the eQuest models as the total number of hours the cooling system is operating for each building type.

| Building Type | HOURSyear | Model source |
|---|---|---|
| Office - High Rise - VAV econ | 2038 | eQuest |
| Office - High Rise - CAV econ | 4849 | eQuest |
| Office - High Rise - CAV no econ | 5682 | eQuest |
| Office - High Rise - FCU | 3069 | eQuest |
| Office - Low Rise | 2481 | eQuest |
| Office - Mid Rise | 3036 | OpenStudio |
| Religious Building | 2830 | eQuest |
| Restaurant | 3350 | eQuest |
| Retail - Department Store | 2528 | eQuest |
| Retail - Strip Mall | 2266 | eQuest |
| Warehouse | 770 | eQuest |
| Unknown | 2718 | n/a |

CF =Summer Peak Coincidence Factor for measure is provided below for different building types[363]:

| HVAC Pumps | CF |
|---|---|
| Assembly | 48.3% |
| Assisted Living | 52.9% |
| College | 14.2% |
| Convenience Store | 57.1% |
| Elementary School | 33.3% |
| Garage | 61.9% |
| Grocery | 47.5% |
| Healthcare Clinic | 61.9% |
| High School | 28.8% |
| Hospital - VAV econ | 57.6% |
| Hospital - CAV econ | 61.5% |
| Hospital - CAV no econ | 64.8% |
| Hospital - FCU | 60.9% |
| Manufacturing Facility | 43.3% |
| MF - High Rise - Common | 43.7% |
| MF - Mid Rise | 24.3% |
| Hotel/Motel - Guest | 62.9% |
| Hotel/Motel - Common | 64.6% |
| Movie Theater | 41.9% |
| Office - High Rise - VAV econ | 43.2% |
| Office - High Rise - CAV econ | 48.3% |
| Office - High Rise - CAV no econ | 50.3% |
| Office - High Rise - FCU | 46.2% |
| Office - Low Rise | 47.4% |
| Office - Mid Rise | 42.8% |
| Religious Building | 43.3% |
| Restaurant | 48.8% |
| Retail - Department Store | 50.5% |
| Retail - Strip Mall | 52.8% |
| Warehouse | 22.5% |
| Unknown | 42.4% |

363 Coincidence Factors are estimated using the eQuest models.

**EXAMPLE**

For example, a blower motor in a low rise office building where air conditioning presence is unknown:

ΔkW = (241 / 2481) * 0.474

= 0.05 kW

**NATURAL GAS ENERGY SAVINGS**

Time of Sale:

ΔTherms = EFLH * Capacity * ((AFUE(eff) – AFUE(base))/AFUE(base))/ 100,000 Btu/Therm

Early replacement[364]:

ΔTherms for remaining life of existing unit (1st 5.5 years):

ΔTherms = EFLH * Capacity * ((AFUE(eff) – AFUE(exist))/ AFUE(exist)) / 100,000 Btu/Therm

ΔTherms for remaining measure life (next 11 years):

ΔTherms = EFLH * Capacity * ((AFUE(eff) - AFUE(base))/AFUE(base)) / 100,000 Btu/Therm

Where:

EFLH = Equivalent Full Load Hours for heating are provided in section 4.4 HVAC End Use

Capacity = Nominal Heating Input Capacity Furnace Size (Btu/hr) for efficient unit not existing unit

= custom Furnace input capacity in Btu/hr

AFUE(exist) = Existing Furnace Annual Fuel Utilization Efficiency Rating

= Use actual AFUE rating where it is possible to measure or reasonably estimate.

If unknown, assume 64.4 AFUE% [365].

AFUE(base) = Baseline Furnace Annual Fuel Utilization Efficiency Rating

Dependent on program type as listed below[366]:

| Program Year | AFUE(base) |
|---|---|
| Time of Sale | 80% |
| Early Replacement | 90% |

AFUE(eff) = Efficent Furnace Annual Fuel Utilization Efficiency Rating.

= Actual. If Unknown, assume 95%[367]

[364] The two equations are provided to show how savings are determined during the initial phase of the measure (existing to efficient) and the remaining phase (new baseline to efficient). In practice, the screening tools used may either require a First Year savings (using the first equation) and then a "number of years to adjustment" and "savings adjustment" input which would be the (new base to efficient savings)/(existing to efficient savings).

[365] Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren PY3-PY4.

[366] Though the Federal Minimum AFUE is 78%, there were only 50 models listed in the AHRI database at that level. At AFUE 79% the total rises to 308. There are 3,548 active furnace models listed with AFUE ratings between 78 and 80.

[367]Minimum ENERGY STAR efficiency after 2.1.2012.

**EXAMPLE**

ΔTherms = 1428 * 150,000 * ((0.92-0.80)/0.80)/ 100,000

= 321 Therms

## WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

## DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

**MEASURE CODE: CI-HVC-FRNC-V08-190101**

**REVIEW DEADLINE: 1/1/2022**

## 4.4.12 Infrared Heaters (all sizes), Low Intensity

**DESCRIPTION**

This measure applies to natural gas fired low-intensity infrared heaters with an electric ignition that use non-conditioned air for combustion

This measure was developed to be applicable to the following program types: TOS, NC. If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

To qualify for this measure the installed equipment must be a natural gas heater with an electric ignition that uses non-conditioned air for combustion

**DEFINITION OF BASELINE EQUIPMENT**

The baseline equipment is a standard natural gas fired heater warm air heater.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected measure life is assumed to be 12 years[368]

**DEEMED MEASURE COST**

The incremental capital cost for this measure is $1716[369]

**LOADSHAPE**

N/A

**COINCIDENCE FACTOR**

N/A

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

N/A

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

N/A

**NATURAL GAS ENERGY SAVINGS**

The annual natural gas energy savings from this measure is a deemed value equaling 451 Therms[370]

[368]ENERGY STAR and CEE do not currently provide calculators for this type of equipment therefore deemed values from Nicor Gas were used. Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562, May 27, 2011

[369]Ibid.

[370]Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562, May 27, 2011. These deemed values should be compared to PY evaluation and revised as necessary.

### Water Impact Descriptions and Calculation

N/A

### Deemed O&M Cost Adjustment Calculation

N/A

**Measure Code: CI-HVC-IRHT-V01-190101**

**Review Deadline: 1/1/2022**

## 4.4.13 Package Terminal Air Conditioner (PTAC) and Package Terminal Heat Pump (PTHP)

### Description

A PTAC is a packaged terminal air conditioner that cools and sometimes provides heat through an electric resistance heater (heat strip). A PTHP is a packaged terminal heat pump. A PTHP uses its compressor year round to heat or cool. In warm weather, it efficiently captures heat from inside your building and pumps it outside for cooling. In cool weather, it captures heat from outdoor air and pumps it into your home, adding heat from electric heat strips as necessary to provide heat.

This measure characterizes:

a) Time of Sale: the purchase and installation of a new efficient PTAC or PTHP.

b) Early Replacement: the early removal of an existing PTAC or PTHP from service, prior to its natural end of life, and replacement with a new efficient PTAC or PTHP unit. Savings are calculated between existing unit and efficient unit consumption during the remaining life of the existing unit, and between new baseline unit and efficient unit consumption for the remainder of the measure life. The measure is only valid for non-fuel switching installations – for example replacing a cooling only PTAC with a PTHP can currently not use the TRM.

This measure was developed to be applicable to the following program types: TOS NC, EREP. If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

In order for this characterization to apply, the efficient equipment is assumed to be PTACs or PTHPs that exceed baseline efficiencies.

### Definition of Baseline Equipment

Time of Sale: the baseline condition is equipment that meets the Code energy efficiency requirements (IECC or Code of Federal Regulations whichever is higher) in effect on the date of equipment purchase (if date is unknown, assume current Code minimum).

Early Replacement: the baseline is the existing PTAC or PTHP for the assumed remaining useful life of the unit and the new baseline as defined above for the remainder of the measure life.

### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 8 years. [371]

Remaining life of existing equipment is assumed to be 3 years[372]

### Deemed Measure Cost

Time of Sale: The incremental capital cost for this equipment is estimated to be $84/ton.[373]

Early Replacement: The measure cost is the full cost of removing the existing unit and installing a new one. The actual program cost should be used. If unknown assume $1,047 per ton[374].

[371] Based on 2015 DOE Technical Support Document, as recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.
[372]Standard assumption of one third of effective useful life.
[373] DEER 2008. This assumes that baseline shift from IECC 2012 to IECC 2015 carries the same incremental costs. Values should be verified during evaluation
[374] Based on DCEO – IL PHA Efficient Living Program data.

The assumed deferred cost (after 5 years) of replacing existing equipment with new baseline unit is assumed to be \$1,039 per ton[375]. This cost should be discounted to present value using the nominal discount rate.

### LOADSHAPE

Loadshape C03 - Commercial Cooling

### COINCIDENCE FACTOR

The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the *average* savings over the defined summer peak period, and is presented so that savings can be bid into PJM's Forward Capacity Market. Both values provided are based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren.

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [376]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [377]

## Algorithm

### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

Electric savings for PTACs and PTHPs should be calculated using the following algorithms

### ENERGY SAVINGS

Time of Sale:

PTAC ΔkWh[378] $= \text{Annual kWh Savings}_{cool}$

PTHP ΔkWh $= \text{Annual kWh Savings}_{cool} + \text{Annual kWh Savings}_{heat}$

$\text{Annual kWh Savings}_{cool} = (kBtu/hr_{cool}) * [(1/EERbase) – (1/EERee)] * EFLH_{cool}$

$\text{Annual kWh Savings}_{heat} = (kBtu/hr_{heat})/3.412 * [(1/COPbase) – (1/COPee)] * EFLH_{heat}$

Early Replacement:

ΔkWh for remaining life of existing unit (1st 5years) $= \text{Annual kWh Savings}_{cool} + \text{Annual kWh Savings}_{heat}$

$\text{Annual kWh Savings}_{cool} = (kBtu/hr_{cool}) * [(1/EERexist) – (1/EERee)] * EFLH_{cool}$

$\text{Annual kWh Savings}_{heat} = (kBtu/hr_{heat})/3.412 * [(1/COPexist) – (1/COPee)] * EFLH_{heat}$

ΔkWh for remaining measure life (next 10 years) $= \text{Annual kWh Savings}_{cool} + \text{Annual kWh Savings}_{heat}$

$\text{Annual kWh Savings}_{cool} = (kBtu/hr_{cool}) * [(1/EERbase) – (1/EERee)] * EFLH_{cool}$

---

375 Based on subtracting TOS incremental cost from the DCEO data and incorporating inflation rate of 1.91%.
376 Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility's peak hour is divided by the maximum AC load during the year.
377 Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year
378 There are no heating efficiency improvements for PTACs since although some do provide heating, it is always through electric resistance and therefore the COPbase and COPee would be 1.0.

Annual kWh $Savings_{heat}$ = $(kBtu/hr_{heat})/3.412 * [(1/COPbase) – (1/COPee)] * EFLH_{heat}$

Where:

$kBtu/hr_{cool}$ = capacity of the cooling equipment in kBtu per hour (1 ton of cooling capacity equals 12 kBtu/hr).

= Actual installed

$EFLH_{cool}$ = Equivalent Full Load Hours for cooling are provided in section 4.4 HVAC End Use:

$EFLH_{heat}$ = Equivalent Full Load Hours for heating are provided in section 4.4 HVAC End Use

EERexist = Energy Efficiency Ratio of the existing equipment

= Actual. If unknown assume 8.1 EER[379]

EERbase = Energy Efficiency Ratio of the baseline equipment; see the table below for values.

= Based on applicable Code on date of equipment purchase(if unknown assume current Code

***Copy of Table C403.2.3(3): Minimum Efficiency Reguirements: Electrically operated packaged terminal air conditioners, packaged terminal heat pumps***

| Equipment Type | IECC 2012 Minimum Efficiency (baseline effective 1/1/2013) | IECC 2015/2018 Minimum Efficiency (baseline effective 1/1/2016) | Federal Regulations Minimum Efficiency (baseline effective 1/1/2019) |
|---|---|---|---|
| PTAC (Cooling mode) New Construction | 13.8 – (0.300 x Cap/1000) EER | 14.0 – (0.300 x Cap/1000) EER | 14.0 – (0.300 x Cap/1000) EER Compliance date: 1/1/2017 |
| PTAC (Cooling mode) Replacements | 10.9 – (0.213 x Cap/1000) EER | 10.9 – (0.213 x Cap/1000) EER | 10.9 – (0.213 x Cap/1000) EER Compliance date: 10/7/2010 |
| PTHP (Cooling mode) New Construction | 14.0 – (0.300 x Cap/1000) EER | 14.0 – (0.300 x Cap/1000) EER | 14.0 – (0.300 x Cap/1000) EER Complainace date: 10/8/2012 |
| PTHP (Cooling mode) Replacements | 10.8 – (0.213 x Cap/1000) EER | 10.8 – (0.213 x Cap/1000) EER | 10.8 – (0.213 x Cap/1000) EER Compliance date: 10/7/2010 |
| PTHP (Heating mode) New Construction | 3.2 – (0.026 x Cap/1000) COP | 3.2 – (0.026 x Cap/1000) COP | 3.7 – (0.052 x Cap/1000) COP Compliance date: 10/8/2012 |
| PTHP (Heating mode) Replacements | 2.9 – (0.026 x Cap/1000) COP | 2.9 – (0.026 x Cap/1000) COP | 2.9 – (0.026 x Cap/1000) COP Compliance date: 10/7/2010 |

[379] Estimated using the 2000 IECC building energy code, for equipment up until year 2003, p107, and assuming a 1 ton unit; EER = 10 – (0.16 * 12,000/1,000) = 8.1.

**Table notes: "Cap" = The rated cooling capacity of the project in Btu/hr. If the units capacity is less than 7000 Btu/hr, use 7,000 Btu/hr in the calculation. If the unit's capacity is greater than 15,000 Btu/hr, use 15,000 Btu/hr in the calculations.**

**Replacement unit shall be factory labeled as follows "MANUFACTURED FOR REPLACEMENT APPLICATIONS ONLY; NOT TO BE INSTALLED IN NEW CONSTRUCTION PROJECTS", Replacement efficiencies apply only to units with existing sleeves less than 16 inches (406mm) in height and less than 42 inches (1067 mm) in width.**

EERee = Energy Efficiency Ratio of the energy efficient equipment. For air-cooled units < 65 kBtu/hr, if the actual EERee is unknown, assume the following conversion from SEER to EER for calculation of peak savings[380]: EER = (-0.02 * SEER$^2$) + (1.12 * SEER)

= Actual installed

$kBtu/hr_{heat}$ = capacity of the heating equipment in kBtu per hour.

= Actual installed

3.412 = Btu per Wh.

COPexist = coefficient of performance of the existing equipment

= Actual. If unknown assume 1.0 COP for PTAC units and 2.6 COP[381] for PTHPs.

COPbase = coefficient of performance of the baseline equipment; see table above for values.

COPee = coefficient of performance of the energy efficient equipment.

= Actual installed

**EXAMPLE:**

Time of Sale (assuming new construction baseline):

For example a 1 ton PTAC with an efficient EER of 12 at a guest hotel in Rockford with a building permit dated before 1/1/2016 saves:

= [(12) * [(1/10.4) – (1/12)] * 1,042

= 160 kWh

Early Replacement (assuming replacement baseline for deferred replacement in 5 years):

For example a 1 ton PTHP with an efficient EER of 12, COP of 3.0 at a guest hotel in Rockford replaces a PTAC unit (with electric resistance heat) with unknown efficiency.

ΔkWh for remaining life of existing unit (1$^{st}$ 5years)

= (12 * (1/8.1 – 1/12) * 1,042) + (12/3.412 * (1/1.0 – 1/3.0) * 1,758)

= 502 + 4,122

= 4,624 kWh

ΔkWh for remaining measure life (next 10 years)

= (12 * (1/8.3 – 1/12) * 1,042) + (12/3.412 * (1/1.0 – 1/3.0) * 1,758)

= 465 + 4,122

= 34,587 kWh

## SUMMER COINCIDENT PEAK DEMAND SAVINGS

Time of Sale:

[380] Based on Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder. Note this is appropriate for single speed units only.

[381] Estimated using the 2000 IECC building energy code, for equipment up until year 2003, p107, and assuming a 1 ton unit; COP = 2.9 – (0.026 * 12,000/1,000) = 2.6

ΔkW = $(kBtu/hr_{cool})$ * [(1/EERbase) – (1/EERee)] *CF

Early Replacement:

ΔkW for remaining life of existing unit (1st 5years) = $(kBtu/hr_{cool})$ * [(1/EERexist) – (1/EERee)] *CF

ΔkW for remaining measure life (next 10 years) = $(kBtu/hr_{cool})$ * [(1/EERbase) – (1/EERee)] *CF

Where:

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [382]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [383]

**EXAMPLE**

Time of Sale:

For example a 1 ton replacement cooling unit with no heating with an efficient EER of 12 saves:

$\Delta kW_{SSP}$ = (12 * (1/10.4 – 1/12) *0.913

= 0.14 kW

For example a 1 ton PTHP with an efficient EER of 12, COP of 3.0 replacing a PTAC unit with unknown efficiency saves:

ΔkW for remaining life of existing unit (1st 5years):

$\Delta kW_{SSP}$ = 12 * (1/8.1 – 1/12) * 0.913

= 0.44 kW

ΔkW for remaining measure life (next 10 years):

$\Delta kW_{SSP}$ = 12 * (1/8.3 – 1/12) * 0.913

= 0.41 kW

## NATURAL GAS ENERGY SAVINGS

N/A

## WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

## DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

## MEASURE CODE: CI-HVC-PTAC-V09-190101

## REVIEW DEADLINE: 1/1/2022

[382] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility's peak hour is divided by the maximum AC load during the year.

[383] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year

## 4.4.14 Pipe Insulation

### DESCRIPTION

This measure provides rebates for installation of ≥1” or ≥2” fiberglass, foam, calcium silicate or other types of insulation with similar insulating properties to existing bare pipe on straight piping as well as other pipe components such as elbows, tees, valves, and flanges for all non-residential installations.

Default per linear foot savings estimates are provided for the both exposed indoor or above ground outdoor piping distributing fluid in the following system types (natural gas fired systems only):

- Hydronic heating systems (with or without outdoor reset controls), including:
    - boiler systems that do not circulate water around a central loop and operate upon demand from a thermostat (“non-recirculation”)
    - systems that recirculate during heating season only (“Recirculation – heating season only”)
    - systems recirculating year round (“Recirculation – year round”)
- Domestic hot water
- Low and high-pressure steam systems
    - non-recirculation
    - recirculation - heating season only
    - recirculation - year round

Process piping can also use the algorithms provided but requires custom entry of hours.

Minimum qualifying nominal pipe diameter is 1.” Indoor piping must have at least 1” of insulation and outdoor piping must have at least 2” of insulation and include an all-weather protective jacket. New advanced insulating materials may be thinner and savings can be calculated with 3E Plus.

This measure was developed to be applicable to the following program types: RF, DI

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

The efficient case is installing pipe wrap insulation to a length of pipe. Indoor piping must have at least 1” of insulation (or equivalent R-value) and outdoor piping must have at least 2” of insulation (or equivalent R-value) and include an all-weather protective jacket. Minimum qualifying pipe diameter is 1.” Insulation must be continuous and contiguous over fittings that directly connect to straight pipe, including elbows and tees.[384]

### DEFINITION OF BASELINE EQUIPMENT

The base case for savings estimates is a bare pipe. Pipes are required by new construction code to be insulated but are still commonly found uninsulated in older commercial buildings.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 15 years.[385]

[384] *ASHRAE Handbook—Fundamentals*, 23.14; Hart, G., “Saving energy by insulating pipe components on steam and hot water distribution systems”, *ASHRAE Journal*, October 2011

[385] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.

**DEEMED MEASURE COST**

Actual costs should be used if known. Otherwise the deemed measure costs below based on RS Means[386] pricing reference materials may be used.[387] The following table summarizes the estimated costs for this measure per foot of insulation added and include installation costs:

| Insulation Thickness | | |
|---|---|---|
| | 1 Inch (Indoor) | 2 Inches (Outdoor) |
| Pipe- RS Means # | 220719.10.5170 | 220719.10.5530 |
| Jacket- RS Means # | 220719.10.0156 | 220719.10.0320 |
| Jacket Type | PVC | Aluminum |
| Insulation Cost per foot | $9.40 | $13.90 |
| Jacket Cost per foot | $4.57 | $7.30 |
| **Total Cost per foot** | **$13.97** | **$21.20** |

**LOADSHAPE**

N/A

**COINCIDENCE FACTOR**

N/A

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

N/A

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

N/A

**NATURAL GAS SAVINGS**

Δtherms per foot[388] $= [((Q_{base} – Q_{eff}) * EFLH) / (100{,}000 * \eta Boiler)] * TRF$

= [Modeled or provided by tables below] * TRF

Δtherms $= (L_{sp} + L_{oc,i}) *$ Δtherms per foot

Where:

EFLH = Equivalent Full Load Hours for Heating

= Actual or defaults by building type provided in Section 4.4, HVAC end use

For year round recirculation or domestic hot water:

= 8,766

For heating season recirculation, hours with the outside air temperature below 55°F:

[386] RS Means 2008. Mechanical Cost Data, pages 106 to 119

[387] RS Means 2010: "for fittings, add 3 linear feet for each fitting plus 4 linear feet for each flange of the fitting"

[388] This value comes from the reference table "Savings Summary by Building Type and System Type." The formula and the input tables in this section document assumptions used in calculation spreadsheet "Pipe Insulation Savings 2013-11-12.xlsx"

| Zone | Hours |
|---|---|
| Zone 1 (Rockford) | 5,039 |
| Zone 2 (Chicago) | 4,963 |
| Zone 3 (Springfield) | 4,495 |
| Zone 4 (Belleville/ | 4,021 |
| Zone 5 (Marion) | 4,150 |
| Zone 1 (Rockford) | 5,039 |

$Q_{base}$ = Heat Loss from Bare Pipe (Btu/hr/ft)

= Calculated where possible using 3E Plusv4.0 software. For defaults see table below

$Q_{eff}$ = Heat Loss from Insulated Pipe (Btu/hr/ft)

= Calculated where possible using 3E Plusv4.0 software. For defaults see table below

100,000 = conversion factor (1 therm = 100,000 Btu)

ηBoiler = Efficiency of the boiler being used to generate the hot water or steam in the pipe

= Actual or if unknown use default values given below:

= 81.9% for water boilers [389]

= 80.7% for steam boilers, except multifamily low-pressure [390]

= 64.8% for multifamily low-pressure steam boilers [391]

TRF = Thermal Regain Factor for space type, applied only to space heating energy and is applied to values resulting from Δtherms/ft tables below [392]

= See table below for base TRF values by pipe location

May vary seasonally such as: TRF[summer] * summer hours + TRF[winter] * winter hours where TRF values reflecting summer and winter conditions are apportioned by the hours for those conditions. TRF may also be adjusted by building specific balance temperature and operating hours above and below that balance temperature.[393]

| Pipe Location | Assumed Regain | TRF, Thermal Regain Factor |
|---|---|---|
| Outdoor | 0% | 1.0 |
| Indoor, heated space | 85% | 0.15 |
| Indoor, semi- heated, (unconditioned space, with heat transfer to conditioned space. E.g.: boiler room, ceiling plenum, basement, crawlspace, wall) | 30% | 0.70 |

[389] Average efficiencies of units from the California Energy Commission (CEC).
[390] Ibid.
[391] Katrakis, J. and T.S. Zawacki. "Field-Measured Seasonal Efficiency of Intermediate-sized Low-Pressure Steam Boilers". ASHRAE V99, pt. 2, 1993.
[392] Thermal regain for *residential* pipe insulation measures is discussed in Home Energy Services Impact Evaluation, prepared for the Massachusetts Residential Retrofit and Low Income Program Area Evaluation, Cadmus Group, Inc., August 2012 and Andrews, John, Better Duct Systems for Home Heating and Cooling, U.S. Department of Energy, 2001. Recognizing the differences between residential and commercial heating systems, the factors have been adjusted based on professional judgment. This factor would benefit from additional study and evaluation.
[393] Thermal Regain Factor_4-30-14.docx

| Pipe Location | Assumed Regain | TRF, Thermal Regain Factor |
|---|---|---|
| Indoor, unheated, (no heat transfer to conditioned space) | 0% | 1.0 |
| Location not specified | 85% | 0.15 |
| Custom | Custom | 1 – assumed regain |

$L_{sp}$ = Length of straight pipe to be insulated (linear foot)

= actual installed ((linear foot)

$L_{oc,I}$ = Total equivalent length of the other components (valves and tees) of pipe to be insulated

= Actual installed (linear foot). See table "Equivalent Length of Other Components – Elbows and Tees" for equivalent lengths.

The heat loss estimates ($Q_{base}$ and $Q_{eff}$) were developed using the 3E Plus v4.0 software program.[394] The energy savings analysis is based on adding 1-inch (indoor) or 2-inch (outdoor) thick insulation around bare pipe. The thermal conductivity of pipe insulation varies by material and temperature rating; to obtain a typical value, a range of materials allowed for this measure were averaged. For insulation materials not in the table below, use 3E Plusv4.0 software to calculate $Q_{base}$ and $Q_{eff.}$

| Insulation Type | Conductivity (Btu.in / hr.ft$^2$.ºF @ 75F) | Max temp (ºF) |
|---|---|---|
| Polyethylene foam | 0.25 | 200 |
| Flexible polyurethane-based foam | 0.27 | 200 |
| Fiberglass | 0.31 | 250 |
| Melamine foam | 0.26 | 350 |
| Flexible silicon foam | 0.40 | 392 |
| Calcium silicate | 0.40 | 1200 |
| Cellular glass | 0.31 | 400 |
| Average conductivity of all these materials (Btu.in / hr.ft$^2$.ºF @ 75ºF) | 0.31 | |

The pipe fluid temperature assumption used depends upon both the system type and whether there is outdoor reset controls:

| System Type | Fluid temperature assumption (°F) |
|---|---|
| Hot Water space heating with outdoor reset - Non recirculation | 145 |
| Hot Water space heating without outdoor reset - Non recirculation | 170 |
| Hot Water space heating with outdoor reset – Recirculation heating season only | 145 |
| Hot Water space heating without outdoor reset – Recirculation heating season only | 170 |
| Hot Water space heating with outdoor reset – Recirculation year round | 130 |
| Hot Water space heating without outdoor reset – Recirculation year round | 170 |
| Domestic Hot Water | 125 |
| Low Pressure Steam | 225 |
| High Pressure Steam | 312 |

[394] 3E Plus is a heat loss calculation software provided by the NAIMA (North American Insulation Manufacturer Association).

| | Indoor Insulation, Hot Water | Indoor Insulation, Low Pressure Steam | Indoor Insulation, High Pressure Steam | Domestic Hot Water | Outdoor Insulation, Hot Water | Outdoor Insulation, Low Pressure Steam | Outdoor Insulation, High Pressure Steam |
|---|---|---|---|---|---|---|---|
| Insulation thickness (inch) | 1 | 1 | 1 | 1 | 2 | 2 | 2 |
| Temperature, Fluid in Pipe (ºF) | 170 (w/o reset)<br>145 (w/ reset heat)<br>130 (w/reset year) | 225 | 312 | 125 | 170 (w/o reset)<br>145 (w/ reset heat)<br>130 (w/reset year) | 225 | 312 |
| Av. steam pressure (psig) | n/a | 10.9 | 82.8 | n/a | n/a | 10.9 | 82.8 |
| Operating Time (hrs/yr) | 2,746 (non-recirc)<br>5,039 (recirc heating season)<br>8,760 (recirc year round) | | | | | | |
| Ambient Temperature (ºF)[395] | 75 | 75 | 75 | 75 | 48.6 | 48.6 | 48.6 |
| Wind speed (mph)[396] | 0 | 0 | 0 | 0 | 9.4 | 9.4 | 9.4 |
| **Pipe parameters** | | | | | | | |
| Pipe material | Copper | Steel | Steel | Copper | Copper | Steel | Steel |
| Pipe size for Heat Loss Calc | 2” | 2” | 2” | 2” | 2” | 2” | 2” |
| Outer Diameter, Pipe, actual | 2.38” | 2.38” | 2.38” | 2.38” | 2.38” | 2.38” | 2.38” |
| Heat Loss, Bare Pipe (from 3EPlus) (Btu/hr.ft) | 114 (w/o reset)<br>78 (w/ reset heat)<br>58 (w/reset year) | 232 | 432 | 52 | 460 (w/o reset)<br>363 (w/ reset heat)<br>306 (w/reset year) | 710 | 1101 |
| **Insulation parameters** | | | | | | | |
| Outer diameter, insulation | 4.38” | 4.38” | 4.38” | 4.38” | 4.38” | 4.38” | 4.38” |
| Average Heat Loss, Insulation (from 3EPlus) (Btu/hr.ft) | 24 (w/o reset)<br>17 (w/ reset heat)<br>13 (w/reset year) | 40 | 70 | 13.25 | 21 (w/o reset)<br>16 (w/ reset heat)<br>13 (w/reset year) | 32 | 52 |
| **Annual Energy Savings** | | | | | | | |
| Boiler / Water Heater efficiency | 81.9% | 80.7% (64.8% for MF) | 80.7% | 67% | 81.9% | 80.7% (64.8% for MF) | 80.7% |
| Annual Gas Use, Base Case (therms/yr/ft) | 3.8 (w/o reset)<br>4.8 (w/ reset heat)<br>6.2 (w/reset year) | 7.9 (non recirc)<br>14.5 (recirc heat)<br>25.2 (recirc year) | 14.7 (non recirc)<br>27.0 (recirc heat)<br>46.9 (recirc year) | 6.76 | 15.4 (w/o reset)<br>22.5 (w/ reset heat)<br>32.7 (w/reset year) | 24.1 (non recirc)<br>44.3 (recirc heat)<br>77.0 (recirc year) | 37.5 (non recirc)<br>68.7 (recirc heat)<br>119.5 (recirc year) |
| Annual Gas Use, Measure case (therms/yr/ft) | 0.8 (w/o reset)<br>1.1 (w/ reset heat)<br>1.4 (w/reset year) | 1.4 (non recirc)<br>2.5 (recirc heat)<br>4.4 (recirc year) | 2.4 (non recirc)<br>4.4 (recirc heat)<br>7.6 (recirc year) | 1.73 | 0.7 (w/o reset)<br>1.0 (w/ reset heat)<br>1.4 (w/reset year) | 1.1 (non recirc)<br>2.0 (recirc heat)<br>3.4 (recirc year) | 1.8 (non recirc)<br>3.2 (recirc heat)<br>5.6 (recirc year) |
| Annual Gas Savings (therms/yr/ft) | 3.0 (w/o reset)<br>3.7 (w/ reset heat)<br>4.8 (w/reset year) | 6.5 (non recirc)<br>12.0 (recirc heat)<br>20.8 (recirc year) | 12.3 (non recirc)<br>22.6 (recirc heat)<br>39.3 (recirc year) | 5.0 | 14.7 (w/o reset)<br>21.4 (w/ reset heat)<br>31.3 (w/reset year) | 23.1 (non recirc)<br>42.3 (recirc heat)<br>73.6 (recirc year) | 35.7 (non recirc)<br>65.5 (recirc heat)<br>113.9 (recirc year) |

Heat = heating season only, year = year round

[395] DOE Weather Data, TMY3 (Typical Meteorological Year), developed by NREL for the average ambient temperature for Aurora, IL. Ibid.
[396] Ibid.

Values below must be multiplied by the appropriate Thermal Regain Factor (TRF). All variables were the same except for hours of operation in the calculation of the default savings per foot for the various building types and applications as presented in the table below:

**Savings Summary for Indoor pipe insulation by System Type and Building Type (Δtherms per foot) (continues for 3.5 pages)**

| | | | Annual therm Savings per linear foot (therm /ft) (2" pipe / 1" insulation for hot water, 2" insulation for steam) | | | | |
|---|---|---|---|---|---|---|---|
| Location | System Type | Building Type | Zone 1 (Rockford) | Zone 2 (Chicago) | Zone 3 (Springfield) | Zone 4 (Belleville) | Zone 5 (Marion) |
| Indoor | Hot Water Space Heating with outdoor reset – non-recirculation | Assembly | 1.32 | 1.36 | 1.21 | 0.81 | 1.24 |
| | | Assisted Living | 1.25 | 1.22 | 1.07 | 0.79 | 0.95 |
| | | College | 1.13 | 1.06 | 0.95 | 0.53 | 0.63 |
| | | Convenience Store | 1.10 | 1.01 | 0.90 | 0.65 | 0.72 |
| | | Elementary School | 1.32 | 1.29 | 1.13 | 0.78 | 0.95 |
| | | Garage | 0.73 | 0.72 | 0.63 | 0.50 | 0.56 |
| | | Grocery | 1.19 | 1.19 | 1.04 | 0.65 | 0.78 |
| | | Healthcare Clinic | 1.17 | 1.20 | 1.05 | 0.71 | 0.75 |
| | | High School | 1.37 | 1.38 | 1.23 | 0.88 | 1.03 |
| | | Hospital - CAV no econ | 1.31 | 1.35 | 1.15 | 0.99 | 1.12 |
| | | Hospital - CAV econ | 1.33 | 1.37 | 1.17 | 1.01 | 1.15 |
| | | Hospital - VAV econ | 0.54 | 0.51 | 0.39 | 0.23 | 0.25 |
| | | Hospital - FCU | 0.98 | 1.12 | 0.91 | 1.07 | 1.44 |
| | | Hotel/Motel | 1.31 | 1.27 | 1.14 | 0.78 | 0.96 |
| | | Hotel/Motel - Common | 1.19 | 1.21 | 1.15 | 0.93 | 0.98 |
| | | Hotel/Motel - Guest | 1.30 | 1.26 | 1.13 | 0.75 | 0.93 |
| | | Manufacturing Facility | 0.78 | 0.75 | 0.70 | 0.42 | 0.47 |
| | | MF - High Rise | 1.13 | 1.12 | 1.02 | 0.87 | 0.87 |
| | | MF - High Rise - Common | 1.35 | 1.31 | 1.17 | 0.81 | 1.04 |
| | | MF - High Rise - Residential | 1.09 | 1.08 | 0.99 | 0.85 | 0.83 |
| | | MF - Mid Rise | 1.23 | 1.25 | 1.07 | 0.79 | 0.90 |
| | | Movie Theater | 1.35 | 1.33 | 1.24 | 0.94 | 1.12 |
| | | Office - High Rise - CAV no econ | 1.50 | 1.52 | 1.38 | 0.93 | 1.01 |
| | | Office - High Rise - CAV econ | 1.55 | 1.58 | 1.45 | 1.00 | 1.10 |
| | | Office - High Rise - VAV econ | 1.13 | 1.15 | 0.95 | 0.56 | 0.63 |
| | | Office - High Rise - FCU | 0.83 | 0.82 | 0.71 | 0.37 | 0.39 |
| | | Office - Low Rise | 1.06 | 1.06 | 0.84 | 0.51 | 0.59 |
| | | Office - Mid Rise | 1.17 | 1.18 | 0.99 | 0.63 | 0.70 |
| | | Religious Building | 1.19 | 1.11 | 1.07 | 0.78 | 0.89 |
| | | Restaurant | 1.00 | 1.00 | 0.90 | 0.68 | 0.81 |
| | | Retail - Department Store | 1.03 | 0.95 | 0.89 | 0.58 | 0.66 |
| | | Retail - Strip Mall | 0.99 | 0.91 | 0.81 | 0.56 | 0.60 |
| | | Warehouse | 1.08 | 1.01 | 1.04 | 0.65 | 0.80 |
| | | Unknown | 1.15 | 1.14 | 1.01 | 0.73 | 0.84 |
| | Hot Water Space Heating without outdoor reset – non-recirculation | Assembly | 1.96 | 2.00 | 1.79 | 1.19 | 1.83 |
| | | Assisted Living | 1.84 | 1.80 | 1.58 | 1.16 | 1.40 |
| | | College | 1.67 | 1.56 | 1.40 | 0.78 | 0.93 |
| | | Convenience Store | 1.62 | 1.50 | 1.33 | 0.95 | 1.06 |
| | | Elementary School | 1.95 | 1.90 | 1.68 | 1.16 | 1.40 |
| | | Garage | 1.08 | 1.06 | 0.93 | 0.74 | 0.82 |

| Location | System Type | Building Type | Annual therm Savings per linear foot (therm /ft) (2" pipe / 1" insulation for hot water, 2" insulation for steam) Zone 1 (Rockford) | Zone 2 (Chicago) | Zone 3 (Springfield) | Zone 4 (Belleville) | Zone 5 (Marion) |
|---|---|---|---|---|---|---|---|
| | | Grocery | 1.76 | 1.75 | 1.54 | 0.96 | 1.15 |
| | | Healthcare Clinic | 1.73 | 1.77 | 1.55 | 1.05 | 1.11 |
| | | High School | 2.02 | 2.03 | 1.82 | 1.30 | 1.52 |
| | | Hospital - CAV no econ | 1.93 | 1.99 | 1.69 | 1.46 | 1.65 |
| | | Hospital - CAV econ | 1.96 | 2.03 | 1.73 | 1.50 | 1.70 |
| | | Hospital - VAV econ | 0.80 | 0.76 | 0.57 | 0.34 | 0.37 |
| | | Hospital - FCU | 1.45 | 1.65 | 1.35 | 1.58 | 2.13 |
| | | Hotel/Motel | 1.93 | 1.87 | 1.69 | 1.16 | 1.41 |
| | | Hotel/Motel - Common | 1.75 | 1.78 | 1.69 | 1.38 | 1.45 |
| | | Hotel/Motel - Guest | 1.92 | 1.86 | 1.66 | 1.11 | 1.37 |
| | | Manufacturing Facility | 1.15 | 1.11 | 1.03 | 0.62 | 0.69 |
| | | MF - High Rise | 1.67 | 1.65 | 1.50 | 1.28 | 1.28 |
| | | MF - High Rise - Common | 1.99 | 1.93 | 1.73 | 1.19 | 1.54 |
| | | MF - High Rise - Residential | 1.61 | 1.60 | 1.46 | 1.26 | 1.23 |
| | | MF - Mid Rise | 1.82 | 1.84 | 1.59 | 1.17 | 1.33 |
| | | Movie Theater | 1.99 | 1.96 | 1.83 | 1.39 | 1.66 |
| | | Office - High Rise - CAV no econ | 2.21 | 2.24 | 2.04 | 1.37 | 1.49 |
| | | Office - High Rise - CAV econ | 2.29 | 2.33 | 2.14 | 1.48 | 1.63 |
| | | Office - High Rise - VAV econ | 1.67 | 1.70 | 1.40 | 0.83 | 0.93 |
| | | Office - High Rise - FCU | 1.22 | 1.21 | 1.04 | 0.55 | 0.58 |
| | | Office - Low Rise | 1.56 | 1.56 | 1.24 | 0.76 | 0.87 |
| | | Office - Mid Rise | 1.73 | 1.74 | 1.47 | 0.94 | 1.04 |
| | | Religious Building | 1.75 | 1.65 | 1.58 | 1.15 | 1.32 |
| | | Restaurant | 1.48 | 1.48 | 1.33 | 1.01 | 1.19 |
| | | Retail - Department Store | 1.52 | 1.40 | 1.31 | 0.85 | 0.97 |
| | | Retail - Strip Mall | 1.46 | 1.35 | 1.19 | 0.82 | 0.89 |
| | | Warehouse | 1.59 | 1.49 | 1.53 | 0.96 | 1.18 |
| | | Unknown | 1.70 | 1.68 | 1.50 | 1.07 | 1.25 |
| | Hot Water with outdoor reset | All buildings, Recirculation heating season only (Hours below 55F) | 3.73 | 3.68 | 3.33 | 2.98 | 3.08 |
| | Hot Water w/o outdoor reset | All buildings, Recirculation heating season only (Hours below 55F) | 5.51 | 5.43 | 4.92 | 4.40 | 4.54 |
| | Hot Water with outdoor reset | All buildings, Recirculation year round (All hours) | 4.79 | 4.79 | 4.79 | 4.79 | 4.79 |
| | Hot Water w/o outdoor reset | All buildings, Recirculation year round (All hours) | 9.58 | 9.58 | 9.58 | 9.58 | 9.58 |
| | Domestic Hot Water | DHW circulation loop | 5.02 | 5.02 | 5.02 | 5.02 | 5.02 |
| | LP Steam – non-recirculation | Assembly | 4.25 | 4.36 | 3.89 | 2.59 | 3.97 |
| | | Assisted Living | 4.01 | 3.92 | 3.44 | 2.53 | 3.04 |
| | | College | 3.64 | 3.40 | 3.04 | 1.69 | 2.02 |
| | | Convenience Store | 3.52 | 3.26 | 2.89 | 2.07 | 2.32 |
| | | Elementary School | 4.24 | 4.13 | 3.64 | 2.52 | 3.05 |
| | | Garage | 2.34 | 2.31 | 2.03 | 1.62 | 1.79 |
| | | Grocery | 3.83 | 3.81 | 3.34 | 2.08 | 2.49 |
| | | Healthcare Clinic | 3.76 | 3.85 | 3.36 | 2.29 | 2.42 |

| Location | System Type | Building Type | Annual therm Savings per linear foot (therm /ft) (2" pipe / 1" insulation for hot water, 2" insulation for steam) Zone 1 (Rockford) | Zone 2 (Chicago) | Zone 3 (Springfield) | Zone 4 (Belleville) | Zone 5 (Marion) |
|---|---|---|---|---|---|---|---|
| | | High School | 4.39 | 4.42 | 3.96 | 2.82 | 3.30 |
| | | Hospital - CAV no econ | 4.20 | 4.33 | 3.69 | 3.17 | 3.60 |
| | | Hospital - CAV econ | 4.25 | 4.41 | 3.76 | 3.26 | 3.70 |
| | | Hospital - VAV econ | 1.74 | 1.65 | 1.24 | 0.75 | 0.81 |
| | | Hospital - FCU | 3.15 | 3.60 | 2.93 | 3.44 | 4.63 |
| | | Hotel/Motel | 4.19 | 4.07 | 3.67 | 2.51 | 3.07 |
| | | Hotel/Motel - Common | 3.81 | 3.87 | 3.68 | 3.00 | 3.15 |
| | | Hotel/Motel - Guest | 4.18 | 4.05 | 3.62 | 2.42 | 2.98 |
| | | Manufacturing Facility | 2.49 | 2.41 | 2.23 | 1.35 | 1.51 |
| | | MF - High Rise | 4.52 | 4.46 | 4.07 | 3.46 | 3.47 |
| | | MF - High Rise - Common | 5.38 | 5.22 | 4.68 | 3.23 | 4.17 |
| | | MF - High Rise - Residential | 4.37 | 4.34 | 3.94 | 3.41 | 3.33 |
| | | MF - Mid Rise | 4.94 | 4.99 | 4.30 | 3.16 | 3.60 |
| | | Movie Theater | 4.33 | 4.26 | 3.98 | 3.03 | 3.61 |
| | | Office - High Rise - CAV no econ | 4.81 | 4.88 | 4.45 | 2.98 | 3.24 |
| | | Office - High Rise - CAV econ | 4.97 | 5.07 | 4.66 | 3.21 | 3.54 |
| | | Office - High Rise - VAV econ | 3.64 | 3.71 | 3.06 | 1.81 | 2.01 |
| | | Office - High Rise - FCU | 2.66 | 2.62 | 2.27 | 1.20 | 1.26 |
| | | Office - Low Rise | 3.40 | 3.39 | 2.69 | 1.65 | 1.89 |
| | | Office - Mid Rise | 3.77 | 3.78 | 3.19 | 2.03 | 2.26 |
| | | Religious Building | 3.82 | 3.58 | 3.43 | 2.51 | 2.87 |
| | | Restaurant | 3.21 | 3.22 | 2.89 | 2.19 | 2.60 |
| | | Retail - Department Store | 3.31 | 3.04 | 2.86 | 1.86 | 2.12 |
| | | Retail - Strip Mall | 3.17 | 2.94 | 2.59 | 1.79 | 1.93 |
| | | Warehouse | 3.46 | 3.23 | 3.33 | 2.08 | 2.56 |
| | | Unknown | 3.70 | 3.66 | 3.26 | 2.34 | 2.71 |
| | LP Steam | All buildings, Recirculation heating season only (Hours below 55F) | 11.99 | 11.81 | 10.70 | 9.57 | 9.88 |
| | LP Steam | All buildings, Recirculation year round (All hours) | 20.84 | 20.84 | 20.84 | 20.84 | 20.84 |
| | HP Steam – non-recirculation | Assembly | 8.02 | 8.22 | 7.34 | 4.89 | 7.49 |
| | | Assisted Living | 7.56 | 7.39 | 6.49 | 4.77 | 5.73 |
| | | College | 6.87 | 6.42 | 5.73 | 3.18 | 3.81 |
| | | Convenience Store | 6.65 | 6.14 | 5.45 | 3.91 | 4.37 |
| | | Elementary School | 8.00 | 7.79 | 6.87 | 4.75 | 5.76 |
| | | Garage | 4.42 | 4.35 | 3.82 | 3.05 | 3.38 |
| | | Grocery | 7.22 | 7.19 | 6.30 | 3.93 | 4.70 |
| | | Healthcare Clinic | 7.09 | 7.27 | 6.35 | 4.32 | 4.57 |
| | | High School | 8.28 | 8.34 | 7.48 | 5.33 | 6.23 |
| | | Hospital - CAV no econ | 7.92 | 8.16 | 6.95 | 5.98 | 6.79 |
| | | Hospital - CAV econ | 8.03 | 8.32 | 7.09 | 6.14 | 6.98 |
| | | Hospital - VAV econ | 3.28 | 3.12 | 2.35 | 1.41 | 1.53 |
| | | Hospital - FCU | 5.95 | 6.79 | 5.53 | 6.50 | 8.73 |
| | | Hotel/Motel | 7.91 | 7.69 | 6.93 | 4.74 | 5.79 |
| | | Hotel/Motel - Common | 7.18 | 7.30 | 6.95 | 5.65 | 5.94 |
| | | Hotel/Motel - Guest | 7.89 | 7.64 | 6.83 | 4.57 | 5.62 |

| Location | System Type | Building Type | Annual therm Savings per linear foot (therm /ft) (2" pipe / 1" insulation for hot water, 2" insulation for steam) Zone 1 (Rockford) | Zone 2 (Chicago) | Zone 3 (Springfield) | Zone 4 (Belleville) | Zone 5 (Marion) |
|---|---|---|---|---|---|---|---|
| | | Manufacturing Facility | 4.70 | 4.55 | 4.22 | 2.55 | 2.84 |
| | | MF - High Rise | 6.85 | 6.76 | 6.16 | 5.25 | 5.26 |
| | | MF - High Rise - Common | 8.15 | 7.91 | 7.09 | 4.89 | 6.31 |
| | | MF - High Rise - Residential | 6.62 | 6.57 | 5.97 | 5.17 | 5.04 |
| | | MF - Mid Rise | 7.48 | 7.57 | 6.51 | 4.79 | 5.46 |
| | | Movie Theater | 8.16 | 8.04 | 7.52 | 5.71 | 6.80 |
| | | Office - High Rise - CAV no econ | 9.07 | 9.20 | 8.39 | 5.62 | 6.12 |
| | | Office - High Rise - CAV econ | 9.38 | 9.57 | 8.80 | 6.06 | 6.67 |
| | | Office - High Rise - VAV econ | 6.86 | 6.99 | 5.76 | 3.41 | 3.80 |
| | | Office - High Rise - FCU | 5.02 | 4.95 | 4.27 | 2.27 | 2.38 |
| | | Office - Low Rise | 6.41 | 6.40 | 5.08 | 3.11 | 3.56 |
| | | Office - Mid Rise | 7.12 | 7.12 | 6.03 | 3.84 | 4.27 |
| | | Religious Building | 7.20 | 6.75 | 6.46 | 4.73 | 5.41 |
| | | Restaurant | 6.06 | 6.08 | 5.46 | 4.13 | 4.90 |
| | | Retail - Department Store | 6.25 | 5.74 | 5.39 | 3.51 | 4.00 |
| | | Retail - Strip Mall | 5.98 | 5.54 | 4.89 | 3.37 | 3.63 |
| | | Warehouse | 6.53 | 6.09 | 6.29 | 3.93 | 4.84 |
| | | Unknown | 6.97 | 6.91 | 6.14 | 4.41 | 5.11 |
| | HP Steam | All buildings, Recirculation heating season only (Hours below 55F) | 22.62 | 22.28 | 20.18 | 18.05 | 18.63 |
| | HP Steam | All buildings, Recirculation year round (All hours) | 39.32 | 39.32 | 39.32 | 39.32 | 39.32 |

**Savings Summary for Outdoor pipe insulation by System Type and Building Type (Δtherms per foot) (continues for 3.5 pages)**

| Location | System Type | Building Type | Annual therm Savings per linear foot (therm /ft) (2" pipe / 1" insulation for hot water, 2" insulation for steam) Zone 1 (Rockford) | Zone 2 (Chicago) | Zone 3 (Springfield) | Zone 4 (Belleville) | Zone 5 (Marion) |
|---|---|---|---|---|---|---|---|
| Outdoor | Hot Water Space Heating with outdoor reset – non-recirculation | Assembly | 7.58 | 7.77 | 6.94 | 4.62 | 7.08 |
| | | Assisted Living | 7.14 | 6.98 | 6.13 | 4.51 | 5.42 |
| | | College | 6.49 | 6.07 | 5.41 | 3.01 | 3.60 |
| | | Convenience Store | 6.28 | 5.80 | 5.15 | 3.70 | 4.13 |
| | | Elementary School | 7.56 | 7.36 | 6.50 | 4.49 | 5.44 |
| | | Garage | 4.18 | 4.11 | 3.61 | 2.88 | 3.19 |
| | | Grocery | 6.82 | 6.80 | 5.96 | 3.72 | 4.44 |
| | | Healthcare Clinic | 6.70 | 6.87 | 6.00 | 4.09 | 4.32 |
| | | High School | 7.83 | 7.88 | 7.07 | 5.03 | 5.89 |
| | | Hospital - CAV no econ | 7.49 | 7.71 | 6.57 | 5.65 | 6.41 |
| | | Hospital - CAV econ | 7.59 | 7.86 | 6.70 | 5.81 | 6.60 |
| | | Hospital - VAV econ | 3.10 | 2.95 | 2.22 | 1.33 | 1.44 |
| | | Hospital - FCU | 5.62 | 6.42 | 5.23 | 6.14 | 8.26 |
| | | Hotel/Motel | 7.47 | 7.26 | 6.55 | 4.48 | 5.47 |
| | | Hotel/Motel - Common | 6.79 | 6.90 | 6.57 | 5.34 | 5.61 |
| | | Hotel/Motel - Guest | 7.46 | 7.22 | 6.45 | 4.32 | 5.31 |

| | | | Annual therm Savings per linear foot (therm /ft) (2" pipe / 1" insulation for hot water, 2" insulation for steam) | | | | |
|---|---|---|---|---|---|---|---|
| Location | System Type | Building Type | Zone 1 (Rockford) | Zone 2 (Chicago) | Zone 3 (Springfield) | Zone 4 (Belleville) | Zone 5 (Marion) |
| | | Manufacturing Facility | 4.45 | 4.30 | 3.98 | 2.41 | 2.69 |
| | | MF - High Rise | 6.48 | 6.39 | 5.83 | 4.96 | 4.97 |
| | | MF - High Rise - Common | 7.70 | 7.48 | 6.70 | 4.62 | 5.96 |
| | | MF - High Rise - Residential | 6.26 | 6.21 | 5.64 | 4.89 | 4.77 |
| | | MF - Mid Rise | 7.07 | 7.15 | 6.15 | 4.53 | 5.16 |
| | | Movie Theater | 7.71 | 7.60 | 7.10 | 5.40 | 6.43 |
| | | Office - High Rise - CAV no econ | 8.57 | 8.70 | 7.93 | 5.31 | 5.78 |
| | | Office - High Rise - CAV econ | 8.86 | 9.04 | 8.32 | 5.73 | 6.31 |
| | | Office - High Rise - VAV econ | 6.48 | 6.61 | 5.45 | 3.22 | 3.59 |
| | | Office - High Rise - FCU | 4.75 | 4.67 | 4.04 | 2.14 | 2.25 |
| | | Office - Low Rise | 6.06 | 6.05 | 4.80 | 2.94 | 3.36 |
| | | Office - Mid Rise | 6.73 | 6.73 | 5.70 | 3.63 | 4.03 |
| | | Religious Building | 6.80 | 6.38 | 6.11 | 4.47 | 5.11 |
| | | Restaurant | 5.73 | 5.75 | 5.16 | 3.90 | 4.63 |
| | | Retail - Department Store | 5.91 | 5.42 | 5.09 | 3.31 | 3.78 |
| | | Retail - Strip Mall | 5.65 | 5.23 | 4.62 | 3.19 | 3.44 |
| | | Warehouse | 6.18 | 5.76 | 5.94 | 3.71 | 4.57 |
| | | Unknown | 6.59 | 6.53 | 5.81 | 4.17 | 4.83 |
| | Hot Water Space Heating without outdoor reset – non-recirculation | Assembly | 9.59 | 9.83 | 8.77 | 5.85 | 8.96 |
| | | Assisted Living | 9.04 | 8.83 | 7.76 | 5.70 | 6.86 |
| | | College | 8.21 | 7.68 | 6.85 | 3.80 | 4.56 |
| | | Convenience Store | 7.95 | 7.34 | 6.52 | 4.68 | 5.22 |
| | | Elementary School | 9.56 | 9.32 | 8.22 | 5.68 | 6.89 |
| | | Garage | 5.28 | 5.20 | 4.57 | 3.65 | 4.04 |
| | | Grocery | 8.63 | 8.60 | 7.54 | 4.70 | 5.62 |
| | | Healthcare Clinic | 8.47 | 8.70 | 7.59 | 5.17 | 5.47 |
| | | High School | 9.90 | 9.97 | 8.94 | 6.37 | 7.45 |
| | | Hospital - CAV no econ | 9.47 | 9.76 | 8.31 | 7.15 | 8.11 |
| | | Hospital - CAV econ | 9.60 | 9.95 | 8.48 | 7.35 | 8.34 |
| | | Hospital - VAV econ | 3.93 | 3.73 | 2.80 | 1.68 | 1.82 |
| | | Hospital - FCU | 7.11 | 8.12 | 6.61 | 7.77 | 10.45 |
| | | Hotel/Motel | 9.45 | 9.19 | 8.29 | 5.67 | 6.92 |
| | | Hotel/Motel - Common | 8.59 | 8.73 | 8.31 | 6.76 | 7.10 |
| | | Hotel/Motel - Guest | 9.44 | 9.13 | 8.16 | 5.47 | 6.72 |
| | | Manufacturing Facility | 5.63 | 5.44 | 5.04 | 3.05 | 3.40 |
| | | MF - High Rise | 8.19 | 8.08 | 7.37 | 6.27 | 6.29 |
| | | MF - High Rise - Common | 9.74 | 9.46 | 8.48 | 5.85 | 7.54 |
| | | MF - High Rise - Residential | 7.92 | 7.86 | 7.14 | 6.18 | 6.03 |
| | | MF - Mid Rise | 8.94 | 9.05 | 7.78 | 5.73 | 6.53 |
| | | Movie Theater | 9.76 | 9.61 | 8.99 | 6.83 | 8.14 |
| | | Office - High Rise - CAV no econ | 10.84 | 11.01 | 10.03 | 6.72 | 7.32 |
| | | Office - High Rise - CAV econ | 11.21 | 11.44 | 10.52 | 7.25 | 7.98 |
| | | Office - High Rise - VAV econ | 8.20 | 8.36 | 6.89 | 4.07 | 4.54 |
| | | Office - High Rise - FCU | 6.00 | 5.91 | 5.11 | 2.71 | 2.84 |
| | | Office - Low Rise | 7.67 | 7.65 | 6.08 | 3.72 | 4.25 |
| | | Office - Mid Rise | 8.51 | 8.52 | 7.21 | 4.59 | 5.10 |

| Location | System Type | Building Type | Annual therm Savings per linear foot (therm /ft) (2" pipe / 1" insulation for hot water, 2" insulation for steam) Zone 1 (Rockford) | Zone 2 (Chicago) | Zone 3 (Springfield) | Zone 4 (Belleville) | Zone 5 (Marion) |
|---|---|---|---|---|---|---|---|
| | | Religious Building | 8.61 | 8.07 | 7.73 | 5.66 | 6.47 |
| | | Restaurant | 7.25 | 7.27 | 6.53 | 4.94 | 5.85 |
| | | Retail - Department Store | 7.47 | 6.86 | 6.44 | 4.19 | 4.78 |
| | | Retail - Strip Mall | 7.15 | 6.62 | 5.85 | 4.03 | 4.35 |
| | | Warehouse | 7.81 | 7.29 | 7.52 | 4.69 | 5.78 |
| | | Unknown | 8.34 | 8.26 | 7.35 | 5.27 | 6.11 |
| | Hot Water with outdoor reset | All buildings, Recirculation heating season only (Hours below 55F) | 21.38 | 21.06 | 19.07 | 17.06 | 17.61 |
| | Hot Water without outdoor reset | All buildings, Recirculation heating season only (Hours below 55F) | 27.05 | 26.64 | 24.13 | 21.58 | 22.28 |
| | Hot Water with outdoor reset | All buildings, Recirculation year round (All hours) | 31.30 | 31.30 | 31.30 | 31.30 | 31.30 |
| | Hot Water without outdoor reset | All buildings, Recirculation year round (All hours) | 47.02 | 47.02 | 47.02 | 47.02 | 47.02 |
| | LP Steam – non-recirculation | Assembly | 15.01 | 15.38 | 13.73 | 9.15 | 14.02 |
| | | Assisted Living | 14.14 | 13.82 | 12.15 | 8.93 | 10.73 |
| | | College | 12.85 | 12.01 | 10.72 | 5.95 | 7.13 |
| | | Convenience Store | 12.44 | 11.49 | 10.20 | 7.32 | 8.17 |
| | | Elementary School | 14.96 | 14.58 | 12.86 | 8.88 | 10.78 |
| | | Garage | 8.27 | 8.14 | 7.15 | 5.71 | 6.32 |
| | | Grocery | 13.51 | 13.46 | 11.80 | 7.36 | 8.79 |
| | | Healthcare Clinic | 13.26 | 13.61 | 11.88 | 8.09 | 8.56 |
| | | High School | 15.50 | 15.60 | 13.99 | 9.97 | 11.66 |
| | | Hospital - CAV no econ | 14.82 | 15.27 | 13.01 | 11.19 | 12.70 |
| | | Hospital - CAV econ | 15.02 | 15.57 | 13.27 | 11.50 | 13.06 |
| | | Hospital - VAV econ | 6.14 | 5.84 | 4.39 | 2.64 | 2.85 |
| | | Hospital - FCU | 11.13 | 12.71 | 10.35 | 12.16 | 16.35 |
| | | Hotel/Motel | 14.80 | 14.38 | 12.97 | 8.87 | 10.84 |
| | | Hotel/Motel - Common | 13.45 | 13.66 | 13.00 | 10.58 | 11.12 |
| | | Hotel/Motel - Guest | 14.77 | 14.29 | 12.78 | 8.56 | 10.52 |
| | | Manufacturing Facility | 8.80 | 8.51 | 7.89 | 4.77 | 5.32 |
| | | MF - High Rise | 15.97 | 15.76 | 14.37 | 12.23 | 12.26 |
| | | MF - High Rise - Common | 18.99 | 18.44 | 16.53 | 11.39 | 14.71 |
| | | MF - High Rise - Residential | 15.43 | 15.31 | 13.92 | 12.05 | 11.75 |
| | | MF - Mid Rise | 17.43 | 17.63 | 15.17 | 11.16 | 12.72 |
| | | Movie Theater | 15.27 | 15.05 | 14.07 | 10.69 | 12.73 |
| | | Office - High Rise - CAV no econ | 16.97 | 17.22 | 15.70 | 10.51 | 11.45 |
| | | Office - High Rise - CAV econ | 17.55 | 17.91 | 16.47 | 11.35 | 12.49 |
| | | Office - High Rise - VAV econ | 12.83 | 13.09 | 10.79 | 6.37 | 7.11 |
| | | Office - High Rise - FCU | 9.40 | 9.26 | 8.00 | 4.25 | 4.45 |
| | | Office - Low Rise | 12.00 | 11.97 | 9.51 | 5.82 | 6.66 |
| | | Office - Mid Rise | 13.32 | 13.33 | 11.28 | 7.18 | 7.98 |
| | | Religious Building | 13.47 | 12.64 | 12.10 | 8.86 | 10.13 |
| | | Restaurant | 11.34 | 11.38 | 10.21 | 7.73 | 9.16 |
| | | Retail - Department Store | 11.69 | 10.74 | 10.08 | 6.56 | 7.48 |
| | | Retail - Strip Mall | 11.19 | 10.36 | 9.15 | 6.31 | 6.80 |
| | | Warehouse | 12.23 | 11.40 | 11.77 | 7.35 | 9.05 |

| | | | Annual therm Savings per linear foot (therm /ft) (2" pipe / 1" insulation for hot water, 2" insulation for steam) | | | | |
|---|---|---|---|---|---|---|---|
| Location | System Type | Building Type | Zone 1 (Rockford) | Zone 2 (Chicago) | Zone 3 (Springfield) | Zone 4 (Belleville) | Zone 5 (Marion) |
| | | Unknown | 13.05 | 12.93 | 11.50 | 8.25 | 9.57 |
| | LP Steam | All buildings, Recirculation heating season only (Hours below 55F) | 42.33 | 41.69 | 37.76 | 33.78 | 34.86 |
| | LP Steam | All buildings, Recirculation year round (All hours) | 73.59 | 73.59 | 73.59 | 73.59 | 73.59 |
| | HP Steam – non-recirculation | Assembly | 23.24 | 23.81 | 21.26 | 14.16 | 21.70 |
| | | Assisted Living | 21.89 | 21.40 | 18.80 | 13.82 | 16.61 |
| | | College | 19.90 | 18.60 | 16.60 | 9.22 | 11.04 |
| | | Convenience Store | 19.26 | 17.79 | 15.79 | 11.33 | 12.65 |
| | | Elementary School | 23.16 | 22.57 | 19.91 | 13.75 | 16.69 |
| | | Garage | 12.80 | 12.60 | 11.08 | 8.84 | 9.78 |
| | | Grocery | 20.91 | 20.83 | 18.26 | 11.39 | 13.61 |
| | | Healthcare Clinic | 20.53 | 21.07 | 18.39 | 12.53 | 13.25 |
| | | High School | 23.99 | 24.15 | 21.66 | 15.43 | 18.05 |
| | | Hospital - CAV no econ | 22.94 | 23.64 | 20.14 | 17.32 | 19.66 |
| | | Hospital - CAV econ | 23.25 | 24.10 | 20.54 | 17.80 | 20.22 |
| | | Hospital - VAV econ | 9.51 | 9.03 | 6.79 | 4.08 | 4.42 |
| | | Hospital - FCU | 17.24 | 19.67 | 16.02 | 18.82 | 25.31 |
| | | Hotel/Motel | 22.90 | 22.27 | 20.08 | 13.74 | 16.77 |
| | | Hotel/Motel - Common | 20.81 | 21.15 | 20.13 | 16.38 | 17.21 |
| | | Hotel/Motel - Guest | 22.87 | 22.13 | 19.78 | 13.24 | 16.28 |
| | | Manufacturing Facility | 13.63 | 13.18 | 12.21 | 7.38 | 8.24 |
| | | MF - High Rise | 19.85 | 19.59 | 17.86 | 15.20 | 15.24 |
| | | MF - High Rise - Common | 23.60 | 22.92 | 20.55 | 14.16 | 18.28 |
| | | MF - High Rise - Residential | 19.18 | 19.03 | 17.30 | 14.98 | 14.61 |
| | | MF - Mid Rise | 21.67 | 21.92 | 18.86 | 13.87 | 15.81 |
| | | Movie Theater | 23.64 | 23.29 | 21.78 | 16.55 | 19.71 |
| | | Office - High Rise - CAV no econ | 26.27 | 26.66 | 24.30 | 16.28 | 17.73 |
| | | Office - High Rise - CAV econ | 27.16 | 27.72 | 25.49 | 17.57 | 19.33 |
| | | Office - High Rise - VAV econ | 19.87 | 20.26 | 16.70 | 9.87 | 11.00 |
| | | Office - High Rise - FCU | 14.54 | 14.33 | 12.38 | 6.57 | 6.89 |
| | | Office - Low Rise | 18.58 | 18.53 | 14.72 | 9.00 | 10.31 |
| | | Office - Mid Rise | 20.61 | 20.64 | 17.46 | 11.12 | 12.36 |
| | | Religious Building | 20.85 | 19.56 | 18.72 | 13.71 | 15.67 |
| | | Restaurant | 17.55 | 17.61 | 15.81 | 11.96 | 14.18 |
| | | Retail - Department Store | 18.10 | 16.63 | 15.61 | 10.16 | 11.58 |
| | | Retail - Strip Mall | 17.32 | 16.04 | 14.17 | 9.77 | 10.53 |
| | | Warehouse | 18.93 | 17.65 | 18.21 | 11.37 | 14.02 |
| | | Unknown | 20.20 | 20.01 | 17.80 | 12.77 | 14.81 |
| | HP Steam | All buildings, Recirculation heating season only (Hours below 55F) | 65.53 | 64.54 | 58.45 | 52.29 | 53.97 |
| | HP Steam | All buildings, Recirculation year round (All hours) | 113.92 | 113.92 | 113.92 | 113.92 | 113.92 |

For insulation covering elbows and tees that connect straight pipe, a calculated surface area will be assumed based on the dimensions for fittings given by ANSI/ASME B36.19. The surface area is then converted to an equivalent length of pipe that must be added to the total length of straight pipe in order to calculate total savings. Equivalent pipe lengths are given in 1” increments in pipe diameter for simplicity. In the case of pipe diameters in between full inch diameters, the closest equivalent length should be used. The larger pipe sizes mostly apply to steam header piping, which has the most heat loss per foot.

**Calculated Surface Areas of Elbows and Tees**

| Nominal Pipe Diameter | Calculated Surface Area (ft) | |
|---|---|---|
| | 90 Degree Elbow[397] | Straight Tee[398] |
| 1” | 0.10 | 0.13 |
| 2” | 0.41 | 0.39 |
| 3” | 0.93 | 0.77 |
| 4” | 1.64 | 1.21 |
| 5” | 2.57 | 1.77 |
| 6” | 3.70 | 2.44 |
| 8” | 6.58 | 3.95 |
| 10” | 10.28 | 5.98 |
| 12” | 14.80 | 8.34 |

**Equivalent Length of Other Components – Elbows and Tees ($L_{oc}$)**

| Nominal Pipe Diameter | Equivalent Length of Other Components (ft) | |
|---|---|---|
| | 90 Degree Elbow | Straight Tee |
| 1” | 0.30 | 0.38 |
| 2” | 0.66 | 0.63 |
| 3” | 1.01 | 0.84 |
| 4” | 1.40 | 1.03 |
| 5” | 1.76 | 1.22 |
| 6” | 2.13 | 1.41 |
| 8” | 2.91 | 1.75 |
| 10” | 3.65 | 2.13 |
| 12” | 4.44 | 2.50 |

For insulation around valves or flanges, a surface area from ASTM standard C1129-12 will be assumed for 2” pipes. For 1” pipes, which weren’t included in the standard, a linear-trended value will be used. The surface area is then converted to an equivalent length of either 1” or 2” straight pipe that must be added to the total length of straight pipe in order to calculate total savings.

**Calculated Surface Areas of Flanges and Valves**

| Valves | | | | |
|---|---|---|---|---|
| Class (psi) | 150 | 300 | 600 | 900 |
| NPS (in) | ft$^2$ | ft$^2$ | ft$^2$ | ft$^2$ |
| 1 | 0.69 | 1.8 | 1.8 | 2.4 |
| 2 | 2.21 | 2.94 | 2.94 | 5.2 |
| 2.5 | 2.97 | 3.51 | 3.91 | 6.6 |
| 3 | 3.37 | 4.39 | 4.69 | 6.5 |
| 4 | 4.68 | 6.06 | 7.64 | 9.37 |
| 6 | 7.03 | 9.71 | 13.03 | 15.8 |
| 8 | 10.3 | 13.5 | 18.4 | 23.8 |

| Flanges | | | | |
|---|---|---|---|---|
| Class (psi) | 150 | 300 | 600 | 900 |
| NPS (in) | ft$^2$ | ft$^2$ | ft$^2$ | ft$^2$ |
| 1 | 0.36 | 0.36 | 0.4 | 1.23 |
| 2 | 0.71 | 0.84 | 0.88 | 1.54 |
| | | | | |
| 3 | 1.06 | 1.32 | 1.36 | 1.85 |
| 4 | 1.44 | 1.83 | 2.23 | 2.64 |
| 6 | 2.04 | 2.72 | 3.6 | 4.37 |
| 8 | 2.92 | 3.74 | 4.89 | 6.4 |

397 Based on the dimensions for diameter, long radius, and short radius given by ANSI/ASME 36.19
398 Based on the center to face and diameter dimensions given by ANSI/ASME B36.19

| Valves | | | | |
|---|---|---|---|---|
| Class (psi) | 150 | 300 | 600 | 900 |
| NPS (in) | $ft^2$ | $ft^2$ | $ft^2$ | $ft^2$ |
| 10 | 13.8 | 18 | 26.5 | 32.1 |
| 12 | 16.1 | 24.1 | 31.9 | 41.9 |

| Flanges | | | | |
|---|---|---|---|---|
| Class (psi) | 150 | 300 | 600 | 900 |
| NPS (in) | $ft^2$ | $ft^2$ | $ft^2$ | $ft^2$ |
| 10 | 3.68 | 4.8 | 6.93 | 8.47 |
| 12 | 5.01 | 6.34 | 7.97 | 10.43 |

**Equivalent Length of Other Components - Flanges and Valves ($L_{oc}$)**

| ANSI Class (psi) | Equivalent Length of Other Components (ft) | | | |
|---|---|---|---|---|
| | 1” Valve | 1” Flange | 2” Valve | 2” Flange |
| 150 | 2.00 | 1.04 | 3.56 | 1.14 |
| 300 | 5.22 | 1.04 | 4.73 | 1.35 |
| 600 | 5.22 | 1.16 | 4.73 | 1.42 |
| 900 | 6.96 | 3.57 | 8.37 | 2.48 |
| ANSI Class (psi) | 3" Valve | 3" Flange | 4" Valve | 4" Flange |
| 150 | 3.67 | 1.16 | 3.98 | 1.22 |
| 300 | 4.79 | 1.44 | 5.15 | 1.56 |
| 600 | 5.11 | 1.48 | 6.49 | 1.90 |
| 900 | 7.09 | 2.02 | 7.96 | 2.24 |

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-HVC-PINS-V05-190101**

**REVIEW DEADLINE: 1/1/2023**

## 4.4.15 Single-Package and Split System Unitary Air Conditioners

### Description

This measure promotes the installation of high-efficiency unitary air-, water-, and evaporatively-cooled air conditioning equipment, both single-package and split systems. Air conditioning (AC) systems are a major consumer of electricity and systems that exceed baseline efficiency requirements can significantly reduce energy consumption. This measure could apply to the replacing of an existing unit at the end of its useful life or the installation of a new unit in a new or existing building.

This measure was developed to be applicable to the following program types: TOS, NC, EREP. If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

The efficient equipment is assumed to be a high-efficiency air-, water-, or evaporatively-cooled air conditioner that exceeds the energy efficiency requirements as prescribed by the program.

### Definition of Baseline Equipment

In order for this characterization to apply, the baseline equipment is assumed to be a standard-efficiency air-, water, or evaporatively-cooled air conditioner that meets the Code energy efficiency requirements (IECC or Code of Federal Regulations whichever is higher) in effect on the date of equipment purchase (if date is unknown, assume current Code minimum).

For Early Replacement programs, use the actual efficiency of the existing unit or assume IECC code base in place at the original time of existing unit installation. To qualify under the early replacement characterization, baseline equipment must meet these additional qualifications:

- The existing unit is operational when replaced or the existing unit would be operational with minor repairs[399].

Note: IECC 2018 is scheduled to become effective March 1, 2019 and will become baseline for all New Construction permits from that date.
Note: new Federal Standards become effective January 1, 2023

### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 15 years.[400]

For early replacement, the remaining life of existing equipment is assumed to be 5 years[401].

### Deemed Measure Cost

The incremental capital cost for this measure is based upon capacity and efficiency level (defined be CEE specifications[402]), as outlined in the following table:[403]

[399] Based on ComEd Small Business Trade Ally feedback. For units rated at less than 20 ton units, the cost of common repairs is under $2,000, significantly less than the cost of purchasing new equipment. Therefore, if the cost of repair is less than $2,000, it can be considered early replacement because customers would repair instead of replace a failed unit. Repair cost data was not available for units larger than 20 tons.
[400] Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007.
[401] Assumed to be one third of effective useful life
[402] CEE Commercial Unitary Air-conditioning and Heat Pumps Specification, which provides high efficiency performance specifications for single-package and split system unitary air conditioners.
[403] NEEP Incremental Cost Study (ICS) Final Report – Phase 3, May 2014.

| | Incremental cost ($/ton) | |
|---|---|---|
| Capacity | Up to and including CEE Tier 1 units | CEE Tier 2 and above |
| < 135,000 Btu/hr | $63 | $127 |
| 135,000 Btu/hr to > 250,000 Btu/hr | $63 | $127 |
| 250,000 Btu/hr and greater | $19 | $38 |

For early replacement the full cost of the installed unit should be used. If unknown use defaults below. The assumed deferred cost (after 5 years) of replacing existing equipment with a new baseline unit is also provided. This future cost should be discounted to present value using the real discount rate:

| | Full Install Cost ($/ton) | | |
|---|---|---|---|
| Capacity | Base Units | Up to and including CEE Tier 1 units | CEE Tier 2 and above |
| < 135,000 Btu/hr | $895 | $958 | $1,021 |
| 135,000 Btu/hr to > 250,000 Btu/hr | $762 | $825 | $889 |
| 250,000 Btu/hr and greater | $673 | $691 | $710 |

**LOADSHAPE**

Loadshape C03 - Commercial Cooling

**COINCIDENCE FACTOR**

The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the *average* savings over the defined summer peak period, and is presented so that savings can be bid into PJM's Forward Capacity Market. Both values provided are based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren.

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [404]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [405]

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

Time of Sale:

For units with cooling capacities less than 65 kBtu/hr:

ΔkWH = (kBtu/hr) * [(1/SEERbase) – (1/SEERee)] * EFLH

For units with cooling capacities equal to or greater than 65 kBtu/hr:

ΔkWH = (kBtu/hr) * [(1/IEERbase) – (1/IEERee)] * EFLH

[404] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility's peak hour is divided by the maximum AC load during the year.

[405] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year

Early replacement[406]:

For units with cooling capacities less than 65 kBtu/hr:

For remaining life of existing unit (1st 5 years):

ΔkWH = (kBtu/hr) * [(1/SEERexist) – (1/SEERee)] * EFLH

For remaining measure life (next 10 years):

ΔkWH = (kBtu/hr) * [(1/SEERbase) – (1/SEERee)] * EFLH

For units with cooling capacities equal to or greater than 65 kBtu/hr:

For remaining life of existing unit (1st 5 years):

ΔkWH = (kBtu/hr) * [(1/IEERexist) – (1/IEERee)] * EFLH

NOTE: If the existing equipment age is such that IEER ratings are not available, EER may be substitued when necessary. In such instances both existing and efficient unit efficiencies should be specified in EER.

For remaining measure life (next 10 years):

ΔkWH = (kBtu/hr) * [(1/IEERbase) – (1/IEERee)] * EFLH

Where:

kBtu/hr = capacity of the cooling equipment actually installed in kBtu per hour (1 ton of cooling capacity equals 12 kBtu/hr)

SEERbase = Seasonal Energy Efficiency Ratio of the baseline equipment

= SEER values from tables below, based on applicable Code on date of equipment purchase (if unknown assume current Code).

SEERee = Seasonal Energy Efficiency Ratio of the energy efficient equipment (actually installed)

SEERexist = Seasonal Energy Efficiency Ratio of the existing equipment

= Actual, or assume Code base in place at the original time of existing unit installation

IEERbase = Integrated Energy Efficiency Ratio of the baseline equipment. See table below based on applicable Code on date of equipment purchase (if unknown assume current Code).

IEERee = Integrated Energy Efficiency Ratio of the energy efficient equipment (actually installed)

IEERexist = Integrated Energy Efficiency Ratio of the existing equipment

= Actual, or assume Code base in place at the original time of existing unit installation

EFLH = Equivalent Full Load Hours for cooling are provided in section 4.4 HVAC End Use

The rating conditions for the baseline and efficient equipment efficiencies must be equivalent.

[406] The two equations are provided to show how savings are determined during the initial phase of the measure (existing to efficient) and the remaining phase (new baseline to efficient). In practice, the screening tools used may either require a First Year savings (using the first equation) and then a "number of years to adjustment" and "savings adjustment" input which would be the (new base to efficient savings)/(existing to efficient savings).

**Code of Federal Redulations (baseline effective 1/1/2019):**

| Equipment type | Cooling capacity | Heating type | Efficiency level | Compliance date |
|---|---|---|---|---|
| Small Commercial Packaged Air Conditioning and Heating Equipment (Air-Cooled) | ≥65,000 Btu/h and <135,000 Btu/h | Electric Resistance Heating or No Heating | IEER = 12.9 | 1/1/2018 |
| | | All Other Types of Heating | IEER = 12.7 | 1/1/2018 |
| Large Commercial Packaged Air Conditioning and Heating Equipment (Air-Cooled) | ≥135,000 Btu/h and <240,000 Btu/h | Electric Resistance Heating or No Heating | IEER = 12.4 | 1/1/2018 |
| | | All Other Types of Heating | IEER = 12.2 | 1/1/2018 |
| Very Large Commercial Packaged Air Conditioning and Heating Equipment (Air-Cooled) | ≥240,000 Btu/h and <760,000 Btu/h | Electric Resistance Heating or No Heating | IEER = 11.6 | 1/1/2018 |
| | | All Other Types of Heating | IEER = 11.4 | 1/1/2018 |
| Small Commercial Package Air-Conditioning and Heating Equipment (Air-Cooled, 3-Phase, Split-System) | <65,000 Btu/h | All | SEER = 13.0 | 6/16/2008 |
| Small Commercial Package Air-Conditioning and Heating Equipment (Air-Cooled, 3-Phase, Single-Package) | <65,000Btu/h | All | SEER = 14.0 | 1/1/2017 |

2012 IECC Minimum Efficiency Requirements (baseline effective 1/1/2013)

**TABLE C403.2.3(1)
MINIMUM EFFICIENCY REQUIREMENTS:
ELECTRICALLY OPERATED UNITARY AIR CONDITIONERS AND CONDENSING UNITS**

| EQUIPMENT TYPE | SIZE CATEGORY | HEATING SECTION TYPE | SUBCATEGORY OR RATING CONDITION | MINIMUM EFFICIENCY | | TEST PROCEDURE[a] |
|---|---|---|---|---|---|---|
| | | | | Before 6/1/2011 | As of 6/1/2011 | |
| Air conditioners, air cooled | < 65,000 Btu/h[b] | All | Split System | 13.0 SEER | 13.0 SEER | AHRI 210/240 |
| | | | Single Package | 13.0 SEER | 13.0 SEER | |
| Through-the-wall (air cooled) | ≤ 30,000 Btu/h[b] | All | Split system | 12.0 SEER | 12.0 SEER | |
| | | | Single Package | 12.0 SEER | 12.0 SEER | |
| Small-duct high-velocity (air cooled) | < 65,000 Btu/h[b] | All | Split System | 10.0 SEER | 10.0 SEER | |
| Air conditioners, air cooled | ≥ 65,000 Btu/h and < 135,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 11.2 EER 11.4 IEER | 11.2 EER 11.4 IEER | AHRI 340/360 |
| | | All other | Split System and Single Package | 11.0 EER 11.2 IEER | 11.0 EER 11.2 IEER | |
| | ≥ 135,000 Btu/h and < 240,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 11.0 EER 11.2 IEER | 11.0 EER 11.2 IEER | |
| | | All other | Split System and Single Package | 10.8 EER 11.0 IEER | 10.8 EER 11.0 IEER | |
| | ≥ 240,000 Btu/h and < 760,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 10.0 EER 10.1 IEER | 10.0 EER 10.1 IEER | |
| | | All other | Split System and Single Package | 9.8 EER 9.9 IEER | 9.8 EER 9.9 IEER | |
| | ≥ 760,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 9.7 EER 9.8 IEER | 9.7 EER 9.8 IEER | |
| | | All other | Split System and Single Package | 9.5 EER 9.6 IEER | 9.5 EER 9.6 IEER | |
| Air conditioners, water cooled | < 65,000 Btu/h[b] | All | Split System and Single Package | 12.1 EER 12.3 IEER | 12.1 EER 12.3 IEER | AHRI 210/240 |
| | ≥ 65,000 Btu/h and < 135,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 11.5 EER 11.7 IEER | 12.1 EER 12.3 IEER | AHRI 340/360 |
| | | All other | Split System and Single Package | 11.3 EER 11.5 IEER | 11.9 EER 12.1 IEER | |
| | ≥ 135,000 Btu/h and < 240,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 11.0 EER 11.2 IEER | 12.5 EER 12.7 IEER | |
| | | All other | Split System and Single Package | 10.8 EER 11.0 IEER | 12.3 EER 12.5 IEER | |
| | ≥ 240,000 Btu/h and < 760,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 11.0 EER 11.1 IEER | 12.4 EER 12.6 IEER | |
| | | All other | Split System and Single Package | 10.8 EER 10.9 IEER | 12.2 EER 12.4 IEER | |
| | ≥ 760,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 11.0 EER 11.1 IEER | 12.0 EER 12.4 IEER | |
| | | All other | Split System and Single Package | 10.8 EER 10.9 IEER | 12.0 EER 12.2 IEER | |

*(continued)*

**TABLE C403.2.3(1)—continued**
**MINIMUM EFFICIENCY REQUIREMENTS:**
**ELECTRICALLY OPERATED UNITARY AIR CONDITIONERS AND CONDENSING UNITS**

| EQUIPMENT TYPE | SIZE CATEGORY | HEATING SECTION TYPE | SUB-CATEGORY OR RATING CONDITION | MINIMUM EFFICIENCY | | TEST PROCEDURE[a] |
|---|---|---|---|---|---|---|
| | | | | Before 6/1/2011 | As of 6/1/2011 | |
| Air conditioners, evaporatively cooled | < 65,000 Btu/h[b] | All | Split System and Single Package | 12.1 EER 12.3 IEER | 12.1 EER 12.3 IEER | AHRI 210/240 |
| | ≥ 65,000 Btu/h and < 135,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 11.5 EER 11.7 IEER | 12.1 EER 12.3 IEER | AHRI 340/360 |
| | | All other | Split System and Single Package | 11.3 EER 11.5 IEER | 11.9 EER 12.1 IEER | |
| | ≥ 135,000 Btu/h and < 240,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 11.0 EER 11.2 IEER | 12.0 EER 12.2 IEER | |
| | | All other | Split System and Single Package | 10.8 EER 11.0 IEER | 11.8 EER 12.0 IEER | |
| | ≥ 240,000 Btu/h and < 760,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 11.0 EER 11.1 IEER | 11.9 EER 12.1 IEER | |
| | | All other | Split System and Single Package | 10.8 EER 10.9 IEER | 12.2 EER 11.9 IEER | |
| | ≥ 760,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 10.0 EER 11.1 IEER | 11.7 EER 11.9 IEER | |
| | | All other | Split System and Single Package | 10.8 EER 10.9 IEER | 11.5 EER 11.7 IEER | |
| Condensing units, air cooled | ≥ 135,000 Btu/h | | | 10.1 EER 11.4 IEER | 10.5 EER 14.0 IEER | AHRI 365 |
| Condensing units, water cooled | ≥ 135,000 Btu/h | | | 13.1 EER 13.6 IEER | 13.5 EER 14.0 IEER | |
| Condensing units, evaporatively cooled | ≥ 135,000 Btu/h | | | 13.1 EER 13.6 IEER | 13.5 EER 14.0 IEER | |

For SI: 1 British thermal unit per hour = 0.2931 W.

a. Chapter 6 of the referenced standard contains a complete specification of the referenced test procedure, including the reference year version of the test procedure.

b. Single-phase, air-cooled air conditioners less than 65,000 Btu/h are regulated by NAECA. SEER values are those set by NAECA.

2015 IECC Minimum Efficiency Requirements (baseline effective 1/1/2016)

**TABLE C403.2.3(1)**
**MINIMUM EFFICIENCY REQUIREMENTS:**
**ELECTRICALLY OPERATED UNITARY AIR CONDITIONERS AND CONDENSING UNITS**

| EQUIPMENT TYPE | SIZE CATEGORY | HEATING SECTION TYPE | SUBCATEGORY OR RATING CONDITION | MINIMUM EFFICIENCY | | TEST PROCEDURE[a] |
|---|---|---|---|---|---|---|
| | | | | Before 1/1/2016 | As of 1/1/2016 | |
| Air conditioners, air cooled | < 65,000 Btu/h[b] | All | Split System | 13.0 SEER | 13.0 SEER | AHRI 210/240 |
| | | | Single Package | 13.0 SEER | 14.0 SEER[c] | |
| Through-the-wall (air cooled) | ≤ 30,000 Btu/h[b] | All | Split system | 12.0 SEER | 12.0 SEER | |
| | | | Single Package | 12.0 SEER | 12.0 SEER | |
| Small-duct high-velocity (air cooled) | < 65,000 Btu/h[b] | All | Split System | 11.0 SEER | 11.0 SEER | |
| Air conditioners, air cooled | ≥ 65,000 Btu/h and < 135,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 11.2 EER<br>11.4 IEER | 11.2 EER<br>12.8 IEER | AHRI 340/360 |
| | | All other | Split System and Single Package | 11.0 EER<br>11.2 IEER | 11.0 EER<br>12.6 IEER | |
| | ≥ 135,000 Btu/h and < 240,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 11.0 EER<br>11.2 IEER | 11.0 EER<br>12.4 IEER | |
| | | All other | Split System and Single Package | 10.8 EER<br>11.0 IEER | 10.8 EER<br>12.2 IEER | |
| | ≥ 240,000 Btu/h and < 760,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 10.0 EER<br>10.1 IEER | 10.0 EER<br>11.6 IEER | |
| | | All other | Split System and Single Package | 9.8 EER<br>9.9 IEER | 9.8 EER<br>11.4 IEER | |
| | ≥ 760,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 9.7 EER<br>9.8 IEER | 9.7 EER<br>11.2 IEER | |
| | | All other | Split System and Single Package | 9.5 EER<br>9.6 IEER | 9.5 EER<br>11.0 IEER | |
| Air conditioners, water cooled | < 65,000 Btu/h[b] | All | Split System and Single Package | 12.1 EER<br>12.3 IEER | 12.1 EER<br>12.3 IEER | AHRI 210/240 |
| | ≥ 65,000 Btu/h and < 135,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 12.1 EER<br>12.3 IEER | 12.1 EER<br>13.9 IEER | AHRI 340/360 |
| | | All other | Split System and Single Package | 11.9 EER<br>12.1 IEER | 11.9 EER<br>13.7 IEER | |
| | ≥ 135,000 Btu/h and < 240,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 12.5 EER<br>12.5 IEER | 12.5 EER<br>13.9 IEER | |
| | | All other | Split System and Single Package | 12.3 EER<br>12.5 IEER | 12.3 EER<br>13.7 IEER | |
| | ≥ 240,000 Btu/h and < 760,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 12.4 EER<br>12.6 IEER | 12.4 EER<br>13.6 IEER | |
| | | All other | Split System and Single Package | 12.2 EER<br>12.4 IEER | 12.2 EER<br>13.4 IEER | |
| | ≥ 760,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 12.2 EER<br>12.4 IEER | 12.2 EER<br>13.5 IEER | |
| | | All other | Split System and Single Package | 12.0 EER<br>12.2 IEER | 12.0 EER<br>13.3 IEER | |

*(continued)*

2018 IECC Minimum Efficiency Requirements (baseline effective 3/1/2019 for New Construction measures)

TABLE C403.3.2(1)
MINIMUM EFFICIENCY REQUIREMENTS: ELECTRICALLY OPERATED UNITARY AIR CONDITIONERS AND CONDENSING UNITS

| EQUIPMENT TYPE | SIZE CATEGORY | HEATING SECTION TYPE | SUBCATEGORY OR RATING CONDITION | MINIMUM EFFICIENCY | TEST PROCEDURE[a] |
|---|---|---|---|---|---|
| Air conditioners, air cooled | < 65,000 Btu/h[b] | All | Split System | 13.0 SEER | AHRI 210/240 |
| | | | Single Package | 14.0 SEER | |
| Through-the-wall (air cooled) | ≤ 30,000 Btu/h[b] | All | Split system | 12.0 SEER | |
| | | | Single Package | 12.0 SEER | |
| Small-duct high-velocity (air cooled) | < 65,000 Btu/h[b] | All | Split System | 11.0 SEER | |
| Air conditioners, air cooled | ≥ 65,000 Btu/h and < 135,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 11.2 EER 12.8 IEER | AHRI 340/360 |
| | | All other | Split System and Single Package | 11.0 EER 12.6 IEER | |
| | ≥ 135,000 Btu/h and < 240,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 11.0 EER 12.4 IEER | |
| | | All other | Split System and Single Package | 10.8 EER 12.2 IEER | |
| | ≥ 240,000 Btu/h and < 760,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 10.0 EER 11.6 IEER | |
| | | All other | Split System and Single Package | 9.8 EER 11.4 IEER | |
| | ≥ 760,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 9.7 EER 11.2 IEER | |
| | | All other | Split System and Single Package | 9.5 EER 11.0 IEER | |
| Air conditioners, water cooled | < 65,000 Btu/h[b] | All | Split System and Single Package | 12.1 EER 12.3 IEER | AHRI 210/240 |
| | ≥ 65,000 Btu/h and < 135,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 12.1 EER 13.9 IEER | AHRI 340/360 |
| | | All other | Split System and Single Package | 11.9 EER 13.7 IEER | |
| | ≥ 135,000 Btu/h and < 240,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 12.5 EER 13.9 IEER | |
| | | All other | Split System and Single Package | 12.3 EER 13.7 IEER | |
| | ≥ 240,000 Btu/h and < 760,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 12.4 EER 13.6 IEER | |
| | | All other | Split System and Single Package | 12.2 EER 13.4 IEER | |
| | ≥ 760,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 12.2 EER 13.5 IEER | |
| | | All other | Split System and Single Package | 12.0 EER 13.3 IEER | |

| | | | | | |
|---|---|---|---|---|---|
| Air conditioners, evaporatively cooled | < 65,000 Btu/h[b] | All | Split System and Single Package | 12.1 EER<br>12.3 IEER | AHRI 210/240 |
| | ≥ 65,000 Btu/h and < 135,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 12.1 EER<br>12.3 IEER | AHRI 340/360 |
| | | All other | Split System and Single Package | 11.9 EER<br>12.1 IEER | |
| | ≥ 135,000 Btu/h and < 240,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 12.0 EER<br>12.2 IEER | |
| | | All other | Split System and Single Package | 11.8 EER<br>12.0 IEER | |
| | ≥ 240,000 Btu/h and < 760,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 11.9 EER<br>12.1 IEER | |
| | | All other | Split System and Single Package | 11.7 EER<br>11.9 IEER | |
| | ≥ 760,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 11.7 EER<br>11.9 IEER | |
| | | All other | Split System and Single Package | 11.5 EER<br>11.7 IEER | |
| Condensing units, air cooled | ≥ 135,000 Btu/h | — | — | 10.5 EER<br>11.8 IEER | AHRI 365 |
| Condensing units, water cooled | ≥ 135,000 Btu/h | — | — | 13.5 EER<br>14.0 IEER | |
| Condensing units, evaporatively cooled | ≥ 135,000 Btu/h | — | — | 13.5 EER<br>14.0 IEER | |

For SI: 1 British thermal unit per hour = 0.2931 W.

a. Chapter 6 contains a complete specification of the referenced test procedure, including the reference year version of the test procedure.
b. Single-phase, air-cooled air conditioners less than 65,000 Btu/h are regulated by NAECA. SEER values are those set by NAECA.

> For example a 5 ton air cooled split system with a SEER of 15 at a retail strip mall in Rockford would save:
>
> ΔkWH = (60) * [(1/13) – (1/15)] * 950
>
> = 585 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

Time of Sale:

ΔkW = (kBtu/hr * (1/EERbase - 1/EERee)) * CF

Early Replacement:

For remaining life of existing unit (1st 5 years):

ΔkW = (kBtu/hr) * [(1/EERexist) – (1/EERee)] * CF

For remaining measure life (next 10 years):

ΔkW = (kBtu/hr) * [(1/EERbase) – (1/EERee)] * CF

Where:

EERbase = Energy Efficiency Ratio of the baseline equipment

= EER values from tables above, based on applicable Code on date of equipment purchase (if unknown assume current Code). (For air-cooled units < 65 kBtu/hr, assume the following conversion from SEER to EER for calculation of peak savings:[407] EER = (-0.02 * $SEER^2$) + (1.12 * SEER))

EERee = Energy Efficiency Ratio of the energy efficient equipment. If the actual EERee is unknown, assume the conversion from SEER to EER for calculation of peak savings as above).

= Actual installed

EERexist = Energy Efficiency Ratio of the existing equipment

= Actual, or assume Code base in place at the original time of existing unit installation

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [408]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [409]

> For example, a 5 ton air cooled split system with a SEER of 15 in Rockford would save:
>
> $\Delta kW_{SSP}$ = (60) * [(1/11.2) – (1/12.3)] * .913
>
> = 0.437 kW

[407] Based on Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder. Note this is appropriate for single speed units only.

[408] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility's peak hour is divided by the maximum AC load during the year.

[409]Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year

**NATURAL GAS ENERGY SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**MEASURE CODE: CI-HVC-SPUA-V06-190101**

**REVIEW DEADLINE: 1/1/2022**

## 4.4.16 Steam Trap Replacement or Repair

### DESCRIPTION

The measure is for the repair or replacement of faulty steam traps that are allowing excess steam to escape and thereby increasing steam generation. The measure is applicable to commercial applications, commercial HVAC (low pressure steam) including multifamily buildings, low pressure industrial applications, medium pressure industrial applications, applications and high pressure industrial applications.

This measure was developed to be applicable to the following program types: TOS, RF. If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

Customers must have leaking traps to qualify for rebates. However, if a commercial customer opts to replace all traps without inspection, rebates and the savings are discounted to take into consideration the fact that some traps are being replaced that have not yet failed.

### DEFINITION OF BASELINE EQUIPMENT

The baseline criterion is a faulty steam trap in need of replacing. No minimum leak rate is required. Any leaking or blow through trap can be repaired or replaced. If a commercial customer chooses to repair or replace all the steam traps at the facility without verification, the savings are adjusted. Savings for commercial full replacement projects are reduced by the percentage of traps found to be leaking on average from the studies listed. If an audit is performed on a commercial site, then the leaking and blowdown can be adjusted.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The life of this measure is 6 years[410]

### DEEMED MEASURE COST

| Steam System | Cost per trap[411] ($) |
|---|---|
| Commercial Dry Cleaners | 77 |
| Commercial Heating (including Multifamily), low pressure steam | 77 |
| Industrial Medium Pressure >15 psig psig < 30 psig | 180 |
| Steam Trap, Industrial Medium Pressure ≥30 <75 psig | 223 |
| Steam Trap, Industrial High Pressure ≥75 <125 psig | 276 |
| Steam Trap, Industrial High Pressure ≥125 <175 psig | 322 |
| Steam Trap, Industrial High Pressure ≥175 <250 psig | 370 |
| Steam Trap, Industrial High Pressure ≥250 psig | 418 |

### LOADSHAPE

N/A

[410]Source paper is the CLEAResult "Steam Traps Revision #1" dated August 2011. Primary studies used to prepare the source paper include Enbridge Steam Trap Survey, KW Engineering Steam Trap Survey, Enbridge Steam Saver Program 2005, Armstrong Steam Trap Survey, DOE Federal Energy Management Program Steam Trap Performance Assessment, Oak Ridge National Laboratory Steam System Survey Guide, KEMA Evaluation of PG&E's Steam Trap Program, Sept. 2007. Communication with vendors suggested a inverted bucket steam trap life typically in the range of 5 - 7 years, float and thermostatic traps 4- 6 years, float and thermodynamic disc traps of 1 - 3 years. Cost does not include installation.

[411] Ibid.

**COINCIDENCE FACTOR**

N/A

## Algorithm

**CALCULATION OF SAVINGS**

**ENERGY SAVINGS**

**ELECTRIC ENERGY SAVINGS**

N/A

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

N/A

**NATURAL GAS SAVINGS**

$$\Delta Therm = Sa * (Hv/B) * Hours * L / 100,000$$

Where:

Sa = Average actual steam loss per leaking trap

= 24.24 x Pia x $D^2$ x A x FF

Where:

24.24 = Constant lb/(hr-psia-$in^2$)

Pia = Pig + Patm

= Average steam trap inlet pressure, absolute, psia

Pig = Average steam trap inlet pressure, gauge, psig

Patm = Atmospheric pressure, 14.7 psia

D = Diameter of Orifice, in.

A = Adjustment factor

= 50%,[412] all steam systems. This factor is to account for reducing the maximum theoretical steam flow to the average steam flow (the Enbridge factor).

FF = Flow Factor. In addition to the Adjustment factor (A), an additional 50 percent flow factor adjustment is recommended for medium and high pressure steam systems to address industrial float and thermostatic style traps where additional blockage is possible.

| Steam System | Average Steam Trap Inlet Pressure psig[413] | Diameter of Orifice in | Adjustment Factor | Flow Factor | Average Actual Steam Loss per Leaking Trap (lb/hr/trap) |
|---|---|---|---|---|---|
| Commercial Dry Cleaners | - | - | 50% | 100% | 19.1 |

[412] Enbridge adjustment factor used as referenced in CLEAResult "Work Paper Steam Traps Revision #2" Revision 3 dated March 2, 2012 and DOE Federal Energy Management Program Steam Trap Performance Assessment.

[413] Medium and high pressure steam trap inlet pressure based on Navigant analysis of source collected during program implementation by Nicor Gas for GPY1 through GPY4. For each steam trap project, the data provided measure savings description, operating pressure, installation Zip code, business building type, program year, and annual operating hours.

| Steam System | Average Steam Trap Inlet Pressure psig[413] | Diameter of Orifice in | Adjustment Factor | Flow Factor | Average Actual Steam Loss per Leaking Trap (lb/hr/trap) |
|---|---|---|---|---|---|
| Commercial Heating (including Multifamily) LPS | - | - | 50% | 100% | 6.9 |
| Industrial or Process Low Pressure, <15 psig | - | - | 50% | 100% | 6.9 |
| Medium Pressure >15 psig < 30 psig | 16 | 0.1875 | 50% | 50% | 6.5 |
| Medium Pressure ≥30 <75 psig | 47 | 0.2500 | 50% | 50% | 23.4 |
| High Pressure ≥75 <125 psig | 101 | 0.2500 | 50% | 50% | 43.8 |
| High Pressure ≥125 <175 psig | 146 | 0.2500 | 50% | 50% | 60.9 |
| High Pressure ≥175 <250 psig | 202 | 0.2500 | 50% | 50% | 82.1 |
| High Pressure ≥250 ≤300 psig | 263 | 0.2500 | 50% | 50% | 105.2 |
| High Pressure > 300 psig | Custom | Custom | 50% | 50% | Calculated |

Hv = Heat of vaporization of steam

| Steam System | Average Inlet Pressure psig | Heat of Vaporization[414] (Btu/lb) |
|---|---|---|
| Commercial Dry Cleaners | -- | 890 |
| Commercial Heating (including Multifamily) LPS | -- | 951 |
| Industrial and Process Low Pressure ≤15 psig | -- | 951 |
| Medium Pressure >15 psig < 30 psig | 16 | 944 |
| Medium Pressure ≥30 <75 psig | 47 | 915 |
| High Pressure ≥75 <125 psig | 101 | 880 |
| High Pressure ≥125 <175 psig | 146 | 859 |
| High Pressure ≥175 <250 psig | 202 | 837 |
| High Pressure ≥250 ≤300 psig | 263 | 816 |
| High Pressure > 300 psig | -- | Custom |

B = Boiler efficiency

= custom, if unknown:

= 80.7% for steam boilers, except multifamily low-pressure [415]

= 64.8% for multifamily low-pressure steam boilers [416]

Hours = Annual operating hours of steam plant

= custom, if unknown:

[414] Heat of vaporization of steam at the inlet pressure to the steam trap. Implicit assumption that the average boiler nominal pressure where the vaporization occurs, is essentially that same pressure. Referenced in CLEAResult “Work Paper Steam Traps Revision #2" Revision 3 dated March 2, 2012.

[415] Ibid.

[416] Katrakis, J. and T.S. Zawacki. “Field-Measured Seasonal Efficiency of Intermediate-sized Low-Pressure Steam Boilers”. ASHRAE V99, pt. 2, 1993.

| Steam System | Zone (where applicable) | Hours/Yr[417] |
|---|---|---|
| Commercial Dry Cleaners | All Climate Zones | 2,425 |
| Industrial and Process Low Pressure ≤15 psig | | 8,282 |
| Medium Pressure >15 psig < 30 psig | | 8,282 |
| Medium Pressure ≥30 <75 psig | | 8,282 |
| High Pressure ≥75 <125 psig | | 8,282 |
| High Pressure ≥125 <175 psig | | 8,282 |
| High Pressure ≥175 <250 psig | | 8,282 |
| High Pressure ≥250 psig | | 8,282 |
| Commercial Heating (including Multifamily)LPS[418] | 1 (Rockford) | 4,272 |
| | 2 (Chicago O'Hare) | 4,029 |
| | 3 (Springfield) | 3,406 |
| | 4 (Belleville) | 2,515 |
| | 5 (Marion) | 2,546 |

L = Leaking & blow-thru

L is 1.0 when applied to the replacment of an individual leaking trap. If a number of steam traps are replaced and the system has not been audited, the leaking and blow-thru is applied to reflect the assumed percentage of steam traps that were actually leaking and need to be replaced. A custom value can be utilized if a supported by an evaluation.

| Steam System | L (%)[419] |
|---|---|
| Custom | Custom |
| Commercial Dry Cleaners | 27% |
| Commercial Heating (including Multifamily) LPS | 27% |
| Industrial and Process Low Pressure ≤15 psig | 16% |
| Medium Pressure >15 psig < 30 psig | 16% |
| Medium Pressure ≥30 <75 psig | 16% |
| High Pressure ≥75 <125 psig | 16% |
| High Pressure ≥125 <175 psig | 16% |
| High Pressure ≥175 <250 psig | 16% |
| High Pressure > 300 psig | 16% |

**EXAMPLE**

For example, a commercial dry cleaning facility with the default hours of operation and boiler efficiency;

ΔTherms = Sa * (Hv/B) * Hours * L

= 19.1 lbs/hr/trap * (890 Btu/lb / 80%)/100,000 * 2,425 * 27%

= 138.8 therms per trap

### WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

---

[417] Medium and high pressure steam trap annual operating hours based on Navigant analysis of source collected during program implementation by Nicor Gas for GPY1 through GPY4. For each steam trap project, the data provided measure savings description, operating pressure, installation Zip code, business building type, program year, and annual operating hours.

[418] Since commercial LPS reflect heating systems, Hours/yr are equivalent to HDD55 zone table

[419] Dry cleaners survey data as referenced in CLEAResult “Work Paper Steam Traps Revision #2" Revision 3 dated March 2, 2012.

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-HVC-STRE-V05-180101**

**REVIEW DEADLINE: 1/1/2020**

## 4.4.17 Variable Speed Drives for HVAC Pumps and Cooling Tower Fans

### DESCRIPTION

This measure is applied to variable speed drives (VSD) which are installed on the following HVAC system applications: chilled water pump, hot water pumps and cooling tower fans. There is a separate measure for HVAC supply and return fans. All other VSD applications require custom analysis by the program administrator. The VSD will modulate the speed of the motor when it does not need to run at full load. Since the power of the motor is proportional to the cube of the speed for these types of applications, significant energy savings will result.

This measure is not applicable for:

- Cooling towers, chilled or hot water pumps with any process load.
- VSD installation in existing cooling towers with 2-speed motors. (IECC 2007 requires 2-speed motors for cooling towers with motors greater than 7.5 HP)
- VSD installation in new cooling towers with motors greater than 7.5 HP

This measure was developed to be applicable to the following program types: TOS, RF. If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

The VSD is applied to a motor which does not have a VSD. This measure is not applicable for replacing failed VSDs. The application must have a variable load and installation is to include the necessary controls. Savings are based on application of VSDs to a range of baseline load conditions including no control, inlet guide vanes, outlet guide vanes and throttling valves.

### DEFINITION OF BASELINE EQUIPMENT

The time of sale baseline is a new motor installed without a VSD or other methods of control. Retrofit baseline is an existing motor operating as is. Retrofit baselines may or may not include guide vanes, throttling valves or other methods of control. This information shall be collected from the customer.

Installations of new equipment with VSDs which are required by IECC 2012 or 2015 as adopted by the State of Illinois are not eligible for incentives.

Note IECC 2018 is scheduled to become effective March 1, 2019 and will become baseline for all New Construction permits from that date.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for HVAC application is 15 years;[420] measure life for process is 15 years.[421]

### DEEMED MEASURE COST

Customer provided costs will be used when available. Default measure costs[422] are noted below for up to 20 hp motors. Custom costs must be gathered from the customer for motor sizes not listed below.

| HP | Cost |
|---|---|
| 1 -5 HP | $ 1,330 |
| 7.5 HP | $ 1,622 |
| 10 HP | $ 1,898 |
| 15 HP | $ 2,518 |

[420] Efficiency Vermont TRM 10/26/11 for HVAC VSD motors
[421] DEER 2008
[422] Ohio TRM 8/6/2010 varies by motor/fan size based on equipment costs from Granger 2008 Catalog pp 286-289, average across available voltages and models. Labor costs from RS Means Data 2008 Ohio average cost adjustment applied.

| HP | Cost |
|---|---|
| 20 HP | $ 3,059 |

**LOADSHAPE**

Loadshape C42 - VFD - Boiler feedwater pumps <10 HP

Loadshape C43 - VFD - Chilled water pumps <10 HP

Loadshape C44 - VFD Boiler circulation pumps <10 HP

Loadshape C48 - VFD Boiler draft fans <10 HP

Loadshape C49 - VFD Cooling Tower Fans <10 HP

**COINCIDENCE FACTOR**

The demand savings factor (DSF) is already based upon coincident savings, and thus there is no additional coincidence factor for this characterization.

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

ΔkWh = BHP /EFFi * Hours * ESF

Where:

BHP = System Brake Horsepower

(Nominal motor HP * Motor load factor)

Motors are assumed to have a load factor of 65% for calculating kW if actual values cannot be determined[423]. Custom load factor may be applied if known.

EFFi = Motor efficiency, installed. Actual motor efficiency shall be used to calculate kW. If not known a default value of 93% shall be used.[424]

Hours = Default hours are provided for HVAC applications which vary by HVAC application and building type[425]. When available, actual hours should be used.

| Building Type | Heating Run Hours | Cooling Run Hours | Model Source |
|---|---|---|---|
| Assembly | 4888 | 2150 | eQuest |
| Assisted Living | 4711 | 4373 | eQuest |
| College | 3990 | 1605 | eQuest |
| Convenience Store | 4136 | 2084 | eQuest |
| Elementary School | 5105 | 3276 | eQuest |
| Garage | 4849 | 2102 | eQuest |
| Grocery | 4200 | 2096 | eQuest |

[423] Del Balso, Ryan J. "Investigation into the Reliability of Energy Efficiency/Demand Side Management Savings Estimates for Variable Frequency Drives in Commercial Applications", University of Colorado, Department of Civil, Environmental and Architectural Engineering, 2013.

[424] Ohio TRM 8/6/2010 pp207-209, Com Ed TRM June 1, 2010.

[425] Hours per year are estimated using the eQuest models as the total number of hours the heating or cooling system is operating for each building type. "Heating and Cooling Run Hours" are estimated as the total number of hours fans are operating for heating, cooling and ventilation for each building type. This may overclaim certain applications (e.g. pumps) and so where possible actual hours should be used for these applications.

| Building Type | Heating Run Hours | Cooling Run Hours | Model Source |
|---|---|---|---|
| Healthcare Clinic | 5481 | 1987 | eQuest |
| High School | 5480 | 3141 | eQuest |
| Hospital - VAV econ | 3718 | 2788 | eQuest |
| Hospital - CAV econ | 7170 | 2881 | eQuest |
| Hospital - CAV no econ | 7139 | 8760 | eQuest |
| Hospital - FCU | 5844 | 8729 | eQuest |
| Manufacturing Facility | 3821 | 2805 | eQuest |
| MF - High Rise | 4522 | 4237 | eQuest |
| MF - Mid Rise | 5749 | 2899 | eQuest |
| Hotel/Motel - Guest | 4480 | 4479 | eQuest |
| Hotel/Motel - Common | 3292 | 8712 | eQuest |
| Movie Theater | 5063 | 2120 | eQuest |
| Office - High Rise - VAV econ | 4094 | 2038 | eQuest |
| Office - High Rise - CAV econ | 5361 | 4849 | eQuest |
| Office - High Rise - CAV no econ | 5331 | 5682 | eQuest |
| Office - High Rise - FCU | 3758 | 3069 | eQuest |
| Office - Low Rise | 3834 | 2481 | eQuest |
| Office - Mid Rise | 6155 | 3036 | OpenStudio |
| Religious Building | 5199 | 2830 | eQuest |
| Restaurant | 4579 | 3350 | eQuest |
| Retail - Department Store | 4249 | 2528 | eQuest |
| Retail - Strip Mall | 4475 | 2266 | eQuest |
| Warehouse | 4606 | 770 | eQuest |
| Unknown | 4649 | 2718 | n/a |

The type of hours to apply depends on the VFD application, according to the table below.

| Application | Hours Type |
|---|---|
| Hot Water Pump | Heating |
| Chilled Water Pump | Cooling |
| Cooling Tower Fan | Cooling |

ESF = Energy savings factor varies by VFD application. Units are kW/HP.

| Application | ESF |
|---|---|
| Hot Water Pump | 0.424[426] |
| Chilled Water Pump | 0.411[427] |
| Cooling Tower Fan | 0.126[428] |

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$\Delta kW = BHP/EFFi * DSF$

Where:

[426] Based on the methodology described in the Connecticut TRM, 8th Edition (2013); derived using a temperature BIN analysis of typical heating, cooling and fan load profiles.

[427] Ibid

[428] Based on eQuest model for VSD v one-speed fan, see “CT Savings Factors.xlsx”.

DSF = Demand Savings Factor varies by VFD application.[429] Units are kW/HP. Values listed below are based on typical peak load for the listed application.

| Application | DSF |
|---|---|
| Hot Water Pump | 0 |
| Chilled Water Pump | 0.299 |
| Cooling Tower Fan | 0.378 |

### Fossil Fuel Impact Descriptions and Calculation

There are no expected fossil fuel impacts for this measure.

### Water Impact Descriptions and Calculation

N/A

### Deemed O&M Cost Adjustment Calculation

N/A

### Measure Code: CI-HVC-VSDHP-V05-190101

### Review Deadline: 1/1/2021

[429] DSF assumptions are based upon the same source as the ESFs.

## 4.4.18 Small Commercial Programmable Thermostats

### Description

This measure characterizes the energy savings from the installation of a new Programmable Thermostat for reduced heating energy consumption through temperature set-back during unoccupied or reduced demand times. This measure is limited to small businesses, as they have smaller HVAC systems that are similar to residential HVAC systems and may be controlled by a simple manual adjustment thermostat. Mid to large sized businesses will typically have a building automation system or some other form of automated HVAC controls. Therefore, it is limited to select building types, including small office, retail – strip mall, restaurants (characterized as 1, 2 or 3 meal), small manufacturing, religious facilities, and convenience stores. This measure is only appropriate for single zone heating systems. Custom calculations are required for savings for programmable thermostats installed in multi-zone systems.

This measure was developed to be applicable to the following program types: RF, DI.

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

The criteria for this measure are established by replacement of a manual-only temperature control, with one that has the capability to adjust temperature setpoints according to a schedule without manual intervention.

### Definition of Baseline Equipment

For new thermostats the baseline is a non-programmable thermostat requiring manual intervention to change temperature setpoint.

### Deemed Lifetime of Efficient Equipment

The expected measure life of a programmable thermostat is assumed to be 8 years[430]

### Deemed Measure Cost

Actual material and labor costs should be used if the implementation method allows. If unknown the capital and labor cost for this measure is assumed to be $181 per thermostat[431]. For the purposes of screening and planning it should be assumed that one thermostat will serve 5 tons of Cooling Capacity at a cost of $36.20 / ton or 115kBtuh of Heating Capacity at a cost of $1.57 / kBtu.

### Loadshape

N/A

### Coincidence Factor

N/A

[430] 8 years is based upon ASHRAE Applications (2003), Section 36, Table 3 estimate of 16 years for the equipment life, reduced by 50% to account for persistence issues.
[431] Nicor Rider 30 Business EER Program Database, Paid Rebates with Programmable Thermostat Installation Costs, Program to Date as of January 11, 2013.

## Algorithm

### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS[432]

ΔkWh = [Baseline Energy Use (kWh/Ton) – Proposed Energy Use (kWh/Ton)] * Cooling Capacity (Tons)

The following equations are used to calculate baseline and proposed electric energy use.The savings is the difference between the proposed and baseline calculated usage. This approach allows the savings estimate to account for the operational attributes of the baseline as well as the proposed case, yielding a better estimate than an approach that assumes a particular baseline or proposed energy use to determine savings.

**Electric Energy Use Equations (kWh / ton)**

| Building Type | Fan Mode During Occupied Period (*Fo*) | Equation |
|---|---|---|
| Assembly | Continuous | ***CZ***+***Fu****(0.83****Tc***+0.83****Th***+1.67****Ws***-293.018)-0.0922****Tc****Th***+1.291****Ws*** |
| | Intermittent | ***CZ***+***Fu****(1.911-0.12****Tc***)+***Tc****(0.00311****Ws***-0.229)+0.11****Ws*** |
| Convenience Store | Continuous | ***CZ***+***Fu****(-28.629****Tc***-11.69****Th***+19.118****Ws***-2935.12)+0.909****Ws*** |
| | Intermittent | ***CZ***+***Tc****(0.0863****Ws***-12.688)+***Th****(0.043****Ws***-6.38)+1.669****Ws*** |
| Office – Low Rise | Continuous | ***CZ***+***Fu****(7.082****Tc***-41.199****Th***+18.734****Ws***-3288.55)+***Tc****(0.205****Ws***-34.929) |
| | Intermittent | ***CZ***+***Tc****(0.0806****Ws***-8.984)+***Th****(0.0864****Ws***-9.558)+1.178****Ws*** |
| Religious | Continuous | ***CZ***+***Fu****(-1.579****Tc***-18.14****Th***+15.01****Ws***-2417.74)+***Tc****(0.177****Ws***-26.412) |
| | Intermittent | ***CZ***+***Fu****(0.266****Tc***-2.067)+***Tc****(0.0295****Ws***-4.502)+***Th****(0.0517****Ws***-8.251)+0.735****Ws*** |
| Restaurant – Fast Food | Continuous | ***CZ***+***Fu****(0.678****Tc***+0.257****Th***+2.88****Ws***-494.006)+***Tc****(0.0231****Ws***-4.074)+***Th****(0.00936****Ws***-1.655)+0.918****Ws*** |
| | Intermittent | ***CZ***+***Fu****(0.377****Tc***+0.124****Th***+0.13****Ws***-24.893)+***Tc****(-0.0143****Th***+0.0166****Ws***-2.691)+0.898****Ws*** |
| Restaurant – Full Service | Continuous | ***CZ***+***Fu****(-8.41****Th***+11.766****Ws***-1910.81)+***Tc****(0.282****Ws***-43.851) |
| | Intermittent | ***CZ***+0.123****Fu****Tc***+***Tc****(0.0561****Ws***-8.237)+***Th****(0.0219****Ws***-3.284)+1.038****Ws*** |
| Retail – Department Store | Continuous | ***CZ***+***Fu****(-1.475****Th***+0.755****Ws***-114.373)+***Th****(0.151****Ws***-24.016)+1.612****Ws*** |
| | Intermittent | ***CZ***+***Tc****(0.0173****Ws***-1.912)+***Th****(0.0249****Ws***-3.29)+0.511****Ws*** |
| Retail – Strip Mall | Continuous | ***CZ***+***Fu****(1.077****Tc***-10.697****Th***+6.91****Ws***-1117.18)+***Tc****(0.0583****Ws***-7.54)+1.231****Ws*** |
| | Intermittent | ***CZ***+0.0894****Fu****Tc***+***Th****(-0.0142****Tc***+0.04****Ws***-5.278)+0.884****Ws*** |

Where:

CZ = Climate Zone Coefficient

=Depends on Building Type and Fan Mode During Occupied Period (see table below)

Tc = Degrees of Cooling Setback °F

= Must be between 0-15°F

Th = Degrees of Heating Setback °F

=Must be between 0-15°F

Fo = Fan Mode During Occupied Period (Note: Commercial mechanical code requires continuous fan operation during occupied periods to meet ventilation requirements.)

432 Savings equations and factors determined by regression of results of a series of eQuest simulations. See Programmable T-Stat Work Paper_PECI_FinalDraft_140730_Redline.docx for details.

= Continuous for occupied fan that runs continuously (e.g. Fan Mode Set to 'On')

= Intermittent for occupied fan that runs intermittently (e.g. Fan Mode Set to 'Auto')

Fu = Fan Mode During Unoccupied Period

= 0 for unoccupied fan that runs continuously (e.g. Fan Mode Set to 'On')

= 1 for unoccupied fan that runs intermittently (e.g. Fan Mode Set to 'Auto')

Ws = Weekly Hours thermostat is in Occupied mode

= Minimum values depends on Building Type (see table below), maximum value of 168 (24/7)

(e.g.: Weekly occupancy schedule of Mon-Sat 8AM-5PM, Sun 9AM-2PM, Ws = 59)

**Electric Energy Use Climate Zone Coefficients and Minimum Weekly Hours Occupied**

| Building Type | Fan Mode During Occupied Period (*Fo*) | Climate Zone Coefficient (*CZ*)[433] | | | | | Minimum *Ws* |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | |
| Assembly | Continuous | 911.366 | 928.924 | 1152.83 | 1208.999 | 1210.173 | 98 |
| | Intermittent | 735.752 | 762.831 | 966.562 | 998.927 | 1028.906 | |
| Convenience Store | Continuous | 4817.094 | 4832.784 | 5139.133 | 5182.161 | 5208.608 | 108 |
| | Intermittent | 1478.133 | 1514.568 | 1784.384 | 1843.463 | 1930.47 | |
| Office - Low Rise | Continuous | 5047.662 | 5039.592 | 5187.924 | 5217.672 | 5177.449 | 55 |
| | Intermittent | 825.072 | 808.965 | 946.571 | 979.421 | 945.418 | |
| Religious Facility | Continuous | 4197.117 | 4172.858 | 4380.025 | 4370.008 | 4356.054 | 133 |
| | Intermittent | 632.404 | 603.395 | 678.294 | 664.717 | 616.853 | |
| Restaurant – Fast Food | Continuous | 1342.988 | 1378.661 | 1664.018 | 1714.201 | 1727.841 | 108 |
| | Intermittent | 993.764 | 1039.643 | 1307.8 | 1340.544 | 1389.791 | |
| Restaurant – Full Service | Continuous | 4070.35 | 4094.742 | 4428.966 | 4501.829 | 4522.522 | 117 |
| | Intermittent | 1472.014 | 1516.05 | 1856.108 | 1938.441 | 2056.45 | |
| Retail – Department Store | Continuous | 1510.201 | 1496.47 | 1706.105 | 1716.128 | 1688.464 | 93 |
| | Intermittent | 701.27 | 702.129 | 847.735 | 875.12 | 881.677 | |
| Retail – Strip Mall | Continuous | 1926.294 | 1930.137 | 2156.856 | 2174.435 | 2165.03 | 93 |
| | Intermittent | 656.479 | 673.257 | 835.906 | 850.322 | 869.921 | |

[433] Climate Zones Refrenced in Section 3.7, Table 3.6

> **EXAMPLE**
>
> A low rise office in Rockford (Climate Zone 1) is occupied Mon-Fri 7AM-6PM and has a 10 ton DX RTU controlled by a manual thermostat. The fan runs continuously during the occupied hours and building staff do not manually change the fan mode, cooling or heating setpoints during unoccupied periods.
>
> A programmable thermostat is installed by a contractor who sets the occupied schedule to Mon-Fri 7AM-6PM with a 10°F cooling and heating unoccupied temperature setback. The contractor also programs the fan to operate continuously during the occupied periods and to intermittent "auto" during the unoccupied periods.
>
> ΔkWh = [Baseline Energy Use (kWh/Ton) – Proposed Energy Use(kWh/Ton)] * Cooling Capacity (Tons)
>
> Baseline Energy Use (kWh/Ton) = Equation for Office Low Rise, *Fo*=Continuous
>
> $= \boldsymbol{CZ}+\boldsymbol{Fu}*(7.082*\boldsymbol{Tc}-41.199*\boldsymbol{Th}+18.734*\boldsymbol{Ws}-3288.55)+\boldsymbol{Tc}*(0.205*\boldsymbol{Ws}-34.929)$
>
> $= 5047.662+0*(7.082*0-41.199*0+18.734*168-3288.55)+0*(0.205*168-34.929)$
>
> = 5,047.662 kWh/Ton
>
> Proposed Energy Use (kWh/Ton) = Equation for Office Low Rise, *Fo*=Continuous
>
> $= \boldsymbol{CZ}+\boldsymbol{Fu}*(7.082*\boldsymbol{Tc}-41.199*\boldsymbol{Th}+18.734*\boldsymbol{Ws}-3288.55)+\boldsymbol{Tc}*(0.205*\boldsymbol{Ws}-34.929)$
>
> $= 5047.662+1*(7.082*10-41.199*10+18.734*55-3288.55)+10*(0.205*55-34.929)$
>
> = 2,211.722 kWh/Ton
>
> ΔkWh = [5,047.622 (kWh/Ton) – 2,211.722 (kWh/Ton)] * 10 Tons
>
> = 2,835.89 kWh/Ton * 10 Tons
>
> = 28,358.9 kWh

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

### NATURAL GAS ENERGY SAVINGS

ΔTherms = [Baseline Energy Use (Therms/kBtuh) – Proposed Energy Use(Therms/kBtuh)] * Output Heating Capacity (kBtuh)

The following equations are used to calculate baseline and proposed natural gas energy use. The savings is the difference between the proposed and baseline calculated usage. This approach allows the savings estimate to account for the operational attributes of the baseline as well as the proposed case, yielding a better estimate than an approach that assumes a particular baseline or proposed energy use to determine savings.

**Natural Gas Energy Use Equations (therms / kbtu output)**

| Building Type | Fan Mode During Occupied Period (*Fo*) | Equation |
|---|---|---|
| Assembly | Continuous | $\boldsymbol{CZ}+\boldsymbol{Fu}*(0.232*\boldsymbol{Th}+0.0984*\boldsymbol{Ws}-18.79)+\boldsymbol{Th}*(0.00271*\boldsymbol{Ws}-0.535)+0.0142*\boldsymbol{Ws}$ |
| | Intermittent | $\boldsymbol{CZ}+\boldsymbol{Fu}*(0.00405*\boldsymbol{Th}+0.000519*\boldsymbol{Ws}-0.11)+\boldsymbol{Th}*(0.0000689*\boldsymbol{Ws}-0.0118)+0.0022*\boldsymbol{Ws}$ |
| Convenience Store | Continuous | $\boldsymbol{CZ}+\boldsymbol{Fu}*(0.00545*\boldsymbol{Th}-0.00251*\boldsymbol{Ws}+0.416)+\boldsymbol{Th}*(0.000123*\boldsymbol{Ws}-0.0204)+0.00183*\boldsymbol{Ws}$ |
| | Intermittent | $\boldsymbol{CZ}+\boldsymbol{Fu}*(0.00231*\boldsymbol{Th}-0.0349)+\boldsymbol{Th}*(0.000309*\boldsymbol{Ws}-0.0494)+0.00266*\boldsymbol{Ws}$ |
| Office – Low Rise | Continuous | $\boldsymbol{CZ}+\boldsymbol{Fu}*(0.0205*\boldsymbol{Th}+0.364)+\boldsymbol{Th}*(0.00046*\boldsymbol{Ws}-0.0554)+0.00169*\boldsymbol{Ws}$ |
| | Intermittent | $\boldsymbol{CZ}+\boldsymbol{Fu}*(0.00745*\boldsymbol{Th}-0.142)+\boldsymbol{Th}*(0.00077*\boldsymbol{Ws}-0.111)+0.00199*\boldsymbol{Ws}$ |
| Religious | Continuous | $\boldsymbol{CZ}+0.00791*\boldsymbol{Fu}*\boldsymbol{Th}+\boldsymbol{Th}*(0.00096*\boldsymbol{Ws}-0.167)+0.00184*\boldsymbol{Ws}$ |
| | Intermittent | $\boldsymbol{CZ}+\boldsymbol{Fu}*(0.00143*\boldsymbol{Th}-0.0309)+\boldsymbol{Th}*(0.0008*\boldsymbol{Ws}-0.134)+0.00219*\boldsymbol{Ws}$ |
| Restaurant – Fast Food | Continuous | $\boldsymbol{CZ}+\boldsymbol{Fu}*(0.0431*\boldsymbol{Th}+0.0424*\boldsymbol{Ws}-7.517)+\boldsymbol{Th}*(0.00113*\boldsymbol{Ws}-0.213)+0.0119*\boldsymbol{Ws}$ |

| Building Type | Fan Mode During Occupied Period (*Fo*) | Equation |
|---|---|---|
| | Intermittent | $CZ+Fu*(0.0125*Th+0.0036*Ws-0.71)+Th*(0.000329*Ws-0.0615)+0.00738*Ws$ |
| Restaurant –Full Service | Continuous | $CZ+Fu*(0.00445*Ws-0.535)+Th*(0.000679*Ws-0.1)+0.00218*Ws$ |
| | Intermittent | $CZ+Fu*(0.00144*Th+0.000262*Ws-0.0553)+Th*(0.00018*Ws-0.0299)+0.00166*Ws$ |
| Retail – Department Store | Continuous | $CZ+0.00203*Fu*Th+Th*(0.000591*Ws-0.0812)+0.00194*Ws$ |
| | Intermittent | $CZ+Th*(0.000406*Ws-0.0611)+0.00228*Ws$ |
| Retail – Strip Mall | Continuous | $CZ+Fu*(0.00998*Th+0.00207*Ws-0.206)+Th*(0.000665*Ws-0.101)+0.00292*Ws$ |
| | Intermittent | $CZ+Fu*(0.00383*Th-0.0656)+Th*(0.000575*Ws-0.0912)+0.00249*Ws$ |

Where:

CZ = Climate Zone Coefficient

= Depends on Building Type and Fan Mode During Occupied Period (see table below)

Th = Degrees of Heating Setback °F

= Must be between 0-15°F

Fo = Fan Mode During Occupied Period (Note: Commercial mechanical code requires continuous fan operation during occupied periods to meet ventilation requirements.)

= Continuous for occupied fan that runs continuously (e.g. Fan Mode Set to ‘On’)

= Intermittent for occupied fan that runs intermittently (e.g. Fan Mode Set to ‘Auto’)

Fu = Fan Mode During Unoccupied Period

= 0 for unoccupied fan that runs continuously (e.g. Fan Mode Set to ‘On’)

= 1 for unoccupied fan that runs intermittently (e.g. Fan Mode Set to ‘Auto’)

Ws = Weekly Hours thermostat is in Occupied mode

= Minimum values depends on Building Type (see table below), maximum value of 168 (24/7)

(e.g.: Weekly occupancy schedule of Mon-Sat 8AM-5PM, Sun 9AM-2PM, Ws = 59)

**Natural Gas Energy Use Climate Zone Coefficients and Minimum Weekly Hours Occupied**

| Building Type | Fan Mode During Occupied Period (*Fo*) | Climate Zone Coefficient (*CZ*) | | | | | Minimum *Ws* |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | |
| Assembly | Continuous | 19.872 | 17.83 | 15.828 | 15.282 | 13.482 | 98 |
| | Intermittent | 0.237 | 0.0989 | 0.0267 | -0.0131 | -0.0871 | |
| Convenience Store | Continuous | 1.493 | 1.081 | 0.782 | 0.544 | 0.114 | 108 |
| | Intermittent | 1.128 | 0.854 | 0.619 | 0.437 | 0.0854 | |
| Office - Low Rise | Continuous | 1.718 | 1.317 | 0.971 | 0.739 | 0.319 | 55 |
| | Intermittent | 3.447 | 3.022 | 2.503 | 2.251 | 1.646 | |
| Religious Facility | Continuous | 6.294 | 5.55 | 4.678 | 4.202 | 3.122 | 133 |
| | Intermittent | 5.914 | 5.368 | 4.557 | 4.137 | 3.246 | |
| Restaurant – Fast Food | Continuous | 8.383 | 7.211 | 6.034 | 5.767 | 4.71 | 108 |
| | Intermittent | 1.227 | 0.636 | 0.302 | 0.102 | -0.262 | |
| Restaurant – Full Service | Continuous | 5.247 | 4.484 | 3.753 | 3.465 | 2.627 | 117 |
| | Intermittent | 0.951 | 0.704 | 0.51 | 0.381 | 0.0746 | |
| Retail – Department Store | Continuous | 4.385 | 3.854 | 3.192 | 2.784 | 1.858 | 93 |
| | Intermittent | 3.061 | 2.672 | 2.182 | 1.829 | 1.008 | |
| Retail – Strip Mall | Continuous | 3.917 | 3.394 | 2.728 | 2.394 | 1.617 | 93 |
| | Intermittent | 2.659 | 2.292 | 1.811 | 1.543 | 0.909 | |

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-HVC-PROG-V02-190101**

**REVIEW DEADLINE: 1/1/2022**

## 4.4.19 Demand Controlled Ventilation

### DESCRIPTION

Demand control ventilation (DCV) adjusts outside ventilation air based on the number of occupants and the ventilation demands that those occupants create. DCV is part of a building's ventilation system control strategy. It may include hardware, software, and controls as an integral part of a building's ventilation design. Active control of the ventilation system provides the opportunity to reduce heating and cooling energy use.

The primary component is a control sensor to communicate either directly with the economizer or with a central computer. The component is most typically a carbon dioxide (CO2) sensor, occupancy sensor, or turnstile counter. This measure is applicable to multiple building types, and savings are classified by the specific building types defined in the Illinois TRM. This measure is modeled to assume night time set backs are in operation and minimum outside air is being used when the building is unoccupied. Systems that have static louvers or that are open at night will likely have greater savings by using the custom program.

Demand controlled ventilation controls can also be added to the exhaust fans to enclosed parking garages. The fans modulate the ventilation airflow based on pollutant concentrations (primarily carbon monoxide) in the space.

This measure was developed to be applicable to the following program types: RF. If applied to other program types, the measure savings should be verified

### DEFINITION OF EFFICIENT EQUIPMENT

The efficient equipment condition is defined by new $CO_2$ sensors installed on return air systems where no other sensors were previously installed. For heating savings, this measure does not apply to any system with terminal reheat (constant volume or variable air volume). For terminal reheat system a custom savings calculation should be used.

### DEFINITION OF BASELINE EQUIPMENT

The base case for this measure is a space with no demand control capability. The current code minimum for outside air (OA) is 17 CFM per occupant (ASHRAE 62.1 - 2016) which is the value for office space assumed in this measure.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The deemed measure life is 10 years and based on CO2 sensor estimated life. [434]

### DEEMED MEASURE COST

The deemed measure cost is assumed to be the full cost of installation of a DCV retrofit including sensor cost ($500) and installation ($1000 labor) for a total of $1500[435].

Adding demand controlled ventilation to parking garages is assumed to cost $500 per sensor including the cost of the controller. The installation cost is estimated at $1,000 for labor[436].

### LOADSHAPE

Commercial ventilation C23

[434] During the course of conversations with vendors and Building Automation System (BAS) contractors, it was determined that sensors have to be functional for up to 10 years. It is recommended that they are part of a normal preventive maintenance program in which calibration is an important part of extending useful life. Although they are not subject to mechanical failure, they do fall out of tolerance over time.
[435] Discussion with vendors
[436] California Utilities Statewide Codes and Standards Team. 2011. "2013 California Building Energy Efficiency Standards", Garage Exhaust, Section 4.2 Page 14

**COINCIDENCE FACTOR**

N/A

**Algorithm**

**CALCULATION OF ENERGY SAVINGS**

**ELECTRIC ENERGY SAVINGS**

For facilities heated by natural gas,

$$\Delta kWh = \text{Condition Space}/1000 * SF_{cooling}$$

For facilities heated by heat pumps,

$$\Delta kWh = \text{Condition Space}/1000 * SF_{cooling} + \text{Condition Space}/1000 * SF_{Heat\ HP}$$

For facilities heated by electric resistance,

$$\Delta kWh = \text{Condition Space}/1000 * SF_{cooling} + \text{Condition Space}/1000 * SF_{Heat\ ER}$$

Where:

Conditioned Space = actual square footage of conditioned space controlled by sensor

$SF_{cooling}$ = Cooling Savings Factor

= value in table below based on building type and weather zone

$SF_{Heat\ HP}$ = Heating Savings factor for facilities heated by Heat Pump (HP)

= value in table below based on building type and weather zone

$SF_{Heat\ ER}$ = Heating Savings factor for facilities heated by Electric Resistance (ER)

= value in table below based on building type and weather zone

Saving Factor Tables[437]

| Building Type | $SF_{cooling}$ (kWh/1000 SqFt) | | | | |
|---|---|---|---|---|---|
| | Zone 1 (Rockford) | Zone 2 (Chicago) | Zone 3 (Springfield) | Zone 4 (Belleville) | Zone 5 (Marion) |
| Office - Low-rise | 285 | 289 | 299 | 298 | 305 |
| Office - Mid-rise | 225 | 228 | 234 | 233 | 237 |
| Office - High-rise | 267 | 271 | 279 | 279 | 284 |
| Religious Building | 763 | 780 | 886 | 889 | 910 |
| Restaurant | 498 | 510 | 573 | 593 | 615 |
| Retail - Department Store | 388 | 393 | 410 | 415 | 423 |
| Retail - Strip Mall | 269 | 272 | 285 | 285 | 290 |
| Convenience Store | 355 | 357 | 368 | 370 | 374 |
| Elementary School | 358 | 367 | 410 | 405 | 415 |
| High School | 350 | 359 | 401 | 396 | 406 |
| College/University | 400 | 426 | 472 | 488 | 519 |

[437] The electric energy savings was calculated using TMY3 weather data and methodology consistent with ASHRAE standards. Savings are calculated on an annual basis for each given temperature zone in Illinois. Energy savings for DCV were developed utilizing standards, inputs and approaches as set forth by current ASHRAE 62.1and 90.1, respectively. Building input parameters like square footage, equipment efficiencies and occupancy match those used in the EFLH calculations. Reference calculation found in Demand Control Ventilation 12-30-13.xls.

| Building Type | SF$_{cooling}$ (kWh/1000 SqFt) | | | | |
|---|---|---|---|---|---|
| | Zone 1 (Rockford) | Zone 2 (Chicago) | Zone 3 (Springfield) | Zone 4 (Belleville) | Zone 5 (Marion) |
| Healthcare Clinic | 349 | 354 | 389 | 392 | 398 |
| Lodging | 407 | 409 | 423 | 424 | 428 |
| Manufacturing | 175 | 177 | 183 | 248 | 185 |
| Special Assembly Auditorium | 563 | 581 | 668 | 677 | 711 |
| Default (non-garage) | 377 | 385 | 419 | 426 | 433 |
| Enclosed Parking Garage[438] | 925 | 925 | 925 | 925 | 925 |

| Building Type | SF $_{Heat\ HP}$ (kWh/1000 SqFt) | | | | |
|---|---|---|---|---|---|
| | Zone 1 (Rockford) | Zone 2 (Chicago) | Zone 3 (Springfield) | Zone 4 (Belleville) | Zone 5 (Marion) |
| Office - Low-rise | 234 | 205 | 181 | 171 | 147 |
| Office - Mid-rise | 157 | 138 | 121 | 115 | 99 |
| Office - High-rise | 211 | 185 | 163 | 154 | 133 |
| Religious Building | 1,508 | 1,333 | 1,180 | 1,125 | 1,008 |
| Restaurant | 1,067 | 962 | 837 | 816 | 720 |
| Retail - Department Store | 368 | 329 | 291 | 285 | 249 |
| Retail - Strip Mall | 246 | 215 | 195 | 186 | 165 |
| Convenience Store | 180 | 163 | 141 | 138 | 121 |
| Elementary School | 657 | 572 | 508 | 473 | 418 |
| High School | 641 | 558 | 495 | 461 | 406 |
| College/University | 1,267 | 1,114 | 980 | 945 | 798 |
| Healthcare Clinic | 447 | 396 | 348 | 334 | 299 |
| Lodging | 205 | 184 | 159 | 154 | 135 |
| Manufacturing | 130 | 114 | 101 | 172 | 83 |
| Special Assembly Auditorium | 1,773 | 1,564 | 1,414 | 1,378 | 1,212 |
| Default (non-garage) | 606 | 535 | 474 | 460 | 400 |

| Building Type | SF $_{Heat\ ER}$ (kWh/1000 SqFt) | | | | |
|---|---|---|---|---|---|
| | Zone 1 (Rockford) | Zone 2 (Chicago) | Zone 3 (Springfield) | Zone 4 (Belleville) | Zone 5 (Marion) |
| Office - Low-rise | 703 | 615 | 542 | 512 | 441 |
| Office - Mid-rise | 471 | 413 | 364 | 345 | 298 |
| Office - High-rise | 633 | 554 | 489 | 462 | 398 |
| Religious Building | 4,523 | 3,999 | 3,541 | 3,376 | 3,024 |
| Restaurant | 3,201 | 2,886 | 2,511 | 2,449 | 2,159 |
| Retail - Department Store | 1,103 | 987 | 874 | 855 | 748 |
| Retail - Strip Mall | 738 | 646 | 584 | 559 | 495 |
| Convenience Store | 541 | 488 | 423 | 413 | 364 |
| Elementary School | 1,972 | 1,715 | 1,523 | 1,420 | 1,254 |
| High School | 1,924 | 1,673 | 1,484 | 1,383 | 1,219 |
| College/University | 3,801 | 3,341 | 2,940 | 2,834 | 2,394 |

[438] Savings are estimated based on a study done by California Utilities Statewide Codes and Standards Team, “2013 California Building Energy Efficiency Standards”, 2013, Section 2.4, Table 1. The savings are primarily fan savings, and are not dependent on climate zone.

| Building Type | SF $_{Heat\ ER}$ (kWh/1000 SqFt) | | | | |
|---|---|---|---|---|---|
| | Zone 1 (Rockford) | Zone 2 (Chicago) | Zone 3 (Springfield) | Zone 4 (Belleville) | Zone 5 (Marion) |
| Healthcare Clinic | 1,341 | 1,188 | 1,044 | 1,001 | 896 |
| Lodging | 616 | 551 | 477 | 462 | 406 |
| Manufacturing | 390 | 343 | 303 | 516 | 250 |
| Special Assembly Auditorium | 5,320 | 4,691 | 4,243 | 4,133 | 3,636 |
| Default (non-garage) | 1,819 | 1,606 | 1,423 | 1,381 | 1,199 |

For example: 7,500 SqFt of low-rise office space in Chicago with gas heat.

ΔkWh = 7,500 /1000 *289

= 2,168 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

NA

**NATURAL GAS SAVINGS**

$$\Delta therms = Condition\ Space/1000 * SF_{Heat\ Gas}$$

Where:

$SF_{Heat\ Gas}$ = value in table below based on building type and weather zone[439]

| Building Type | $SF_{Heat\ Gas}$ (Therm/1000 sq ft) | | | | |
|---|---|---|---|---|---|
| | Zone 1 (Rockford) | Zone 2 (Chicago) | Zone 3 (Springfield) | Zone 4 (Belleville) | Zone 5 (Marion) |
| Office - Low-rise | 30 | 26 | 23 | 22 | 19 |
| Office - Mid-rise | 20 | 18 | 16 | 15 | 13 |
| Office- High-rise | 27 | 24 | 21 | 20 | 17 |
| Religious Building | 193 | 171 | 151 | 144 | 129 |
| Restaurant | 137 | 123 | 107 | 104 | 92 |
| Retail - Department Store | 47 | 42 | 37 | 36 | 32 |
| Retail - Strip Mall | 31 | 28 | 25 | 24 | 21 |
| Convenience Store | 23 | 21 | 18 | 18 | 16 |
| Elementary School | 84 | 73 | 65 | 61 | 53 |
| High School | 82 | 71 | 63 | 59 | 52 |
| College/ University | 162 | 143 | 125 | 121 | 102 |
| Healthcare Clinic | 57 | 51 | 45 | 43 | 38 |
| Lodging | 26 | 23 | 20 | 20 | 17 |
| Manufacturing | 17 | 15 | 13 | 22 | 11 |
| Special Assembly Auditorium | 227 | 200 | 181 | 176 | 155 |
| De-fault | 78 | 68 | 61 | 59 | 51 |

[439] The natural gas energy savings was calculated using TMY3 weather data and methodology consistent with ASHRAE standards. Savings are calculated on an annual basis for each given temperature zone in Illinois. Energy savings for DCV were developed utilizing standards, inputs and approaches as set forth by ASHRAE 62.1 and 90.1, respectively. Building input parameters like square footage, equipment efficiencies and occupancy match those used in the EFLH calculations. Reference calculation found in Demand Control Ventilation 12-30-13.xls.

For example: 7500 SqFt of low-rise office space in Chicago.

$$\Delta Therms = 7{,}500/1{,}000 * 26$$
$$= 195 \text{ Therms}$$

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-HVC-DCV-V05-190101**

**REVIEW DEADLINE: 1/1/2024**

## 4.4.20 High Turndown Burner for Space Heating Boilers

### DESCRIPTION

This measure is for a non-residential boilers equipped with linkageless controls providing space heating with burners having a turndown less than 6:1.[440] Turndown is the ratio of the high firing rate to the low firing rate. When boilers are subjected to loads below the low firing rate, the boiler must cycle on/off to meet the load requirements. A higher turndown ratio reduces burner startups, provides better load control, saves wear-and-tear on the burner, and reduces purge-air requirements, all of these benefits result in better overall efficiency.

This measure was developed to be applicable to the following program types: NC, TOS, RF.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

To qualify the boiler linkageless burner must operate with a turndown greater than or equal to 10:1 and be subjected to loads less than or equal to 30%[441] of the full fire input MBH for greater than 60%[442] of the operating hours.

### DEFINITION OF BASELINE EQUIPMENT

The baseline boiler utilizes a linkageless burner with a turndown ration of 6:1 or less and is used primarily for space heating. Redundant boilers do not qualify.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 21 years.[443]

### DEEMED MEASURE COST

The deemed installed measure cost including labor is approximately $2.53/MBtu/hr.[444]

### DEEMED O&M COST ADJUSTMENTS

N/A

### LOADSHAPE

N/A

### COINCIDENCE FACTOR

N/A

---

[440] The standard turndown ratio for boilers is 6:1. Understanding Fuel Savings in the Boiler Room, ASHRAE Journal, David Eoff, December, 2008 p 38

[441] Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, March 22, 2010. This factor implies that boilers are 30% oversized on average.

[442] FES Analysis of bin hours based upon a 30% oversizing factor.

[443] "Burner," Obtained from a nation-wide survey conducted by ASHRAE TC 1.8 (Akalin 1978). Data changed by TC 1.8 in 1986.

[444] FES review of PY2/PY3 costs for custom People's and North Shore high turndown burner projects. See High Turndown Costs.xlsx for details.

**Algorithm**

## CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

N/A

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

### NATURAL GAS SAVINGS

Δtherms = Ngi * SF * EFLH / 100

Where:

Ngi = Boiler gas input size (kBtu/hr) = custom

SF = Savings Factor = Percentage of energy loss per hour

= (∑ ((EL_base – EL_eff) * H_cycling)) / H)*100

Where:

EL_base = Base Boiler Percentage of energy loss due to cycling at % of Base Boiler Load where BL_base ≤ TDR_base

= 0.003 * $(\text{Cycles\_base})^2$ – 0.001 * Cycles_base [445]

Where:

Cycles_base = Number of Cycles/hour of base boiler

= TDR_base / BL

Where:

BL = % of full boiler load at bin hours being evaluated. This is assumed to be a straight line based on 0% load at the building balance point (assumed to be 55F), and full load corrected for the oversizing (OSF) at the lowest temperature bin of -10 to -5F.

OSF = Oversizing Factor = 1.3[446] or custom

TDR_base = Turndown ratio = 0.33[447] or custom

EL_eff = Efficient Boiler Percentage of energy loss due to cycling at % of Efficient Boiler Load

= 0.003 * $(\text{Cycles\_eff})^2$ – 0.001 * Cycles_eff

Where:

Cycles_eff = Number of Cycles/hour

= TDR_eff / BL

---

445 Release 3.0 Operations & Maintenance Best Practices A Guide to Achieving Operational Efficiency, August 2010, Federal Energy Management Program, US Department of Energy. The equation was determined by plotting the values in Table 9.2.1 – Boiler Cycling Energy Loss.

446 PA Consulting, KEMA, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, March 22, 2010, Page 4-12.

447 Ibid.

Where:

TDR_eff = Turndown ratio = 0.10[448] or custom

H_cycling = Hours base boiler is cycling at % of base boiler load

= see table below or custom

H = Total Number of Hours in Heating Season

= 4,946 or custom

100 = convert to a percentage

SF = 69.1 / 4946 *100 = 1.4% or custom (see table below for summary of values)

| Temperature | H_cycling | BL | EL_base | EL_eff | (EL_base-EL_eff)* Hours |
|---|---|---|---|---|---|
| 50 to 55 | 601 | 6.0% | 8.5% | 0.7% | 47.2 |
| 45 to 50 | 603 | 12.0% | 2.0% | 0.0% | 12.0 |
| 40 to 45 | 455 | 18.0% | 0.8% | 0.0% | 3.8 |
| 35 to 40 | 925 | 24.0% | 0.4% | 0.0% | 4.0 |
| 30 to 35 | 814 | 30.0% | 0.3% | 0.0% | 2.1 |
| | | | | Total | 69.1 |

EFLH = Equivalent Full Load Hours for heating are provided in section 4.4 HVAC End Use.

100 = convert kBtu to therms

**Water Impact Descriptions and Calculation**

N/A

**Deemed O&M Cost Adjustment Calculation**

N/A

**Measure Code: CI-HVAC-HTBC-V04-140601**

**Review Deadline: 1/1/2020**

448 10:1 ratio used to qualify for efficient equipment.

## 4.4.21 Linkageless Boiler Controls for Space Heating

### DESCRIPTION

This measure is for a non-residential boiler providing space heating and currently having single point positioning combustion control. In single-point positioning control, the fuel valve is linked to the combustion air damper via a jackshaft mechanism to maintain correspondence between fuel and combustion air input. Most boilers with single point positioning control do not maintain low excess air levels over their entire firing range. Generally these boilers are calibrated at high fire, but due to the non-linearity required for efficient combustion, excess air levels tend to dramatically increase as the firing rate decreases. Boiler efficiency drops as the excess air levels are increased.

This measure was developed to be applicable to the following program types: TOS, RF.
If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

To qualify the boiler burner must have a linkageless control system allowing the combustion air damper position to be adjusted and set for optimal efficiency at several firing rates throughout the burner's firing range. This requires the fuel valve and combustion air damper to each be powered by a separate actuator. An alternative to the combustion air damper is a Variable Speed Drive on the combustion air fan.

### DEFINITION OF BASELINE EQUIPMENT

The baseline boiler utilizes single point positioning for the burner combustion control.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 16 years.[449]

### DEEMED MEASURE COST

The deemed measure cost is estimated at $2.50/MBtu/hr burner input.[450]

### DEEMED O&M COST ADJUSTMENTS

N/A

### LOADSHAPE

N/A

### COINCIDENCE FACTOR

N/A

**Algorithm**

### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

When a Variable Speed Drive is incorporated, electrical savings are calculated according to the "4.4.17 Variable Speed Drive for HVAC Pumps and Cooling Tower Fans" measure.

[449] Total number of hours for heating with a base temperature of 55°F for Chicago, IL as noted by National Climate Data Center

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

N/A

**NATURAL GAS SAVINGS**

$$\Delta Therms = Ngi * SF * EFLH / 100$$

Where:

Ngi = Boiler gas input size (kBtu/hr) = custom

SF = Savings factor

Note: Savings factor is the percentage increase in efficiency as a result of the addition of linkageless burner controls. At an average boiler load of 35%, single point controls are assumed to have excess air of 91%, while linkageless controls are assumed to have 34% excess air.[451] The difference between controls types is 57% at this average operating condition. A 15% reduction in excess air is approximately a 1% increase in efficiency.[452] Therefore the nominal combustion efficiency increase is 57 / 15 * 1% = 3.8%.

= 3.8%

EFLH = Equivalent Full Load Hours for heating are provided in section 4.4 HVAC End Use

100 = convert kBtu to therms

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-HVC-LBC-V05-160601**

**REVIEW DEADLINE: 1/1/2022**

[451] Available and Emerging Technologies for Reducing Greenhouse Gas Emissions from Industrial, Commercial, and Institutional Boilers, Prepared by the Sector Policies and Programs Division Office of Air Quality Planning and Standards U.S. Environmental Protection Agency Research Triangle Park, North Carolina 27711, October 2010, Table 1. ICI Boilers – Summary of Greenhouse Gas Emission Reduction Measures, pg. 8

[452] Department of Energy (DOE). January 2012, Steam Tip Sheet #4, Improve Your Boiler's Combustion Efficiency. Advanced Manufacturing Office. Washington, DC: U.S. Department of Energy. This value was determined as an appropriate average over the stack temperatures and excess air levels indicated.

## 4.4.22 Oxygen Trim Controls for Space Heating Boilers

### Description

This measure is for a non-residential boiler providing space heating without oxygen trim combustion controls. Oxygen trim controls limit the amount of excess oxygen provided to the burner for combustion. This oxygen level is dependent upon the amount of air provided. Oxygen trim control converts parallel positioning, linkageless controls, into a closed-loop control configuration with the addition of an exhaust gas analyzer and PID controller. Boilers with oxygen trim controls can maintain a predetermined excess air rate (generally 15% to 30% excess air) over the entire burner firing rate. Boilers without these controls typically have excess air rates around 30% over the entire firing rate. Boiler efficiency drops as the excess air levels are increased.

This measure was developed to be applicable to the following program types: NC, TOS, RF.

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

To qualify the boiler burner must have an oxygen control system allowing the combustion air to be adjusted to maintain a predetermined excess oxygen level in the flue exhaust at all firing rates throughout the burner's firing range. This requires an oxygen sensor in the flue exhaust and linkageless fuel valve and combustion air controls.

### Definition of Baseline Equipment

The baseline boiler utilizes single point positioning for the burner combustion control.

### Deemed Lifetime of Efficient Equipment

The measure life for the O2 Trim controls is 18 years.[453]

### Deemed Measure Cost

The deemed measure cost is approximately $23,250.[454]

### Loadshape

N/A

### Coincidence Factor

N/A

**Algorithm**

### Calculation of Savings

### Electric Energy Savings

N/A

### Summer Coincident Peak Demand Savings

N/A

[453] State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report: August 25, 2009, Table 1-2. Recommended Measure Life by WISeerts Group Description, pg. 1-4.

[454] CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE) PROCESS BOILERS, 2013 California Building Energy Efficiency Standards, California Utilities Statewide Codes and Standards Team, October 2011, pg. 22

**NATURAL GAS ENERGY SAVINGS**

ΔTherms = Ngi * SF * EFLH / 100

Where:

Ngi = Boiler gas input size (kBtu/hr)

= Custom

SF = Savings factor

Note: Savings factor is the percentage reduction in gas consumption as a result of the addition of O2 trim controls. Linkageless controls have an excess air rate of 28% over the entire firing range.[455] O2 trim controls have an excess air rate of 15%.[456] The average difference is 13%. A 15% reduction in excess air is approximately a 1% increase in efficiency.[457] Therefore the nominal combustion efficiency increase is 13 / 15 * 1% = 0.87%.

= 0.87%

EFLH = Default Equivalent Full Load Hours for heating are provided in section 4.4 HVAC End Use. When available, actual hours should be used.

100 = convert kBtu to therms

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

The deemed annual Operations and Maintenance cost is $800.[458]

**MEASURE CODE: CI-HVC-O2TC-V01-140601**

**REVIEW DEADLINE: 1/1/2022**

[455] Department of Energy (DOE). 2009. Energy Matters newsletter. Fall 2009- Vol. 1, Iss. 1. Washington, DC: U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Industrial Technologies Program.

[456] Ibid

[458] Department of Energy (DOE). January 2012, Steam Tip Sheet #4, Improving Your Boiler's Combustion Efficiency. Advanced Manufacturing Office. Washington, DC: U.S. Department of Energy. This value was determined as an appropriate average over the stack temperatures and excess air levels indicated.

## 4.4.23 Shut Off Damper for Space Heating Boilers or Furnaces

**DESCRIPTION**

This measure is for non-residential atmospheric boilers or furnaces providing space heating without a shut off damper. When appliances are on standby mode warm room air is drawn through the stack via the draft hood or dilution air inlet at a rate proportional to the stack height, diameter and outdoor temperature. More air is drawn through the vent immediately after the appliance shuts off and the flue is still hot. Installation of a new shut off damper can prevent heat from being drawn up the warm vent and reducing the amount of air that passes through the furnace or boiler heat exchanger. This reduction in air can slightly increase overall operating efficiency by reducing the time needed to achieve steady-state operating conditions.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

To qualify the space heating boiler or furnace must have a new electrically or thermally activated shut off damper installed on either the exhaust flue or combustion air intake. Barometric dampers do not qualify. The damper actuation shall be interlocked with the firing controls.

**DEFINITION OF BASELINE EQUIPMENT**

The baseline boiler or furnace incorporates no shut off damper on the combustion air intake or flue exhaust.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The measure life for the shut off damper is 15 years.[459]

**DEEMED MEASURE COST**

The deemed measure cost for this approximately $1,500.[460]

**LOADSHAPE**

N/A

**COINCIDENCE FACTOR**

N/A

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

N/A

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

N/A

[459] State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report: August 25, 2009, Table 1-2. Recommended Measure Life by WISeerts Group Description, pg. 1-4.
[460] CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE) PROCESS BOILERS, 2013 California Building Energy Efficiency Standards, California Utilities Statewide Codes and Standards Team, October 2011, pg. 22

**NATURAL GAS ENERGY SAVINGS**

$$\Delta Therms = Ngi * SF * EFLH / 100$$

Where:

Ngi = Boiler gas input size (kBtu/hr)

= Custom

SF = Savings factor

= 1%[461]

Note: The savings factor assumes the boiler or furnace is located in an unconditioned space. The savings factor can be higher for those units located within conditioned space.

EFLH = Default Equivalent Full Load Hours for heating are provided in section 4.4 HVAC End Use. When available, actual hours should be used.

100 = convert kBtu to therms

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

The deemed annual Operations and Maintenance cost is $112.[462]

**MEASURE CODE: CI-HVC-SODP-V01-140601**

**REVIEW DEADLINE: 1/1/2020**

---

461 Based on internet review of savings potential;
"Up to 4%": Use of Automatic Vent Dampers for New and Existing Boilers and Furnaces, Energy Innovators Initiative Technical Fact Sheet, Office of Energy Efficiency, Canada, 2002
"Up to 1%": Page 9, The Carbon Trust, "Steam and high temperature hot water boilers", March 2012,
"1 - 2%": Page 2, Sustainable Energy Authority of Ireland "Steam Systems Technical Guide".

462 CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE) PROCESS BOILERS, 2013 California Building Energy Efficiency Standards, California Utilities Statewide Codes and Standards Team, October 2011, pg. 22

## 4.4.24 Small Pipe Insulation

### Description

This measure provides rebates for adding insulation to bare pipes with inner diameters of ½” and ¾”. Insulation must be at least one inch thick. Since new construction projects are required by code to have pipe insulation, this measure is only for retrofits of existing facilities. This covers bare straight pipe as well as all fittings.

Default savings are provided on a per linear foot basis. It is assumed that the majority of pipes less than one inch in commercial facilities are used for domestic hot water. However, this measure can cover hydronic heating systems as well as low and high pressure steam systems.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

The efficient case is a ½“or ¾“ diameter pipe with at least one inch of insulation. Insulation must be protected from damage which includes moisture, sunlight, equipment maintenance and wind. Outdoor pipes should have a weather protective jacket. Insulation must be continuous over straight pipe, elbows and tees.

### Definition of Baseline Equipment

The base case for savings estimates is a bare hot water or steam pipe with a fluid temperature of 105 degrees Fahrenheit or greater. Current new construction code requires insulation amounts similar to this measure though this base case is commonly found in older existing buildings.

### Deemed Lifetime of Efficient Equipment

The measure life is assumed to be 15 years.[463]

### Deemed Measure Cost

The incremental measure cost for insulation is the full cost of adding insulation to the pipe. Actual installation costs should be used for the measure cost. For planning purposes, the following costs can be used to estimate the full cost of materials and labor.[464]

| Insulation Thickness | ¾” pipe | ½” pipe |
|---|---|---|
| 1” | $4.45 | $4.15 |

### Loadshape

N/A

### Coincidence Factor

N/A

[463] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
[464] A market survey was performed to determine these costs.

**Algorithm**

### Calculation of Energy Savings

#### Electric Energy Savings

N/A

#### Summer Coincident Peak Demand Savings

N/A

#### Natural Gas Savings

ΔTherms per foot[465] = $[((Q_{base} – Q_{eff}) * EFLH) / (100{,}000 * \eta Boiler)] * TRF$

= [Modeled or provided by tables below] * TRF

ΔTherms = $(L_{sp} + L_{oc,i}) * \Delta therms\ per\ foot$

Where:

EFLH = Equivalent Full Load Hours for Heating

= Actual or defaults by building type provided in Section 4.4, HVAC end use

For year round recirculation or domestic hot water:

= 8,766

For heating season recirculation, hours with the outside air temperature below 55°F:

| Zone | Hours |
|---|---|
| Zone 1 (Rockford) | 5,039 |
| Zone 2 (Chicago) | 4,963 |
| Zone 3 (Springfield) | 4,495 |
| Zone 4 (Belleville/ | 4,021 |
| Zone 5 (Marion) | 4,150 |

$Q_{base}$ = Heat Loss from Bare Pipe (Btu/hr/ft)

= Calculated where possible using 3E Plusv4.0 software. For defaults see table below

$Q_{eff}$ = Heat Loss from Insulated Pipe (Btu/hr/ft)

= Calculated where possible using 3E Plusv4.0 software. For defaults see table below

100,000 = conversion factor (1 therm = 100,000 Btu)

ηBoiler = Efficiency of the boiler being used to generate the hot water or steam in the pipe

= 81.9% for water boilers [466]

= 80.7% for steam boilers, except multifamily low-pressure [467]

[465] This value comes from the reference table “Savings Summary by Building Type and System Type.” The formula and the input tables in this section document assumptions used in calculation spreadsheet “Pipe Insulation Savings 2013-11-12.xlsx”

[466] Average efficiencies of units from the California Energy Commission (CEC).

[467] Ibid.

= 64.8% for multifamily low-pressure steam boilers [468]

TRF = Thermal Regain Factor for space type, applied only to space heating energy and is applied to values resulting from Δtherms/ft tables below [469]

= See table below for base TRF values by pipe location

May vary seasonally such as: TRF[summer] * summer hours + TRF[winter] * winter hours where TRF values reflecting summer and winter conditions are apportioned by the hours for those conditions. TRF may also be adjusted by building specific balance temperature and operating hours above and below that balance temperature.470

| Pipe Location | Assumed Regain | TRF, Thermal Regain Factor |
|---|---|---|
| Outdoor | 0% | 1.0 |
| Indoor, heated space | 85% | 0.15 |
| Indoor, semi- heated, (unconditioned space, with heat transfer to conditioned space. E.g.: boiler room, ceiling plenum, basement, crawlspace, wall) | 30% | 0.70 |
| Indoor, unheated, (no heat transfer to conditioned space) | 0% | 1.0 |
| Location not specified | 85% | 0.15 |
| Custom | Custom | 1 – assumed regain |

$L_{sp}$ = Length of straight pipe to be insulated (linear foot)

$L_{oc,i}$ = Total equivalent length of (elbows and tees) of pipe to be insulated. Use table below to determine equivalent lengths.

| Nominal Pipe Diameter | Equivalent Length (ft) | |
|---|---|---|
| | 90 Degree Elbow | Straight Tee |
| 1/2" | 0.04 | 0.03 |
| 3/4" | 0.06 | 0.05 |

The table below shows the deemed therm savings by building type and region on a per linear foot basis for both ½” and ¾” copper pipe.

The following table provides deemed values for 1/2" copper pipe, temperatures are assumed by category below, and insulation is assumed to be one inch fiberglass.

| Piping Use | Building Type | Annual Therms Saved / Linear Foot | | | | |
|---|---|---|---|---|---|---|
| | | Zone 1 (Rockford) | Zone 2 (Chicago) | Zone 3 (Springfield) | Zone 4 (Belleville) | Zone 5 (Marion) |
| Space Heating | Assembly | 0.117 | 0.120 | 0.107 | 0.071 | 0.109 |
| | Assisted Living | 0.110 | 0.107 | 0.094 | 0.069 | 0.083 |
| | College | 0.100 | 0.093 | 0.083 | 0.046 | 0.055 |

[468] Katrakis, J. and T.S. Zawacki. “Field-Measured Seasonal Efficiency of Intermediate-sized Low-Pressure Steam Boilers”. ASHRAE V99, pt. 2, 1993.

[469] Thermal regain for *residential* pipe insulation measures is discussed in Home Energy Services Impact Evaluation, prepared for the Massachusetts Residential Retrofit and Low Income Program Area Evaluation, Cadmus Group, Inc., August 2012 and Andrews, John, Better Duct Systems for Home Heating and Cooling, U.S. Department of Energy, 2001. Recognizing the differences between residential and commercial heating systems, the factors have been adjusted based on professional judgment. This factor would benefit from additional study and evaluation.

[470] Thermal Regain Factor_4-30-14.docx

| Piping Use | Building Type | Annual Therms Saved / Linear Foot | | | | |
|---|---|---|---|---|---|---|
| | | Zone 1 (Rockford) | Zone 2 (Chicago) | Zone 3 (Springfield) | Zone 4 (Belleville) | Zone 5 (Marion) |
| Non-recirculating | Convenience Store | 0.097 | 0.089 | 0.079 | 0.057 | 0.064 |
| | Elementary School | 0.116 | 0.113 | 0.100 | 0.069 | 0.084 |
| | Garage | 0.064 | 0.063 | 0.056 | 0.044 | 0.049 |
| | Grocery | 0.105 | 0.105 | 0.092 | 0.057 | 0.068 |
| | Healthcare Clinic | 0.103 | 0.106 | 0.092 | 0.063 | 0.066 |
| | High School | 0.120 | 0.121 | 0.109 | 0.077 | 0.091 |
| | Hospital - CAV no econ | 0.115 | 0.119 | 0.101 | 0.087 | 0.099 |
| | Hospital - CAV econ | 0.117 | 0.121 | 0.103 | 0.089 | 0.101 |
| | Hospital - VAV econ | 0.048 | 0.045 | 0.034 | 0.020 | 0.022 |
| | Hospital - FCU | 0.087 | 0.099 | 0.080 | 0.094 | 0.127 |
| | Hotel/Motel | 0.115 | 0.112 | 0.101 | 0.069 | 0.084 |
| | Hotel/Motel - Common | 0.104 | 0.106 | 0.101 | 0.082 | 0.086 |
| | Hotel/Motel - Guest | 0.115 | 0.111 | 0.099 | 0.066 | 0.082 |
| | Manufacturing Facility | 0.068 | 0.066 | 0.061 | 0.037 | 0.041 |
| | MF - High Rise | 0.100 | 0.098 | 0.090 | 0.076 | 0.076 |
| | MF - High Rise - Common | 0.118 | 0.115 | 0.103 | 0.071 | 0.092 |
| | MF - High Rise - Residential | 0.096 | 0.096 | 0.087 | 0.075 | 0.073 |
| | MF - Mid Rise | 0.109 | 0.110 | 0.095 | 0.070 | 0.079 |
| | Movie Theater | 0.119 | 0.117 | 0.109 | 0.083 | 0.099 |
| | Office - High Rise - CAV no econ | 0.132 | 0.134 | 0.122 | 0.082 | 0.089 |
| | Office - High Rise - CAV econ | 0.136 | 0.139 | 0.128 | 0.088 | 0.097 |
| | Office - High Rise - VAV econ | 0.100 | 0.102 | 0.084 | 0.050 | 0.055 |
| | Office - High Rise - FCU | 0.073 | 0.072 | 0.062 | 0.033 | 0.035 |
| | Office - Low Rise | 0.093 | 0.093 | 0.074 | 0.045 | 0.052 |
| | Office - Mid Rise | 0.103 | 0.104 | 0.088 | 0.056 | 0.062 |
| | Religious Building | 0.105 | 0.098 | 0.094 | 0.069 | 0.079 |
| | Restaurant | 0.088 | 0.088 | 0.079 | 0.060 | 0.071 |
| | Retail - Department Store | 0.091 | 0.083 | 0.078 | 0.051 | 0.058 |
| | Retail - Strip Mall | 0.087 | 0.081 | 0.071 | 0.049 | 0.053 |
| | Warehouse | 0.095 | 0.089 | 0.091 | 0.057 | 0.070 |
| | Unknown | 0.101 | 0.100 | 0.089 | 0.064 | 0.074 |
| Space Heating - recirculation heating season only | All buildings (Hours below 55°F) | 0.329 | 0.324 | 0.293 | 0.262 | 0.271 |
| Space Heating - recirculation year round | All buildings (All hours) | 0.572 | 0.572 | 0.572 | 0.572 | 0.572 |
| DHW | Recirculation loop | 0.572 | 0.572 | 0.572 | 0.572 | 0.572 |
| Process | Custom | Custom | | | | |

The following table provides deemed savings values for 3/4" copper pipe with temperatures assumed by category below, insulation is assumed to be one inch fiberglass.

| Piping Use | Building Type | Annual Therms Saved / Linear Foot | | | | |
|---|---|---|---|---|---|---|
| | | Zone 1 (Rockford) | Zone 2 (Chicago) | Zone 3 (Springfield) | Zone 4 (Belleville) | Zone 5 (Marion) |
| Space Heating Non-recirculating | Assembly | 0.142 | 0.145 | 0.129 | 0.086 | 0.132 |
| | Assisted Living | 0.133 | 0.130 | 0.115 | 0.084 | 0.101 |
| | College | 0.121 | 0.113 | 0.101 | 0.056 | 0.067 |
| | Convenience Store | 0.117 | 0.108 | 0.096 | 0.069 | 0.077 |
| | Elementary School | 0.141 | 0.137 | 0.121 | 0.084 | 0.102 |
| | Garage | 0.078 | 0.077 | 0.067 | 0.054 | 0.060 |
| | Grocery | 0.127 | 0.127 | 0.111 | 0.069 | 0.083 |
| | Healthcare Clinic | 0.125 | 0.128 | 0.112 | 0.076 | 0.081 |
| | High School | 0.146 | 0.147 | 0.132 | 0.094 | 0.110 |
| | Hospital - CAV no econ | 0.140 | 0.144 | 0.123 | 0.105 | 0.120 |
| | Hospital - CAV econ | 0.142 | 0.147 | 0.125 | 0.108 | 0.123 |
| | Hospital - VAV econ | 0.058 | 0.055 | 0.041 | 0.025 | 0.027 |
| | Hospital - FCU | 0.105 | 0.120 | 0.098 | 0.115 | 0.154 |
| | Hotel/Motel | 0.140 | 0.136 | 0.122 | 0.084 | 0.102 |
| | Hotel/Motel - Common | 0.127 | 0.129 | 0.123 | 0.100 | 0.105 |
| | Hotel/Motel - Guest | 0.139 | 0.135 | 0.120 | 0.081 | 0.099 |
| | Manufacturing Facility | 0.083 | 0.080 | 0.074 | 0.045 | 0.050 |
| | MF - High Rise | 0.121 | 0.119 | 0.109 | 0.093 | 0.093 |
| | MF - High Rise - Common | 0.144 | 0.140 | 0.125 | 0.086 | 0.111 |
| | MF - High Rise - Residential | 0.117 | 0.116 | 0.105 | 0.091 | 0.089 |
| | MF - Mid Rise | 0.132 | 0.134 | 0.115 | 0.085 | 0.096 |
| | Movie Theater | 0.144 | 0.142 | 0.133 | 0.101 | 0.120 |
| | Office - High Rise - CAV no econ | 0.160 | 0.162 | 0.148 | 0.099 | 0.108 |
| | Office - High Rise - CAV econ | 0.165 | 0.169 | 0.155 | 0.107 | 0.118 |
| | Office - High Rise - VAV econ | 0.121 | 0.123 | 0.102 | 0.060 | 0.067 |
| | Office - High Rise - FCU | 0.089 | 0.087 | 0.075 | 0.040 | 0.042 |
| | Office - Low Rise | 0.113 | 0.113 | 0.090 | 0.055 | 0.063 |
| | Office - Mid Rise | 0.126 | 0.126 | 0.106 | 0.068 | 0.075 |
| | Religious Building | 0.127 | 0.119 | 0.114 | 0.084 | 0.095 |
| | Restaurant | 0.107 | 0.107 | 0.096 | 0.073 | 0.086 |
| | Retail - Department Store | 0.110 | 0.101 | 0.095 | 0.062 | 0.071 |
| | Retail - Strip Mall | 0.106 | 0.098 | 0.086 | 0.059 | 0.064 |
| | Warehouse | 0.115 | 0.108 | 0.111 | 0.069 | 0.085 |
| | Unknown | 0.123 | 0.122 | 0.108 | 0.078 | 0.090 |
| Space Heating - recirculation heating season only | All buildings (Hours below 55°F) | 0.399 | 0.393 | 0.356 | 0.319 | 0.329 |
| Space Heating - recirculation year round | All buildings (All hours) | 0.694 | 0.694 | 0.694 | 0.694 | 0.694 |
| DHW | Recirculation loop | 0.694 | 0.694 | 0.694 | 0.694 | 0.694 |
| Process | Custom | Custom | | | | |

## WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

## DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

**MEASURE CODE: CI-HVC-SPIN-V02-160601**

**REVIEW DEADLINE: 1/1/2023**

## 4.4.25 Small Commercial Programmable Thermostat Adjustments

### Description

This measure involves reprogramming existing commercial programmable thermostats or building automation systems for reduced energy consumption through adjustments of unoccupied heating/cooling setpoints and/or fan control. This measure is limited to packaged HVAC units that are controlled by a commercial thermostat or building automation system. The measure is limited to select building types presented below.

**Eligible Small Commercial Building Types**

| Building Type |
|---|
| Assembly |
| Convenience Store |
| Office - Low Rise |
| Restaurant - Fast Food |
| Religious Facility |
| Restaurant - Full Service |
| Retail - Strip Mall |
| Retail - Department Store |

This measure was developed to be applicable to the following program types: RF, DI.

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

The criteria for this measure is established by optimizing heating/cooling temperature setbacks and fan operation with a commercial programmable thermostat or building automation system, which reprogrammed to match actual facility occupancy.

### Definition of Baseline Equipment

The baseline for this measure is a commercial programmable thermostat or building automation system that is currently operating packaged HVAC units with heating/cooling temperature setbacks and fan operation that do not align with a facilities actual occupancy.

### Deemed Lifetime of Efficient Equipment

The expected measure life of a programmable thermostat is assumed to be 8 years[471]. For the purposes of claiming savings for a adjustment of an existing programmable thermostat, this is reduced to a 25% persistence factor to give a final measure life of 2 years. It is recommended that this assumption be evaluated by future energy measurement and verification activities.

### Deemed Measure Cost

Actual labor costs should be used if the implementation method allows. If unknown the labor cost for this measure is assumed to be $70.34[472] per thermostat, as summarized in the table below.

[471] 8 years is based upon ASHRAE Applications (2003), Section 36, Table 3 estimate of 16 years for the equipment life, reduced by 50% to account for persistence issues.

[472] RSMeans, “Instrumentation and Control for HVAC”, Mechanical Cost Data , Kingston, MA: Reed Construction Data, 2010, pg. 255 & 632

| Measure | Units | Materials | Labor | Total Cost (including O&P) | City Cost Index (Install Only)* | Total | Source |
|---|---|---|---|---|---|---|---|
| Adjust Temperature Set Points | 4 | $0.00 | $5.95 | $6.55 | 134.5% | $35.24 | RS Means 2010 (pg 255, Section 23-09-8100) |
| Adjust Fan Schedule | 2 | $0.00 | $11.86 | $13.05 | 134.5% | $35.10 | RS Means 2010 (pg 255, Section 23-09-8120) |
| **Totals** | | | | | | **$70.34** | |

* Chicago, IL - Division 23

**LOADSHAPE**

N/A

**COINCIDENCE FACTOR**

N/A

## Algorithm

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**[473]

ΔkWh = [Baseline Energy Use (kWh/Ton) – Proposed Energy Use (kWh/Ton)] * Cooling Capacity (Tons)

The following equations are used to calculate baseline and proposed electric energy use. The savings is the difference between the proposed and baseline calculated usage. This approach allows the savings estimate to account for the operational attributes of the baseline as well as the proposed case, yielding a better estimate than an approach that assumes a particular baseline or proposed energy use to determine savings.

**Electric Energy Use Equations (kWh / ton)**

| Building Type | Fan Mode During Occupied Period (*Fo*) | Equation |
|---|---|---|
| **Assembly** | Continuous | ***CZ***+***Fu****(0.83****Tc***+0.83****Th***+1.67****Ws***-293.018)-0.0922****Tc****Th***+1.291****Ws*** |
| | Intermittent | ***CZ***+***Fu****(1.911-0.12****Tc***)+***Tc****(0.00311****Ws***-0.229)+0.11****Ws*** |
| **Convenience Store** | Continuous | ***CZ***+***Fu****(-28.629****Tc***-11.69****Th***+19.118****Ws***-2935.12)+0.909****Ws*** |
| | Intermittent | ***CZ***+***Tc****(0.0863****Ws***-12.688)+***Th****(0.043****Ws***-6.38)+1.669****Ws*** |
| **Office – Low Rise** | Continuous | ***CZ***+***Fu****(7.082****Tc***-41.199****Th***+18.734****Ws***-3288.55)+***Tc****(0.205****Ws***-34.929) |
| | Intermittent | ***CZ***+***Tc****(0.0806****Ws***-8.984)+***Th****(0.0864****Ws***-9.558)+1.178****Ws*** |
| **Religious** | Continuous | ***CZ***+***Fu****(-1.579****Tc***-18.14****Th***+15.01****Ws***-2417.74)+***Tc****(0.177****Ws***-26.412) |
| | Intermittent | ***CZ***+***Fu****(0.266****Tc***-2.067)+***Tc****(0.0295****Ws***-4.502)+***Th****(0.0517****Ws***-8.251)+0.735****Ws*** |
| **Restaurant – Fast Food** | Continuous | ***CZ***+***Fu****(0.678****Tc***+0.257****Th***+2.88****Ws***-494.006)+***Tc****(0.0231****Ws***-4.074)+***Th****(0.00936****Ws***-1.655)+0.918****Ws*** |
| | Intermittent | ***CZ***+***Fu****(0.377****Tc***+0.124****Th***+0.13****Ws***-24.893)+***Tc****(-0.0143****Th***+0.0166****Ws***-2.691)+0.898****Ws*** |
| **Restaurant – Sit Down** | Continuous | ***CZ***+***Fu****(-8.41****Th***+11.766****Ws***-1910.81)+***Tc****(0.282****Ws***-43.851) |
| | Intermittent | ***CZ***+0.123****Fu****Tc***+***Tc****(0.0561****Ws***-8.237)+***Th****(0.0219****Ws***-3.284)+1.038****Ws*** |
| **Retail – Large** | Continuous | ***CZ***+***Fu****(-1.475****Th***+0.755****Ws***-114.373)+***Th****(0.151****Ws***-24.016)+1.612****Ws*** |
| | Intermittent | ***CZ***+***Tc****(0.0173****Ws***-1.912)+***Th****(0.0249****Ws***-3.29)+0.511****Ws*** |

473 Savings equations and factors determined by regression of results of a series of eQuest simulations. See Programmable T-Stat Work Paper_PECI_FinalDraft_140730_Redline.docx for details.

| Building Type | Fan Mode During Occupied Period (*Fo*) | Equation |
|---|---|---|
| **Retail – Strip Mall** | Continuous | ***CZ***+***Fu****(1.077****Tc***-10.697****Th***+6.91****Ws***-1117.18)+***Tc****(0.0583****Ws***-7.54)+1.231****Ws*** |
| | Intermittent | ***CZ***+0.0894****Fu*******Tc***+***Th****(-0.0142****Tc***+0.04****Ws***-5.278)+0.884****Ws*** |

Where:

CZ = Climate Zone Coefficient

= Depends on Building Type and Fan Mode During Occupied Period (see table below)

Tc = Degrees of Cooling Setback °F

= Must be between 0-15°F

Th = Degrees of Heating Setback °F

=Must be between 0-15°F

Fo = Fan Mode During Occupied Period (Note: Commercial mechanical code requires continuous fan operation during occupied periods to meet ventilation requirements.)

= Continuous for occupied fan that runs continuously (e.g. Fan Mode Set to 'On')

= Intermittent for occupied fan that runs intermittently (e.g. Fan Mode Set to 'Auto')

Fu = Fan Mode during Unoccupied Period

= 0 for unoccupied fan that runs continuously (e.g. Fan Mode Set to 'On')

= 1 for unoccupied fan that runs intermittently (e.g. Fan Mode Set to 'Auto')

Ws = Weekly Hours thermostat is in Occupied mode,

= Minimum values depend on Building Type (see table below), maximum value of 168 (24/7) ex: Weekly occupancy schedule of Mon-Sat 8AM-5PM, Sun 9AM-2PM, Ws = 59

**Electric Energy Use Climate Zone Coefficients and Minimum Weekly Hours Occupied**

| Building Type | Fan Mode During Occupied Period (*Fo*) | Climate Zone Coefficient (*CZ*) | | | | | Minimum *Ws* |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | |
| **Assembly** | Continuous | 911.366 | 928.924 | 1152.83 | 1208.999 | 1210.173 | 98 |
| | Intermittent | 735.752 | 762.831 | 966.562 | 998.927 | 1028.906 | |
| **Convenience Store** | Continuous | 4817.094 | 4832.784 | 5139.133 | 5182.161 | 5208.608 | 108 |
| | Intermittent | 1478.133 | 1514.568 | 1784.384 | 1843.463 | 1930.47 | |
| **Office - Low Rise** | Continuous | 5047.662 | 5039.592 | 5187.924 | 5217.672 | 5177.449 | 55 |
| | Intermittent | 825.072 | 808.965 | 946.571 | 979.421 | 945.418 | |
| **Religious Facility** | Continuous | 4197.117 | 4172.858 | 4380.025 | 4370.008 | 4356.054 | 133 |
| | Intermittent | 632.404 | 603.395 | 678.294 | 664.717 | 616.853 | |
| **Restaurant – Fast Food** | Continuous | 1342.988 | 1378.661 | 1664.018 | 1714.201 | 1727.841 | 108 |
| | Intermittent | 993.764 | 1039.643 | 1307.8 | 1340.544 | 1389.791 | |
| **Restaurant – Full Service** | Continuous | 4070.35 | 4094.742 | 4428.966 | 4501.829 | 4522.522 | 117 |
| | Intermittent | 1472.014 | 1516.05 | 1856.108 | 1938.441 | 2056.45 | |
| **Retail – Department Store** | Continuous | 1510.201 | 1496.47 | 1706.105 | 1716.128 | 1688.464 | 93 |
| | Intermittent | 701.27 | 702.129 | 847.735 | 875.12 | 881.677 | |

| Building Type | Fan Mode During Occupied Period (*Fo*) | Climate Zone Coefficient (*CZ*) | | | | | Minimum *Ws* |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | |
| **Retail – Strip Mall** | Continuous | 1926.294 | 1930.137 | 2156.856 | 2174.435 | 2165.03 | 93 |
| | Intermittent | 656.479 | 673.257 | 835.906 | 850.322 | 869.921 | |

**EXAMPLE**

A low rise office building in Rockford (Climate Zone 1) is occupied Mon-Fri 7AM-6PM and is heated and cooled with a packaged Gas (150 kBtu output) / DX (10 Ton) RTU which is controlled by a programmable thermostat. When the technician reviews the thermostat schedule they find the unoccupied schedule is programmed incorrectly. During the unoccupied periods the fan is programmed correctly, and runs in intermittent "auto" mode, although the heating and cooling temperature setpoints are not setback.

The technician adjusts the unoccupied schedule to include a 10°F cooling and heating temperature setback during the unoccupied periods.

ΔkWh = [Baseline Energy Use (kWh/Ton) – Proposed Energy Use (kWh/Ton)] * Cooling Capacity (Tons)

Baseline Energy Use (kWh/Ton) = Equation for Office Low Rise, *Fo*=Continuous

= ***CZ***+***Fu****(7.082****Tc***-41.199****Th***+18.734****Ws***-3288.55)+***Tc****(0.205****Ws***-34.929)

= *5047.662*+1*(7.082**0*-41.199**0*+18.734**55*-3288.55)+*0**(0.205**55*-34.929)

= 2,789.482 kWh/Ton

Proposed Energy Use (kWh/Ton) = Equation for Office Low Rise, *Fo*=Continuous

= ***CZ***+***Fu****(7.082****Tc***-41.199****Th***+18.734****Ws***-3288.55)+***Tc****(0.205****Ws***-34.929)

= *5047.662+1**(7.082**10*-41.199*10+18.734*55-3288.55)+*10*(*0.205**55*-34.929)

= 2,211.722 kWh/Ton

ΔkWh = [2,789.482 (kWh/Ton) – 2,211.722 (kWh/Ton)] * 10 Tons

= 577.71 kWh/Ton * 10 Tons

= 5777.1 kWh

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

### NATURAL GAS ENERGY SAVINGS

ΔTherms = [Baseline Energy Use (Therms/kBtuh) – Proposed Energy Use(Therms/kBtuh)] * Output Heating Capacity (kBtuh)

The following equations are used to calculate baseline and proposed natural gas energy use. The savings is the difference between the proposed and baseline calculated usage. This approach allows the savings estimate to account for the operational attributes of the baseline as well as the proposed case, yielding a better estimate than an approach that assumes a particular baseline or proposed energy use to determine savings.

**Natural Gas Energy Use Equations (therms / kbtu)**

| Building Type | Fan Mode During Occupied Period (*Fo*) | Equation |
|---|---|---|
| **Assembly** | Continuous | **CZ+Fu***(0.232*Th+0.0984*Ws-18.79)+Th*(0.00271*Ws-0.535)+0.0142*Ws |
| | Intermittent | ***CZ***+***Fu****(0.00405****Th***+0.000519****Ws***-0.11)+***Th****(0.0000689****Ws***-0.0118)+0.0022****Ws*** |
| **Convenience Store** | Continuous | ***CZ***+***Fu****(0.00545****Th***-0.00251****Ws***+0.416)+***Th****(0.000123****Ws***-0.0204)+0.00183****Ws*** |
| | Intermittent | ***CZ***+***Fu****(0.00231****Th***-0.0349)+***Th****(0.000309****Ws***-0.0494)+0.00266****Ws*** |
| **Office – Low Rise** | Continuous | ***CZ***+***Fu****(0.0205****Th***+0.364)+***Th****(0.00046****Ws***-0.0554)+0.00169****Ws*** |
| | Intermittent | ***CZ***+***Fu****(0.00745****Th***-0.142)+***Th****(0.00077****Ws***-0.111)+0.00199****Ws*** |
| **Religious** | Continuous | ***CZ***+0.00791****Fu****Th***+***Th****(0.00096****Ws***-0.167)+0.00184****Ws*** |
| | Intermittent | ***CZ***+***Fu****(0.00143****Th***-0.0309)+***Th****(0.0008****Ws***-0.134)+0.00219****Ws*** |
| **Restaurant – Fast Food** | Continuous | ***CZ***+***Fu****(0.0431****Th***+0.0424****Ws***-7.517)+***Th****(0.00113****Ws***-0.213)+0.0119****Ws*** |
| | Intermittent | ***CZ***+***Fu****(0.0125****Th***+0.0036****Ws***-0.71)+***Th****(0.000329****Ws***-0.0615)+0.00738****Ws*** |
| **Restaurant –Sit Down** | Continuous | ***CZ***+***Fu****(0.00445****Ws***-0.535)+***Th****(0.000679****Ws***-0.1)+0.00218****Ws*** |
| | Intermittent | ***CZ***+***Fu****(0.00144****Th***+0.000262****Ws***-0.0553)+***Th****(0.00018****Ws***-0.0299)+0.00166****Ws*** |
| **Retail – Large** | Continuous | ***CZ***+0.00203****Fu****Th***+***Th****(0.000591****Ws***-0.0812)+0.00194****Ws*** |
| | Intermittent | ***CZ***+***Th****(0.000406****Ws***-0.0611)+0.00228****Ws*** |
| **Retail – Strip Mall** | Continuous | ***CZ***+***Fu****(0.00998****Th***+0.00207****Ws***-0.206)+***Th****(0.000665****Ws***-0.101)+0.00292****Ws*** |
| | Intermittent | ***CZ***+***Fu****(0.00383****Th***-0.0656)+***Th****(0.000575****Ws***-0.0912)+0.00249****Ws*** |

Where:

CZ = Climate Zone Coefficient

= Depends on Building Type and Fan Mode During Occupied Period (see table below)

Th = Degrees of Heating Setback °F

= Must be between 0-15°F

Fo = Fan Mode During Occupied Period (Note: Commercial mechanical code requires continuous fan operation during occupied periods to meet ventilation requirements.)

= Continuous for occupied fan that runs continuously (e.g. Fan Mode Set to 'On')

= Intermittent for occupied fan that runs intermittently (e.g. Fan Mode Set to 'Auto')

Fu = Fan Mode during Unoccupied Period

= 0 for unoccupied fan that runs continuously (e.g. Fan Mode Set to 'On')

= 1 for unoccupied fan that runs intermittently (e.g. Fan Mode Set to 'Auto')

Ws = Weekly Hours thermostat is in Occupied mode,

= Minimum values depends on Building Type (see table below), maximum value of 168 (24/7) ex: Weekly occupancy schedule of Mon-Sat 8AM-5PM, Sun 9AM-2PM, Ws = 59.

**Natural Gas Energy Use Climate Zone Coefficients and Minimum Weekly Hours Occupied**

| Building Type | Fan Mode During Occupied Period (*Fo*) | Climate Zone Coefficient (*CZ*) | | | | | Minimum *Ws* |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | |
| **Assembly** | Continuous | 19.872 | 17.83 | 15.828 | 15.282 | 13.482 | 98 |
| | Intermittent | 0.237 | 0.0989 | 0.0267 | -0.0131 | -0.0871 | |
| **Convenience Store** | Continuous | 1.493 | 1.081 | 0.782 | 0.544 | 0.114 | 108 |
| | Intermittent | 1.128 | 0.854 | 0.619 | 0.437 | 0.0854 | |
| **Office - Low Rise** | Continuous | 1.718 | 1.317 | 0.971 | 0.739 | 0.319 | 55 |
| | Intermittent | 3.447 | 3.022 | 2.503 | 2.251 | 1.646 | |
| **Religious Facility** | Continuous | 6.294 | 5.55 | 4.678 | 4.202 | 3.122 | 133 |
| | Intermittent | 5.914 | 5.368 | 4.557 | 4.137 | 3.246 | |
| **Restaurant – Fast Food** | Continuous | 8.383 | 7.211 | 6.034 | 5.767 | 4.71 | 108 |
| | Intermittent | 1.227 | 0.636 | 0.302 | 0.102 | -0.262 | |
| **Restaurant – Full Service** | Continuous | 5.247 | 4.484 | 3.753 | 3.465 | 2.627 | 117 |
| | Intermittent | 0.951 | 0.704 | 0.51 | 0.381 | 0.0746 | |
| **Retail – Department Store** | Continuous | 4.385 | 3.854 | 3.192 | 2.784 | 1.858 | 93 |
| | Intermittent | 3.061 | 2.672 | 2.182 | 1.829 | 1.008 | |
| **Retail – Strip Mall** | Continuous | 3.917 | 3.394 | 2.728 | 2.394 | 1.617 | 93 |
| | Intermittent | 2.659 | 2.292 | 1.811 | 1.543 | 0.909 | |

**EXAMPLE**

A low rise office building in Rockford (Climate Zone 1) is occupied Mon-Fri 7AM-6PM and is heated and cooled with a packaged Gas (150 kBtu output) / DX (10 Ton) RTU which is controlled by a programmable thermostat. When the technician reviews the thermostat schedule they find the unoccupied schedule is programmed incorrectly. During the unoccupied periods the fan is programmed correctly, and runs in intermittent "auto" mode, although the heating and cooling temperature setpoints are not setback.

The technician adjusts the unoccupied schedule to include a 10°F cooling and heating temperature setback during the unoccupied periods.

ΔTherms = [Baseline Energy Use (Therms/kBtuh) – Proposed Energy Use(Therms/kBtuh)] * Output Heating Capacity (kBtuh)

Baseline Energy Use (Therms/kBtuh) = Equation for Office Low Rise, *Fo*=Continuous

= ***CZ***+***Fu****(0.0205****Th***+0.364)+***Th****(0.00046****Ws***-0.0554)+0.00169****Ws***

= *1.718*+*1**(0.0205**0*+0.364)+*0**(0.00046**55*-0.0554)+0.00169**55*

= 2.17495 Therms/kBtuh output

Proposed Energy Use (Therms/kBtuh) = Equation for Office Low Rise, *Fo*=Continuous

= ***CZ***+***Fu****(0.0205****Th***+0.364)+***Th****(0.00046****Ws***-0.0554)+0.00169****Ws***

= *1.718*+*1**(0.0205**10*+0.364)+*10**(0.00046**55*-0.0554)+0.00169**55*

= 2.07895 Therms/kBtuh output

ΔTherms = [2.17495 (Therms/kBtuh output) – 2.07895 (Therms/kBtuh output)] * 150kBtuh output

= 0.096 (Therms/kBtuh output) * 150kBtuh output

= 14.4 Thermsrr

### WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-HVC-PRGA-V03-190101**

**REVIEW DEADLINE: 1/1/2022**

## 4.4.26 Variable Speed Drives for HVAC Supply and Return Fans

### Description

This measure is applied to variable speed drives (VSD) which are installed on HVAC supply fans and return fans. There is a separate measure for HVAC pumps and cooling tower fans. All other VSD applications require custom analysis by the program administrator. The VSD will modulate the speed of the motor when it does not need to run at full load. Since the power of the motor is proportional to the cube of the speed for these types of applications, significant energy savings will result.

This measure was developed to be applicable to the following program types: TOS, RF. If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

The VSD is applied to a motor which does not have a VSD. The application must have a variable load and installation is to include the necessary controls. Savings are based on application of VSDs to a range of baseline load conditions including no control, inlet guide vanes, outlet guide vanes and throttling valves.

### Definition of Baseline Equipment

The time of sale baseline is a new motor installed without a VSD or other methods of control. Retrofit baseline is an existing motor operating as is. Retrofit baselines may or may not include guide vanes, throttling valves or other methods of control. This information shall be collected from the customer.

Installations of new equipment with VSDs which are required by IECC 2012 or 2015 as adopted by the State of Illinois are not eligible for incentives.

Note IECC 2018 is scheduled to become effective March 1, 2019 and will become baseline for all New Construction permits from that date.

### Deemed Lifetime of Efficient Equipment

The expected measure life for HVAC application is 15 years;[474] measure life for process is 10 years.[475]

### Deemed Measure Cost

Customer provided costs will be used when available. Default measure costs[476] are noted below for up to 75 hp motors. Custom costs must be gathered from the customer for motor sizes not listed below.

| HP | Cost |
|---|---|
| 5 HP | $ 2,250 |
| 15 HP | $ 3,318 |
| 25 HP | $ 4,386 |
| 50 HP | $ 6,573 |
| 75 HP | $ 8,532 |

### Loadshape

Loadshape C39 - VFD - Supply fans <10 HP

Loadshape C40 - VFD - Return fans <10 HP

Loadshape C41 - VFD - Exhaust fans <10 HP

---

[474] Efficiency Vermont TRM 10/26/11 for HVAC VSD motors

[475] DEER 2008

[476] NEEP Incremental Cost Study Phase Two Final Report

**COINCIDENCE FACTOR**

The demand savings factor (DSF) is already based upon coincident savings, and thus there is no additional coincidence factor for this characterization.

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**[477]

$$kWh_{Base} = \left(0.746 \times HP \times \frac{LF}{\eta_{motor}}\right) \times RHRS_{Base} \times \sum_{0\%}^{100\%} (\%FF \times PLR_{Base})$$

$$kWh_{Retrofit} = \left(0.746 \times HP \times \frac{LF}{\eta_{motor}}\right) \times RHRS_{base} \times \sum_{0\%}^{100\%} (\%FF \times PLR_{Retrofit})$$

$$\Delta kWh_{fan} = kWh_{Base} - kWh_{Retrofit}$$

$$\Delta kWh_{total} = \Delta kWh_{fan} \times (1 + IE_{energy})$$

Where:

$kWh_{Base}$ = Baseline annual energy consumption (kWh/yr)

$kWh_{Retrofit}$ = Retrofit annual energy consumption (kWh/yr)

$\Delta kWh_{fan}$ = Fan-only annual energy savings

$\Delta kWh_{total}$ = Total project annual energy savings

$0.746$ = Conversion factor for HP to kWh

$HP$ = Nominal horsepower of controlled motor

$LF$ = Load Factor; Motor Load at Fan Design CFM (Default = 65%)[478]

$\eta_{motor}$ = Installed nominal/nameplate motor efficiency

Default motor is a NEMA Premium Efficiency, ODP, 4-pole/1800 RPM fan motor

**NEMA Premium Efficiency Motors Default Efficiencies**[479]

| Size HP | Open Drip Proof (ODP) | | | Totally Enclosed Fan-Cooled (TEFC) | | |
|---|---|---|---|---|---|---|
| | # of Poles | | | # of Poles | | |
| | 6 | 4 | 2 | 6 | 4 | 2 |
| | Speed (RPM) | | | Speed (RPM) | | |
| | 1200 | 1800 Default | 3600 | 1200 | 1800 | 3600 |
| 1 | 0.825 | 0.855 | 0.770 | 0.825 | 0.855 | 0.770 |
| 1.5 | 0.865 | 0.865 | 0.840 | 0.875 | 0.865 | 0.840 |
| 2 | 0.875 | 0.865 | 0.855 | 0.885 | 0.865 | 0.855 |

477 Methodology developed and tested in Del Balso, Ryan Joseph. "Investigation into the Reliability of Energy Efficiency/Demand Side Management Savings Estimates for Variable Frequency Drives in Commercial Applications". A project report submitted to the Faculty of the Graduate School of the University of Colorado, 2013.

478 Lawrence Berkeley National Laboratory, and Resource Dynamics Corporation. (2008). "Improving Motor and Drive System Performance; A Sourcebook for Industry". U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. Golden, CO: National Renewable Energy Laboratory.

479 Douglass, J. (2005). Induction Motor Efficiency Standards. Washington State University and the Northwest Energy Efficiency Alliance, Extension Energy Program, Olympia, WA, October 2005.

| Size HP | Open Drip Proof (ODP) | | | Totally Enclosed Fan-Cooled (TEFC) | | |
|---|---|---|---|---|---|---|
| | # of Poles | | | # of Poles | | |
| | 6 | 4 | 2 | 6 | 4 | 2 |
| | Speed (RPM) | | | Speed (RPM) | | |
| | 1200 | 1800 Default | 3600 | 1200 | 1800 | 3600 |
| 3 | 0.885 | 0.895 | 0.855 | 0.895 | 0.895 | 0.865 |
| 5 | 0.895 | 0.895 | 0.865 | 0.895 | 0.895 | 0.885 |
| 7.5 | 0.902 | 0.910 | 0.885 | 0.910 | 0.917 | 0.895 |
| 10 | 0.917 | 0.917 | 0.895 | 0.910 | 0.917 | 0.902 |
| 15 | 0.917 | 0.930 | 0.902 | 0.917 | 0.924 | 0.910 |
| 20 | 0.924 | 0.930 | 0.910 | 0.917 | 0.930 | 0.910 |
| 25 | 0.930 | 0.936 | 0.917 | 0.930 | 0.936 | 0.917 |
| 30 | 0.936 | 0.941 | 0.917 | 0.930 | 0.936 | 0.917 |
| 40 | 0.941 | 0.941 | 0.924 | 0.941 | 0.941 | 0.924 |
| 50 | 0.941 | 0.945 | 0.930 | 0.941 | 0.945 | 0.930 |
| 60 | 0.945 | 0.950 | 0.936 | 0.945 | 0.950 | 0.936 |
| 75 | 0.945 | 0.950 | 0.936 | 0.945 | 0.954 | 0.936 |
| 100 | 0.950 | 0.954 | 0.936 | 0.950 | 0.954 | 0.941 |
| 125 | 0.950 | 0.954 | 0.941 | 0.950 | 0.954 | 0.950 |
| 150 | 0.954 | 0.958 | 0.941 | 0.958 | 0.958 | 0.950 |
| 200 | 0.954 | 0.958 | 0.950 | 0.958 | 0.962 | 0.954 |
| 250 | 0.954 | 0.958 | 0.950 | 0.958 | 0.962 | 0.958 |
| 300 | 0.954 | 0.958 | 0.954 | 0.958 | 0.962 | 0.958 |
| 350 | 0.954 | 0.958 | 0.954 | 0.958 | 0.962 | 0.958 |
| 400 | 0.958 | 0.958 | 0.958 | 0.958 | 0.962 | 0.958 |
| 450 | 0.962 | 0.962 | 0.958 | 0.958 | 0.962 | 0.958 |
| 500 | 0.962 | 0.962 | 0.958 | 0.958 | 0.962 | 0.958 |

$RHRS_{Base}$ = Annual operating hours for fan motor based on building type

Default hours are provided for HVAC applications which vary by HVAC application and building type[480]. When available, actual hours should be used.

| Building Type | Total Fan Run Hours | Model Source |
|---|---|---|
| Assembly | 7235 | eQuest |
| Assisted Living | 8760 | eQuest |
| College | 6103 | eQuest |
| Convenience Store | 7004 | eQuest |
| Elementary School | 7522 | eQuest |
| Garage | 7357 | eQuest |
| Grocery | 7403 | eQuest |
| Healthcare Clinic | 6345 | eQuest |
| High School | 7879 | eQuest |
| Hospital - VAV econ | 8760 | eQuest |
| Hospital - CAV econ | 8760 | eQuest |
| Hospital - CAV no econ | 8760 | eQuest |

[480] Hours per year are estimated using the eQuest models as the total number of hours the fans are operating for heating, cooling and ventilation for each building type.

| Building Type | Total Fan Run Hours | Model Source |
|---|---|---|
| Hospital - FCU | 8760 | eQuest |
| Manufacturing Facility | 8706 | eQuest |
| MF - High Rise | 8760 | eQuest |
| MF - Mid Rise | 8760 | eQuest |
| Hotel/Motel - Guest | 8760 | eQuest |
| Hotel/Motel - Common | 8760 | eQuest |
| Movie Theater | 7505 | eQuest |
| Office - High Rise - VAV econ | 6064 | eQuest |
| Office - High Rise - CAV econ | 5697 | eQuest |
| Office - High Rise - CAV no econ | 5682 | eQuest |
| Office - High Rise - FCU | 6163 | eQuest |
| Office - Low Rise | 6288 | eQuest |
| Office - Mid Rise | 6856 | OpenStudio |
| Religious Building | 7380 | eQuest |
| Restaurant | 7809 | eQuest |
| Retail - Department Store | 7155 | OpenStudio |
| Retail - Strip Mall | 6846 | eQuest |
| Warehouse | 6832 | OpenStudio |
| Unknown | 7100 | n/a |

$\%FF$ = Percentage of run-time spent within a given flow fraction range

Default Fan Duty Cycle Based on 2012 ASHRAE Handbook; HVAC Systems and Equipment, page 45.11, Figure 12.

| Flow Fraction (% of design cfm) | Percent of Time at Flow Fraction |
|---|---|
| 0% to 10% | 0.0% |
| 10% to 20% | 1.0% |
| 20% to 30% | 5.5% |
| 30% to 40% | 15.5% |
| 40% to 50% | 22.0% |
| 50% to 60% | 25.0% |
| 60% to 70% | 19.0% |
| 70% to 80% | 8.5% |
| 80% to 90% | 3.0% |
| 90% to 100% | 0.5% |

$PLR_{Base}$ = Part load ratio for a given flow fraction range based on the baseline flow control type

$PLR_{Retrofit}$ = Part load ratio for a given flow fraction range based on the retrofit flow control type

| Control Type | Flow Fraction | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% | 100% |
| No Control or Bypass Damper | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Discharge Dampers | 0.46 | 0.55 | 0.63 | 0.70 | 0.77 | 0.83 | 0.88 | 0.93 | 0.97 | 1.00 |
| Outlet Damper, BI & Airfoil Fans | 0.53 | 0.53 | 0.57 | 0.64 | 0.72 | 0.80 | 0.89 | 0.96 | 1.02 | 1.05 |

| Control Type | Flow Fraction | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% | 100% |
| Inlet Damper Box | 0.56 | 0.60 | 0.62 | 0.64 | 0.66 | 0.69 | 0.74 | 0.81 | 0.92 | 1.07 |
| Inlet Guide Vane, BI & Airfoil Fans | 0.53 | 0.56 | 0.57 | 0.59 | 0.60 | 0.62 | 0.67 | 0.74 | 0.85 | 1.00 |
| Inlet Vane Dampers | 0.38 | 0.40 | 0.42 | 0.44 | 0.48 | 0.53 | 0.60 | 0.70 | 0.83 | 0.99 |
| Outlet Damper, FC Fans | 0.22 | 0.26 | 0.30 | 0.37 | 0.45 | 0.54 | 0.65 | 0.77 | 0.91 | 1.06 |
| Eddy Current Drives | 0.17 | 0.20 | 0.25 | 0.32 | 0.41 | 0.51 | 0.63 | 0.76 | 0.90 | 1.04 |
| Inlet Guide Vane, FC Fans | 0.21 | 0.22 | 0.23 | 0.26 | 0.31 | 0.39 | 0.49 | 0.63 | 0.81 | 1.04 |
| VFD with duct static pressure controls | 0.09 | 0.10 | 0.11 | 0.15 | 0.20 | 0.29 | 0.41 | 0.57 | 0.76 | 1.01 |
| VFD with low/no duct static pressure | 0.05 | 0.06 | 0.09 | 0.12 | 0.18 | 0.27 | 0.39 | 0.55 | 0.75 | 1.00 |

Provided below is the resultant values based upon the defaults provided above:

| Control Type | $\sum_{0\%}^{100\%}(\%FF \times PLR_{Base})$ |
|---|---|
| No Control or Bypass Damper | 1.00 |
| Discharge Dampers | 0.80 |
| Outlet Damper, BI & Airfoil Fans | 0.78 |
| Inlet Damper Box | 0.69 |
| Inlet Guide Vane, BI & Airfoil Fans | 0.63 |
| Inlet Vane Dampers | 0.53 |
| Outlet Damper, FC Fans | 0.53 |
| Eddy Current Drives | 0.49 |
| Inlet Guide Vane, FC Fans | 0.39 |
| VFD with duct static pressure controls | 0.30 |
| VFD with low/no duct static pressure | 0.27 |

$IE_{energy}$ = HVAC interactive effects factor for energy (default = 15.7%)

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$kW_{Base} = \left(0.746 \times HP \times \frac{LF}{\eta_{motor}}\right) \times PLR_{Base,FFpeak}$$

$$kW_{Retrofit} = \left(0.746 \times HP \times \frac{LF}{\eta_{motor}}\right) \times PLR_{Retrofit,FFpeak}$$

$$\Delta kW_{fan} = kW_{Base} - kW_{Retrofit}$$

$$\Delta kW_{total} = \Delta kW_{fan} \times (1 + IE_{demand})$$

Where:

$kW_{Base}$ = Baseline summer coincident peak demand (kW)

$kW_{Retrofit}$ = Retrofit summer coincident peak demand (kW)

$\Delta kW_{fan}$ = Fan-only summer coincident peak demand impact

$\Delta kW_{total}$ = Total project summer coincident peak demand impact

$PLR_{Base,FFpeak}$ = The part load ratio for the average flow fraction between the peak daytime hours during the weekday peak time period based on the baseline flow control type (default average flow fraction during peak period = 90%)

$PLR_{Retrofit,FFpeak}$ = The part load ratio for the average flow fraction between the peak daytime hours during the weekday peak time period based on the retrofit flow control type (default average flow fraction during peak period = 90%)

$IE_{demand}$ = HVAC interactive effects factor for summer coincident peak demand (default = 15.7%)

**FOSSIL FUEL IMPACT DESCRIPTIONS AND CALCULATION**

There are no expected fossil fuel impacts for this measure.

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-HVC-VSDF-V03-190101**

**REVIEW DEADLINE: 1/1/2022**

## 4.4.27 Energy Recovery Ventilator

### Description

This measure includes the addition of energy recovery equipment on existing or new unitary equipment, where energy recovery is not required by the IECC 2012/2015/2018. This measure analyzes the heating and cooling savings potential from recovering energy from exhaust or relief building air. This measure assumes that during unoccupied hours of the building no exhaust or relief air is available for energy recovery.

This measure was developed to be applicable to the following program types: TOS, NC, RF.

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

Efficient equipment is unitary equipment that incorporates energy recovery not required by the IECC 2012/2015/2018.

### Definition of Baseline Equipment

The baseline is unitary equipment not required by IECC 2012/2015/2018 to incorporate energy recovery.

Note IECC 2018 is scheduled to become effective March 1, 2019 and will become baseline for all New Construction permits from that date.

### Deemed Lifetime of Efficient Equipment

The measure life for the domestic energy recovery equipment is 15 years.[481]

### Deemed Measure Cost

The incremental cost for this measure assumes cost of cabinet and controls incorporated into packaged and built up air handler units. Additionally it assumes a 1 to 1 ratio of fresh and exhausted air.

| Energy Recovery Equipment Type | Incremental Cost $/CFM[482] |
|---|---|
| Plate Heat Exchanger | $6 |
| Rotary Wheel | $6 |
| Heat Pipe | $6 |

### Deemed O&M Cost Adjustments

There are no expected O&M savings associated with this measure.

### Loadshape

N/A

### Coincidence Factor

N/A

[481] Assumed service life limited by controls -" Demand Control Ventilation Using CO2 Sensors", pg. 19, by US Department of Energy Efficiency and Renewable Energy

[482]"Map to HVAC Solutions", by Michigan Air, Issue 3, 2006

**Algorithm**

### CALCULATION OF ENERGY SAVINGS ELECTRIC ENERGY SAVINGS

The electric energy savings calculation here represents the net electric energy savings from reduced cooling requirements after accounting for increased fan power caused by additional pressure drop from the ERV device. These savings do not account for heating energy savings in HVAC systems using heat pumps or electric resistance heat. This calculation does not apply to wheel-type devices with purge sections, or to sensible-only devices such as heat pipes.

ΔkWh = (cfm) * Normalized Electric Energy Savings

cfm = design supply air flow of energy recovery ventilator in cubic feet per minute

= rated energy recovery ventilator supply air flow * (1 – Exhaust Air Transfer Ratio)

Exhaust Air Transfer Ratio = percentage of supply air made up of cross-leakage from exhaust air; value provided by vendor

= 0.05 (default)

Normalized Electric Energy Savings

= kWh/cfm savings value for the expected energy savings (net of fan energy penalty) as detailed in Table 1 – Electric Energy Savings Summary (kWh/cfm)

**Table 1 – Electric Energy Savings Summary (kWh/cfm)[483]**

| Building Type | Normalized Electricity Savings (kWh/OA cfm) | | | | |
|---|---|---|---|---|---|
| | Zone 1 - Rockford | Zone 2 - Chicago | Zone 3 - Springfield | Zone 4 - Mt. Vernon/Belleville | Zone 5 - Marion |
| **Enthalpy Wheel - 75% sensible and latent effectiveness** | | | | | |
| Assembly | NA | NA | NA | 0.107 | 0.229 |
| Education | NA | NA | 0.371 | 0.245 | 0.369 |
| Grocery | NA | NA | 0.239 | 0.523 | 0.630 |
| Healthcare | 1.551 | 1.594 | 2.508 | 2.999 | 3.077 |
| Multifamily | 2.178 | 2.566 | 3.781 | 4.746 | 5.029 |
| Office | 0.974 | 1.169 | 2.379 | 2.998 | 3.194 |
| Retail | 0.048 | 0.124 | 0.389 | 1.027 | 1.063 |
| **Enthalpy Plate - 50% sensible and latent effectiveness** | | | | | |
| Assembly | NA | NA | NA | NA | NA |
| Education | NA | NA | NA | NA | 0.035 |
| Grocery | NA | NA | NA | 0.002 | 0.102 |
| Healthcare | 0.923 | 0.963 | 1.548 | 1.841 | 1.908 |
| Multifamily | 0.627 | 0.908 | 1.450 | 2.341 | 2.509 |
| Office | 0.309 | 0.487 | 1.321 | 1.705 | 1.918 |
| Retail | NA | NA | NA | 0.398 | 0.435 |

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = (cfm) * Normalized Electric Peak Demand Savings * CF

= design supply air flow of energy recovery ventilator in cubic feet per minute

483 Energy savings modeled using IL TRM energy models with added energy recovery wheels or enthalpy plates. Energy recovery device specifications based on product data from the AHRI Certification Directory (https://www.ahridirectory.org/Search/SearchHome?ReturnUrl=%2f). See reference "ERV Effectiveness AHRI Directory Survey."

= rated energy recovery ventilator supply air flow * (1 – Exhaust Air Transfer Ratio)

Exhaust Air Transfer Ratio = percentage of supply air made up of cross-leakage from exhaust air; value provided by vendor

= 0.05 (default)

CF = 1.0

Normalized Electric Peak Demand Savings

= kW/cfm savings value for the appropriate combination of building type, climate zone, and measure scenario per Table 2 – Electric Peak Demand Savings Summary (kW/cfm)

### Table 2 – Electric Peak Demand Savings Summary (kW/cfm)[484]

| Building Type | Normalized Electric Demand Savings (kW/OA cfm) | | | | |
|---|---|---|---|---|---|
| | Zone 1 - Rockford | Zone 2 - Chicago | Zone 3 - Springfield | Zone 4 - Mt. Vernon/Belleville | Zone 5 - Marion |
| **Enthalpy Wheel - 75% sensible and latent efficiency** | | | | | |
| Assembly | 0.00127 | 0.00092 | 0.00111 | 0.00213 | 0.00209 |
| Education | 0.00159 | 0.00164 | 0.00282 | 0.00202 | 0.00308 |
| Grocery | 0.00115 | 0.00159 | 0.00152 | 0.00153 | 0.00187 |
| Healthcare | 0.00465 | 0.00433 | 0.00480 | 0.00443 | 0.00443 |
| Multifamily | 0.00210 | 0.00325 | 0.00298 | 0.00370 | 0.00381 |
| Office | 0.00538 | 0.00518 | 0.00527 | 0.00529 | 0.00589 |
| Retail | 0.00156 | 0.00195 | 0.00020 | 0.00217 | 0.00223 |
| **Enthalpy Plate - 50% sensible and latent efficiency** | | | | | |
| Assembly | NA | NA | 0.00024 | 0.00115 | 0.00113 |
| Education | 0.00114 | 0.00118 | 0.00201 | 0.00142 | 0.00218 |
| Grocery | 0.00059 | 0.00089 | 0.00083 | 0.00079 | 0.00102 |
| Healthcare | 0.00287 | 0.00284 | 0.00306 | 0.00292 | 0.00275 |
| Multifamily | NA | 0.00128 | 0.00111 | 0.00172 | 0.00167 |
| Office | 0.00351 | 0.00344 | 0.00344 | 0.00345 | 0.00384 |
| Retail | 0.00087 | 0.00123 | 0.00001 | 0.00119 | 0.00124 |

#### NATURAL GAS SAVINGS

Gas savings algorithm is derived from the following:

ΔTherms = (Design Heating Load * TE_ERV * EFLH * OccHours/24) / (100,000 * µHeat)

Where:

Design Heating Load = (1.08 * CFM * ΔT)

1.08 = A constant for sensible heat equations (BTU/h/CFM.°F)

CFM = Cubic Feet per Minute of Energy Recovery Ventilator

ΔT = T_RA – T_DD

T_RA = Temperature of the Return Air = 70°F or custom

[484] Demand savings modeled using IL TRM energy models with added energy recovery wheels or enthalpy plates. Energy recovery device specifications based on product data from the AHRI Certification Directory (https://www.ahridirectory.org/Search/SearchHome?ReturnUrl=%2f). Coincident demand measured according to TRM guidelines, though in 1-hour increments as established by the eQUEST simulation.

T_DD = Temperature on design day of outside air[485]

= (see Table below) or custom

| Zone | Weather Station | T_DD, Temperature, °F |
|---|---|---|
| 1 | Greater Rockford | -5.8 |
| 2 | Chicago/O'Hare ARPT. | -1.5 |
| 3 | Springfield/Capital | 0.4 |
| 4 | Scott AFB MidAmerica | 9.0 |
| 5 | Cape Girardeau Regional | 9.7 |
| Average | - | 2.4 |

TE_ERV = Thermal Effectiveness of Energy Recovery Equipment[486]

= (see Table below) or custom

| Heat Recovery Equipment Type | TE_ERV (%) |
|---|---|
| Fixed Plate | 0.65 |
| Rotary Equipment | 0.68 |
| Heat Pipe | 0.55 |

EFLH = Equivalent Full Load Hours for heating are provided in section 4.4 HVAC End Use

OccHours = Average Hours per day facility is occupied

= custom or use Modeling Inputs in eQuest models:

| | Weekday | Saturday | Sunday | Holiday | Annual Operating Hours | OccHours |
|---|---|---|---|---|---|---|
| Assembly/Convention Center | 10am-9pm | 10am-9pm | 10am-9pm | closed | 3905 | 10.7 |
| Assisted Living | 24/7 | 24/7 | 24/7 | 24/7 | 8760 | 24.0 |
| College | 8am-9pm | closed | closed | closed | 3263 | 8.9 |
| Convenience Store | 7am-10pm | 9am-9pm | 10am-5pm | 10am-5pm | 4823 | 13.2 |
| Elementary School | 8am-4pm (20% in summer) | closed | closed | closed | 1606 | 4.4 |
| Garage | 7am-5pm | 8am-12pm | closed | closed | 3342 | 9.1 |
| Grocery | 7am-9pm | 7am-9pm | 9am-8pm | closed | 4814 | 13.2 |
| Healthcare Clinic | 7am-7pm | 9am-5pm | closed | closed | 3428 | 9.4 |
| High School | 8am-4pm (20% in summer) | closed | closed | closed | 1606 | 4.4 |
| Hospital | 24/7 | 24/7 | 24/7 | 24/7 | 8760 | 24.0 |
| Motel | 24/7 | 24/7 | 24/7 | 24/7 | 8760 | 24.0 |
| Manufacturing Facility (Light Industry) | Mfg: 6am-10pm, Office: 8am-5pm | Mfg: 6am-10pm, Office: closed | closed | closed | 4848 | 13.3 |
| Multi-Family Mid-Rise | 24/7; Reduced occupancy 7am - 5pm | 24/7; Reduced occupancy 9am - 3pm | 24/7; Reduced occupancy 9am - 3pm | 24/7; Reduced occupancy 9am - 3pm | 7038 | 19.3 |

[485]Weather Station Data, 99.6% Heating DB - 2013 Fundamentals, ASHRAE Handbook
[486]Energy Recovery Fact Sheet - Center Point Energy, MN

| | Weekday | Saturday | Sunday | Holiday | Annual Operating Hours | OccHours |
|---|---|---|---|---|---|---|
| Multi-Family High-Rise | 24/7; Reduced occupancy 7am - 5pm | 24/7; Reduced occupancy 9am - 3pm | 24/7; Reduced occupancy 9am - 3pm | 24/7; Reduced occupancy 9am - 3pm | 7038 | 19.3 |
| Movie Theater | 10am-Midnight | 10am-Midnight | 10am-Midnight | 10am-Midnight | 5110 | 14.0 |
| Office - Low-rise | 8am-5pm | closed | closed | closed | 2259 | 6.2 |
| Office - Mid-rise | 8am-5pm | 20% 8am-noon | closed | closed | 2301 | 6.3 |
| Office - High-rise | 8am-5pm | 20% 8am-noon | closed | closed | 2301 | 6.3 |
| Religious Building | Office: 8am-5pm, other: closed | closed | 8am-1pm | closed | 260 | 0.7 |
| Restaurant | 7am-8pm | 7am-8pm | 7am-8pm | closed | 4615 | 12.6 |
| Retail - Department Store | 9am-9pm | 9am-9pm | 10am-5pm | 10am-5pm | 4070 | 11.1 |
| Retail - Strip Mall | 9am-9pm | 9am-9pm | 10am-5pm | 10am-5pm | 4070 | 11.1 |
| Warehouse (Conditioned Storage) | 7am-7pm | 7am-7pm (reduced occupancy) | closed | closed | 3324 | 9.1 |

µHeat = Efficiency of heating system

= Actual

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-HVC-ERVE-V03-190101**

**REVIEW DEADLINE: 1/1/2020**

## 4.4.28 Stack Economizer for Boilers Serving HVAC Loads

### Measure Description

Stack economizers are designed to recover heat from hot boiler flue gasses. Recovered heat is used to preheat boiler feed water. This measure describes the retrofit of HVAC boilers with stack economizers. HVAC boilers are defined as those used for space heating applications. There is another, similar measure for boilers that serve process loads.

This measure was developed to be applicable to the following program types: NC, TOS, RF.

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

To qualify the economizer must be installed on a boiler exhaust stack. Heat captured by the economizer is to be used to pre-heat boiler feed water.

### Definition of Baseline Equipment

The baseline boiler does not have an economizer installed.

### Deemed Lifetime of Efficient Equipment

The measure life for the boiler stack economizer is 15 years.[487]

### Deemed Measure Cost

The incremental and full measure cost for this measure is custom.

### Deemed O&M Cost Adjustments

The O&M cost for this measure is custom.

### Loadshape

N/A

### Coincidence Factor

N/A

**Algorithm**

### Calculation of Energy Savings

### Electric Energy Savings

N/A

### Summer Coincident Peak Demand Savings

N/A

### Natural Gas Savings

$$\Delta therms = SF * MBH\_In * EFLH / 100$$

Where:

[487] PA Consulting, Focus on Energy Evaluation, Business Programs: Measure Life Study, August 25, 2009.

SF = (T_existing – T_eff) / 40°F * TRE

= see default Savings Factor table below

Where:

T_existing = Existing Full Fire Boiler Flue Gas Temperature as it exits the Stack

= 425F[488] (water, 81.9% eff) or custom

= 480F[3] (steam, 80.7% eff) or custom

T_eff = Efficient Full Fire Boiler Flue Gas Temperature as it exits the Stack

= 338°F (conventional economizer – Water Boiler)[489] or custom

= 365°F (conventional economizer – Steam Boiler)[490] or custom

= 280°F (condensing economizer – Water Boiler)[491] or custom

= 308°F (condensing economizer – Steam Boiler)[492] or custom

TRE = % efficiency increase for 40°F of stack temperature reduction

= 1%[493] or custom

Based on defaults provided above:

| Boiler Type | SF[494] | |
|---|---|---|
| | Conventional Economizer | Condensing Economizer |
| Hot Water Boiler | 2.19% average SF or custom | 3.63% average SF or custom |
| Steam Boiler | 2.88% average SF or custom | 4.31% average SF or custom |

MBH_In = Rated boiler input capacity, in MBH

= Actual

EFLH = Equivalent Full Load Hours for heating are provided in Section 4.4 HVAC End Use

488 Cleaver Brooks. March 2012, Boiler Efficiency Guide, Pg. 7, Figure 1.

489 The minimum stack temperature for a non-condensing economizer is 250°F from Department of Energy (DOE). January 2012, Steam Tip Sheet #26A, Consider Installing a Condensing Economizer. Advanced Manufacturing Office. Washington, DC: U.S. Department of Energy. The average temperature drop is assumed to be ½ way between the existing and efficient temperature minimum, ( 425°F + 250°F ) / 2 = 338°F.

490 The minimum stack temperature for a non-condensing economizer is 250°F from Department of Energy (DOE). January 2012, Steam Tip Sheet #26A, Consider Installing a Condensing Economizer. Advanced Manufacturing Office. Washington, DC: U.S. Department of Energy. The average temperature drop is assumed to be ½ way between the existing and efficient temperature minimum, ( 480°F + 250°F ) / 2 = 365°F.

491 The minimum stack temperature for a condensing economizer is 250°F from Department of Energy (DOE). January 2012, Steam Tip Sheet #26A, Consider Installing a Condensing Economizer. Advanced Manufacturing Office. Washington, DC: U.S. Department of Energy. The average temperature drop is assumed to be ½ way between the existing and efficient temperature minimum, ( 425°F + 135°F ) / 2 = 280°F.

492 The minimum stack temperature for a condensing economizer is 250°F from Department of Energy (DOE). January 2012, Steam Tip Sheet #26A, Consider Installing a Condensing Economizer. Advanced Manufacturing Office. Washington, DC: U.S. Department of Energy. The average temperature drop is assumed to be ½ way between the existing and efficient temperature minimum, ( 480°F + 135°F ) / 2 = 308°F.

493 United States EPA, Climate Wise: Wise Rules for Industrial Efficiency, July 1998. The Wise Rules indicate savings range of 1-2% per 40°F reduction, so utilizing 1% is a conservative approach.

494 These average values should be utilized in absence of actual temperature data. An economizer with a zero temperature change between the existing and the efficient temperatures would not be installed, so these average values are conservative.

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-HVC-BECO-V01-150601**

**REVIEW DEADLINE: 1/1/2021**

## 4.4.29 Stack Economizer for Boilers Serving Process Loads

### MEASURE DESCRIPTION

Stack economizers are designed to recover heat from hot boiler flue gasses. Recovered heat is used to preheat boiler feed water. This measure describes the retrofit of process boilers with stack economizers. Process boilers are defined as those used for industrial, manufacturing, or other non-HVAC applications. There is another, similar measure for boilers that serve HVAC loads.

This measure was developed to be applicable to the following program types: NC, TOS, RF.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

To qualify the economizer must be installed on a boiler exhaust stack. Heat captured by the economizer is to be used to pre-heat boiler feed water.

### DEFINITION OF BASELINE EQUIPMENT

The baseline boiler does not have an economizer installed.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life for the boiler stack economizer is 15 years.[495]

### DEEMED MEASURE COST

The incremental and full measure cost for this measure is custom.

### DEEMED O&M COST ADJUSTMENTS

The O&M cost for this measure is custom.

### LOADSHAPE

N/A

### COINCIDENCE FACTOR

N/A

**Algorithm**

### CALCULATION OF ENERGY SAVINGS

### ELECTRIC ENERGY SAVINGS

N/A

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

### NATURAL GAS SAVINGS

$$\Delta therms = SF * MBH\_In * 8766 * UF / 100$$

[495] PA Consulting, Focus on Energy Evaluation, Business Programs: Measure Life Study, August 25, 2009.

Where:

SF = (T_existing – T_eff)/40°F * TRE

= see default Savings Factor table below

T_existing = Existing Full Fire Boiler Flue Gas Temperature as it exits the Stack

= 425F[496] (water, 81.9% eff per IL TRM) or custom

= 480F[3] (steam, 80.7% eff per IL TRM) or custom

T_eff = Efficient Full Fire Boiler Flue Gas Temperature as it exits the Stack

= 338°F (conventional economizer – Water Boiler)[497] or custom

= 365°F (conventional economizer – Steam Boiler)[498] or custom

= 280°F (condensing economizer – Water Boiler)[499] or custom

= 308°F (condensing economizer – Water Boiler)[500] or custom

TRE = % efficiency increase for 40°F of stack temperature reduction

= 1%[501] or custom

Based on defaults provided above:

| Boiler Type | SF[502] | |
|---|---|---|
| | Conventional Economizer | Condensing Economizer |
| Hot Water Boiler | 2.19% average SF or custom | 3.63% average SF or custom |
| Steam Boiler | 2.88% average SF or custom | 4.31% average SF or custom |

MBH_In = Rated boiler input capacity, in MBH

= Actual

8766 = Hours a year

UF = Utilization Factor

[496] Cleaver Brooks. March 2012, Boiler Efficiency Guide, Pg. 7, Figure 1.

[497] The minimum stack temperature for a non-condensing economizer is 250°F from Department of Energy (DOE). January 2012, Steam Tip Sheet #26A, Consider Installing a Condensing Economizer. Advanced Manufacturing Office. Washington, DC: U.S. Department of Energy. The average temperature drop is assumed to be ½ way between the existing and efficient temperature minimum, ( 425°F + 250°F ) / 2 = 338°F.

[498] The minimum stack temperature for a non-condensing economizer is 250°F from Department of Energy (DOE). January 2012, Steam Tip Sheet #26A, Consider Installing a Condensing Economizer. Advanced Manufacturing Office. Washington, DC: U.S. Department of Energy. The average temperature drop is assumed to be ½ way between the existing and efficient temperature minimum, ( 480°F + 250°F ) / 2 = 365°F.

[499] The minimum stack temperature for a condensing economizer is 250°F from Department of Energy (DOE). January 2012, Steam Tip Sheet #26A, Consider Installing a Condensing Economizer. Advanced Manufacturing Office. Washington, DC: U.S. Department of Energy. The average temperature drop is assumed to be ½ way between the existing and efficient temperature minimum, ( 425°F + 135°F ) / 2 = 280°F.

[500] The minimum stack temperature for a condensing economizer is 250°F from Department of Energy (DOE). January 2012, Steam Tip Sheet #26A, Consider Installing a Condensing Economizer. Advanced Manufacturing Office. Washington, DC: U.S. Department of Energy. The average temperature drop is assumed to be ½ way between the existing and efficient temperature minimum, ( 480°F + 135°F ) / 2 = 308°F.

[501] United States EPA, Climate Wise: Wise Rules for Industrial Efficiency, July 1998. The Wise Rules indicate savings range of 1-2% per 40°F reduction, so utilizing 1% is a conservative approach.

[502] These average values should be utilized in absence of actual temperature data. An economizer with a zero temperature change between the existing and the efficient temperatures would not be installed, so these average values are conservative.

= 41.9%[503] or custom

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-HVC-PECO-V01-150601**

**REVIEW DEADLINE: 1/1/2022**

[503] Work Paper – Tune up for Boilers serving Space Heating and Process Load by Resource Solutions Group, January 2012

## 4.4.30 Notched V Belts for HVAC Systems

### Measure Description

This measure is for replacement of smooth v-belts in non-residential package and split HVAC systems with notched v-belts or for installing new equipment with synchronous belts instead of smooth v-belts. Typically there is a v-belt between the motor and the supply air fan and/or return air fan in larger package and split HVAC systems (RTU).

In general there are two styles of grooved v-belts, notched and synchronous. The DOE defines each as follows;

**Notched V-Belts** - A notched belt has grooves or notches that run perpendicular to the belt's length, which reduces the bending resistance of the belt. Notched belts can use the same pulleys as cross-section standard V-belts. They run cooler, last longer, and are about 2% more efficient than standard V-belts.

**Synchronous Belts** - Synchronous belts (also called cogged, timing, positive-drive, or high-torque drive belts) are toothed and require the installation of mating grooved sprockets. These belts operate with a consistent efficiency of 98% and maintain their efficiency over a wide load range.

Smooth v-belts are usually referred to in five basic groups:

- "L" belts are low end belts that are for small, fractional horsepower motors and these are not used in RTUs.
- "A" and "B" belts are the two types typically used in RTUs. The "A" belt is a ½ inch width by 5/16 inch thickness and the "B" belt is larger, 21/32 inch wide and 12/32 inch thick so it can carry more power. V-belts come in a wide variety of lengths where 20 to 100 inches is typical.
- "C" and "D" belts are primarily for industrial applications with high power transmission requirements.
- V-belts are provided by various vendors. The notched version of these belts typically have an "X" added to the designation. For this HVAC fans notched v-belt Replacement measure, only the "A" and "B" v-belts are considered. A typical "A" v-belt is replaced by a notched "AX" v-belt and a "B" is replaced by a "BX." In general, smooth v-belts have an efficiency of 90% to 98% while notched v-belts have an efficiency of 95% to 98%. Because notched v-belts are more flexible they work with smaller diameter pulleys and they have less resistance to bending. Lower bending resistance increases the power transmission efficiency, lowers the waste heat, and allows the belt to last longer than a smooth belt.

Three research papers[504] [505] [506] show that the notched v-belt efficiency is 2% to 5% better than a typical smooth v-belt. A fourth paper by USDOE's Energy Efficiency and Renewable Energy[507] group reviewed most of the earlier literature and recommended using a conservative 2% efficiency improvement for energy savings for calculations.

For this measure it is assumed that upgrading a standard smooth v-belt with a new notched v-belt will result in a fan energy reduction of 2%.

### Definition of Efficient Equipment

For the Notched V-Belt characterization to apply, the Efficient Equipment is HVAC RTUs that have notched v-belts installed on the supply and/or return air fans. This can be done as a retrofit, TOS, or NC project.

For the Synchronous Belt characterization to apply, the Efficient Equipment is HVAC RTUs that have synchronous belts installed on the supply and/or return air fans. This can be done as a TOS or NC project. Retrofit projects can also claim savings, but costs should be verified independently (typically the cost of installing synchronous belts as a retrofit is not economically viable).

---

[504] "Gates Corporation Announces New EPDM Molded Notch V-Belts," The Gates Rubber Co., June 2010 (Assumed 3% efficiency improvement).

[505] "Synchronous Belt Drives Offer Low Cost Energy Savings," Baldor. February 2009. (attached in Reference Documents)

[506] "Energy Savings from Synchronous Belts," The Gates Rubber Co., February 2014. (Assumed 5% efficiency improvement)

[507] "Motor System Tip Sheet #5, Replace V-Belts with Cogged or Synchronous Belt Drives," USDOE-EERE, September 2005. (Assumed 2% efficiency improvement)

### DEFINITION OF BASELINE EQUIPMENT

The Baseline Equipment is HVAC RTUs that have smooth v-belts installed on the supply and/or return air fans (i.e. RTU does not already have a notched v-belt installed).

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

A v-belt has a life based on fan run hours which varies by building type based primarily on occupancy schedule because the fans are required by code to operate continuously during occupied hours. The supply and return fans will also run a few hours during unoccupied hours for heating and cooling as needed. For the notched v-belt EUL calculation, the default hours[508] in the following table are used for a variety of building types and HVAC applications.

EUL = Belt Life / Occupancy Hours per year

Where:

Belt Life = 24,000 hours[509]

Occupancy Hours per year = values from Table below

The notched v-belt measure EUL is summarized by building type in the following table.

**Notched v-belt Effective Useful Life (EUL)**

| Building Type | Total Fan Run Hours | EUL (Years) | Model Source |
|---|---|---|---|
| Assembly | 7235 | 3.3 | eQuest |
| Assisted Living | 8760 | 2.7 | eQuest |
| College | 6103 | 3.9 | eQuest |
| Convenience Store | 7004 | 3.4 | eQuest |
| Elementary School | 7522 | 3.2 | eQuest |
| Garage | 7357 | 3.3 | eQuest |
| Grocery | 7403 | 3.2 | eQuest |
| Healthcare Clinic | 6345 | 3.8 | eQuest |
| High School | 7879 | 3.0 | eQuest |
| Hospital - VAV econ | 8760 | 2.7 | eQuest |
| Hospital - CAV econ | 8760 | 2.7 | eQuest |
| Hospital - CAV no econ | 8760 | 2.7 | eQuest |
| Hospital - FCU | 8760 | 2.7 | eQuest |
| Manufacturing Facility | 8706 | 2.8 | eQuest |
| MF - High Rise | 8760 | 2.7 | eQuest |
| MF - Mid Rise | 8760 | 2.7 | eQuest |
| Hotel/Motel - Guest | 8760 | 2.7 | eQuest |
| Hotel/Motel - Common | 8760 | 2.7 | eQuest |
| Movie Theater | 7505 | 3.2 | eQuest |
| Office - High Rise - VAV econ | 6064 | 4.0 | eQuest |
| Office - High Rise - CAV econ | 5697 | 4.2 | eQuest |
| Office - High Rise - CAV no econ | 5682 | 4.2 | eQuest |
| Office - High Rise - FCU | 6163 | 3.9 | eQuest |
| Office - Low Rise | 6288 | 3.8 | eQuest |
| Office - Mid Rise | 6856 | 3.5 | OpenStudio |

[508] ComEd Trm June 1, 2010 page 139. The Office hours is based upon occupancy from the eQuest model developed for EFLH, since it was agreed the ComEd value was too low.
[509] "DEER2014-EUL-table-update_2014-02-05.xlsx," Database for Energy Efficiency Resources (DEER), DEER2014 EUL Table. (attached in Reference Documents)

| Building Type | Total Fan Run Hours | EUL (Years) | Model Source |
|---|---|---|---|
| Religious Building | 7380 | 3.3 | eQuest |
| Restaurant | 7809 | 3.1 | eQuest |
| Retail - Department Store | 7155 | 3.4 | OpenStudio |
| Retail - Strip Mall | 6846 | 3.5 | eQuest |
| Warehouse | 6832 | 3.5 | OpenStudio |
| Unknown | 7100 | 3.4 | n/a |

The lifetime of a synchronous belt system is the same as the lifetime of the equipment it is installed on because it is a permanent upgrade, involving the installation of toothed pulleys. Typical HVAC RTU lifetime is 15 years, which applies to synchronous belts as well. This is not to suggest that the actual belt component has an equivalent lifetime because they do require replacement. However, their O&M cost savings (derived from not having to tension, etc.) are assumed to offset the replacement cost of the belt, resulting in a net cost of zero. As a result, neither a separate lifetime nor O&M savings are quantified for synchronous belts and lifetime can therefore be considered as the lifetime of the equipment they're installed on because it would not be possible to install a traditional or notched belt on the synchronous pulleys.

### DEEMED MEASURE COST

A review of the Grainger online[510] pricing for "A," "B," "AX," and "BX" v-belts showed the incremental cost to upgrade to notched v-belts would result in a 28% price increase. The notched v-belt incremental cost is summarized in the table below:

**Notched V-belt Incremental Cost Summary**

| Smooth V-Belt Industry Number | Outside Length (Inches) | Dayton Smooth V-Belt* | Notched V-belt Industry Number | Dayton Notched v-belt* | Price Increase | % Increase |
|---|---|---|---|---|---|---|
| A30 (Item # 1A095) | 32 | $12.70 | AX29 (Item # 3GWU4) | $17.65 | $4.95 | 28% |
| B29 (Item # 6L208) | 32 | $16.75 | BX29 (Item # 5TXL4) | $23.23 | $6.48 | 28% |
| * Pricing based on Dayton Belts as found on Grainger Website 10/30/14 | | | | | | |

Note that the incremental cost for notched V-Belts assumes that the notched belt is purchased and installed instead of a smooth v-belt. There is no difference in the cost of installation, only the material.

**Synchronous Belt Incremental Cost Summary**

| Smooth V-Belt Industry Number | Smooth belt system Price* | Synchronous Belt Industry Number | Synchronous System Price* | Price Difference |
|---|---|---|---|---|
| Belt A30 (Item # 1A095) | $12.70 | Belt 1DHL5 (Item # 322L050) | $20.51 | $7.81 |
| Gearbelt pulley BK47 (Item #5UHD5) | $45.90 | Gearbelt sprocket GTR-36G-8M-12 (Item # 2UWH6) | $113.00 | $67.10 |
| * Costs based on Grainger pricing. | | | | |

Incremental cost for a NC or TOS project is $142. This is the price of synchronous equipment (belt, two sprockets) subtract v-belt equipment (belt, two pulleys). Labor cost is assumed to be equal in the baseline and efficient cases.

510 Grainger catalog on-line web-site for Dayton v-belt pricing

Incremental cost for a RF project is $383.81. This is the price of synchronous equipment and labor[511] to install it (not including a trip charge) subtract the cost of the v-belt (but not the pulleys).

#### DEEMED O&M COST ADJUSTMENTS

N/A

#### LOADSHAPE

Loadshape C05 - Commercial Electric Heating and Cooling

#### COINCIDENCE FACTOR

N/A

## Algorithm

### CALCULATION OF ENERGY SAVINGS

#### ELECTRIC ENERGY SAVINGS

$$\Delta kWh = kW_{connected} * Hours * ESF$$

Where:

$kW_{Connected}$ =kW of equipment is calculated using motor efficiency[512].

= (HP * 0.746 kW/HP* Load Factor)/Motor Efficiency

Load Factor =Motors are assumed to have a load factor of 80% for calculating KW if actual values cannot be determined[513]. Custom load factor may be applied if known.

Motor Efficiency = Actual motor efficiency shall be used to calculate KW. If not known a value from the motor efficiency refrence tables below should be used[514]. Default motor is a NEMA Premium Efficiency, ODP, 4-pole/1800 RPM fan motor

[511] Assumed to be $150 based on mechanical contractor estimate.
[512] Note that kWConnected may be determined using various methodologies. The examples provided use rated HP and assumed load factor. Other methodologies include rated voltage and full load current with assumed load factor, or actual measured voltage and current.
[513] Com Ed TRM June 1, 2010
[514] Efficiency values for motors less than one HP taken from Baldor Electric Catalog 501, standard motor product catalog.

| Baseline Motor Efficiencies (EPACT) | | | | | | |
|---|---|---|---|---|---|---|
| Size HP | Open Drip Proof (ODP) | | | Totally Enclosed Fan-Cooled (TEFC) | | |
| | # of Poles | | | | | |
| | *6* | *4* | *2* | *6* | *4* | *2* |
| | Speed (RPM) | | | | | |
| | *1200* | *1800* | *3600* | *1200* | *1800* | *3600* |
| 1/8 | - | 44.00% | - | - | - | - |
| 1/6 | 57.50% | 62.00% | - | - | - | - |
| 1/4 | 68.00% | 68.00% | - | 68.00% | 64.00% | - |
| 1/3 | 70.00% | 70.00% | 72.00% | 70.00% | 68.00% | 72.00% |
| 1/2 | 78.50% | 80.00% | 68.00% | 72.00% | 74.00% | 68.00% |
| 3/4 | 77.00% | 78.50% | 74.00% | 77.00% | 75.50% | 74.00% |
| 1 | 80.00% | 82.50% | 75.50% | 80.00% | 82.50% | 75.50% |
| 1.5 | 84.00% | 84.00% | 82.50% | 85.50% | 84.00% | 82.50% |
| 2 | 85.50% | 84.00% | 84.00% | 86.50% | 84.00% | 84.00% |
| 3 | 86.50% | 86.50% | 84.00% | 87.50% | 87.50% | 85.50% |
| 5 | 87.50% | 87.50% | 85.50% | 87.50% | 87.50% | 87.50% |
| 7.5 | 88.50% | 88.50% | 87.50% | 89.50% | 89.50% | 88.50% |
| 10 | 90.20% | 89.50% | 88.50% | 89.50% | 89.50% | 89.50% |
| 15 | 90.20% | 91.00% | 89.50% | 90.20% | 91.00% | 90.20% |
| 20 | 91.00% | 91.00% | 90.20% | 90.20% | 91.00% | 90.20% |
| 25 | 91.70% | 91.70% | 91.00% | 91.70% | 92.40% | 91.00% |

| Efficient Motor Efficiencies (NEMA Premium) | | | | | | |
|---|---|---|---|---|---|---|
| Size HP | Open Drip Proof (ODP) | | | Totally Enclosed Fan-Cooled (TEFC) | | |
| | # of Poles | | | # of Poles | | |
| | 2 | 4 | 6 | 2 | 4 | 6 |
| | Speed (RPM) | | | Speed (RPM) | | |
| | 1200 | 1800 (Default) | 3600 | 1200 | 1800 | 3600 |
| 0.125 * | - | 44.00% | - | - | - | - |
| 1/6 | 57.50% | 62.00% | - | - | - | - |
| 1/4 | 68.00% | 68.00% | - | 68.00% | 64.00% | - |
| 1/3 | 70.00% | 70.00% | 72.00% | 70.00% | 68.00% | 72.00% |
| 1/2 | 78.50% | 80.00% | 68.00% | 72.00% | 74.00% | 68.00% |
| 3/4 | 77.00% | 78.50% | 74.00% | 77.00% | 75.50% | 74.00% |
| 1 | 82.50% | 85.50% | 77.00% | 82.50% | 85.50% | 77.00% |
| 1.5 | 86.50% | 86.50% | 84.00% | 87.50% | 86.50% | 84.00% |
| 2 | 87.50% | 86.50% | 85.50% | 88.50% | 86.50% | 85.50% |
| 3 | 88.50% | 89.50% | 85.50% | 89.50% | 89.50% | 86.50% |
| 5 | 89.50% | 89.50% | 86.50% | 89.50% | 89.50% | 88.50% |
| 7.5 | 90.20% | 91.00% | 88.50% | 91.00% | 91.70% | 89.50% |
| 10 | 91.70% | 91.70% | 89.50% | 91.00% | 91.70% | 90.20% |
| 15 | 91.70% | 93.00% | 90.20% | 91.70% | 92.40% | 91.00% |
| 20 | 92.40% | 93.00% | 91.00% | 91.70% | 93.00% | 91.00% |
| 25 | 93.00% | 93.60% | 91.70% | 93.00% | 93.60% | 91.70% |

Hours = When available, actual hours should be used. If actual hours are not available default hours[515] are provided in table below for HVAC fan operation which varies by building type:

| Building Type | Total Fan Run Hours | Model Source |
|---|---|---|
| Assembly | 7235 | eQuest |
| Assisted Living | 8760 | eQuest |
| College | 6103 | eQuest |
| Convenience Store | 7004 | eQuest |
| Elementary School | 7522 | eQuest |
| Garage | 7357 | eQuest |
| Grocery | 7403 | eQuest |
| Healthcare Clinic | 6345 | eQuest |
| High School | 7879 | eQuest |
| Hospital - VAV econ | 8760 | eQuest |
| Hospital - CAV econ | 8760 | eQuest |
| Hospital - CAV no econ | 8760 | eQuest |
| Hospital - FCU | 8760 | eQuest |
| Manufacturing Facility | 8706 | eQuest |
| MF - High Rise | 8760 | eQuest |
| MF - Mid Rise | 8760 | eQuest |
| Hotel/Motel - Guest | 8760 | eQuest |
| Hotel/Motel - Common | 8760 | eQuest |
| Movie Theater | 7505 | eQuest |
| Office - High Rise - VAV econ | 6064 | eQuest |
| Office - High Rise - CAV econ | 5697 | eQuest |
| Office - High Rise - CAV no econ | 5682 | eQuest |
| Office - High Rise - FCU | 6163 | eQuest |
| Office - Low Rise | 6288 | eQuest |
| Office - Mid Rise | 6856 | OpenStudio |
| Religious Building | 7380 | eQuest |
| Restaurant | 7809 | eQuest |
| Retail - Department Store | 7155 | OpenStudio |
| Retail - Strip Mall | 6846 | eQuest |
| Warehouse | 6832 | OpenStudio |
| Unknown | 7100 | n/a |

ESF = Energy Savings Factor, the ESF for notched v-belt Installation is assumed to be 2%

= the ESF for notched Synchronous Belt Installation is assumed to be 3.1%[516]

[515] Hours per year are estimated using the eQuest models as the total number of hours the fans are operating for heating, cooling and ventilation for each building type.

[516] Based on information found in Advanced Manufacturing Office, US DOE, "Replace V-Belts with Notched or Synchronous Drives", (US Department of Energy Motor Systems Tip Sheet #5, DOE/GO-102012-3740, November 2012). V-belt drives can have a peak efficiency of 95% and synchronous belts operate at 98%, therefore ESF is (1-95%/98%) = 3.1%.

**EXAMPLE**

For example, a notched v-belt installation in an low rise office building RTU with a 5 HP NEMA premium efficiency motor using the default hours of operation, motor load and 89.5% motor efficiency;

$$\Delta kWh = kW_{connected} * Hours * ESF$$

$$= ((HP * 0.746\ kW/HP * Load\ Factor)/Motor\ Efficiency) * Hours * ESF$$

$$= ((5\ HP * 0.746\ kW/HP * 80\%) / 89.5\%) * 6288 * 2\%$$

$$= 419\ kWh\ Savings$$

### Summer Coincident Peak Demand Savings

$$\Delta kW = kW_{connected} * ESF$$

Where:

$kW_{Connected}$ = kW of equipment is calculated using motor efficiency.

= (HP *0 .746 kW/HP* Load Factor)/Motor Efficiency

Variables as provided above

**EXAMPLE**

For example, an office building RTU with a 5 HP NEMA premium efficiency motor using the default motor load and 89.5% motor efficiency;

$$\Delta kW = kW_{connected} * ESF$$

$$= ((HP * 0.746\ kW/HP * Load\ Factor)/Motor\ Efficiency) * ESF$$

$$= ((5\ HP * 0.746\ kW/HP * 80\%) / 89.5\%) * 2\%$$

$$= 0.0667\ kW\ Savings$$

### Natural Gas Savings

N/A

### Water Impact Descriptions and Calculation

N/A

### Deemed O&M Cost Adjustment Calculation

N/A

### Measure Code: CI-HVC-NVBE-V04-190101

### Review Deadline: 1/1/2022

## 4.4.31 Small Business Furnace Tune-Up

### Description

This measure is for a natural gas Small Business furnace that provides space heating. The tune-up will improve furnace performance by inspecting, cleaning and adjusting the furnace and appurtenances for correct and efficient operation. Additional savings maybe realized through a complete system tune-up.

This measure was developed to be applicable to the following program types: Small business.

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

To qualify for this measure an approved technician must complete the tune-up requirements[517] listed below:

- Measure combustion efficiency using an electronic flue gas analyzer
- Check and clean blower assembly and components per manufacturer's recommendations
- Where applicable Lubricate motor and inspect and replace fan belt if required
- Inspect for gas leaks
- Clean burner per manufacturer's recommendations and adjust as needed
- Check ignition system and safety systems and clean and adjust as needed
- Check and clean heat exchanger per manufacturer's recommendations
- Inspect exhaust/flue for proper attachment and operation
- Inspect control box, wiring and controls for proper connections and performance
- Check air filter and clean or replace per manufacturer's
- Inspect duct work connected to furnace for leaks or blockages
- Measure temperature rise and adjust flow as needed
- Check for correct line and load volts/amps
- Check thermostat operation is per manufacturer's recommendations (if adjustments made, refer to 'Small Commercial Programmable Thermostat Adjustment' measure for savings estimate)
- Perform Carbon Monoxide test and adjust heating system until results are within standard industry acceptable limits

### Definition of Baseline Equipment

The baseline is furnace assumed not to have had a tune-up in the past 2 years.

### Deemed Lifetime of Efficient Equipment

The measure life for the tune up is 2 years.[518]

### Deemed Measure Cost

The incremental cost for this measure should be the actual cost of tune up.

### Deemed O&M Cost Adjustments

There are no expected O&M savings associated with this measure.

### Loadshape

Loadshape C04 - Commercial Electric Heating

[517] American Standard Heating & Air Conditioning, Maintenance for Indoor Units
[518]Act on Energy Commercial Technical Reference Manual No. 2010-4, 9.2.3 Gas Forced-Air Furnace Tune-up.

**COINCIDENCE FACTOR**

N/A

**Algorithms**

**CALCULATION OF ENERGY SAVINGS**

**ELECTRIC ENERGY SAVINGS**

ΔkWh = ΔTherms * $F_e$ * 29.3

Where:

ΔTherms = as calculated below

$F_e$ = Furnace Fan energy consumption as a percentage of annual fuel consumption

= 3.14%[519]

29.3 = kWh per therm

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

N/A

**NATURAL GAS SAVINGS**

ΔTherms = (Capacity * EFLH * (((Effbefore + Ei)/ Effbefore) – 1)) / 100,000

Where:

Capacity = Furnace gas input size (Btu/hr)

= Actual

EFLH = Equivalent Full Load Hours for heating are provided in section 4.4 HVAC End Use

Effbefore = Efficiency of the furnace before the tune-up

= Actual

*Note: Contractors should select a mid-level firing rate that appropriately represents the average building operating condition over the course of the heating season and take readings at a consistent firing rate for pre and post tune-up.*

EI = Efficiency Improvement of the furnace tune-up measure

= Actual

100,000 = Converts Btu to therms

[519] $F_e$ is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the Energy Star version 3 criteria for 2% $F_e$. See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference.

**EXAMPLE**

A 200 kBtu furnace in a Rockford low rise office records an efficiency prior to tune up of 82% AFUE and a 1.8% improvement in efficiency are tune up:

$$\Delta therms = (200,000 * 1428 * (((0.82 + 0.018)/ 0.82) – 1)) /100,000$$

$$= 62.3 \text{ therms}$$

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-HVC-FTUN-V02-160601**

**REVIEW DEADLINE: 1/1/2022**

## 4.4.32 Combined Heat and Power

### DESCRIPTION

The Combined Heat and Power (CHP) measure can provide energy savings within the State of Illinois through the development and operation of CHP projects. This measure is applicable for Conventional or Topping Cycle CHP systems, as well as Waste Heat-to-Power (WHP) or Bottoming Cycle CHP systems. The measure will reduce the total Btu's of energy required to meet the end use needs of the facility.

It is recognized that CHP system design and configuration may be complex, and as such the calculation of energy savings may not be reducible to the equations within this measure. In such cases a more comprehensive engineering and financial analysis may be developed that more accurately incorporates the attributes of complex CHP configurations such as variable-capacity systems, and partial combined-cycle CHP systems. Where noted, the use of values that are determined through an external engineering analysis may be substituted by agreement between the participant, the program administrator and independent evaluator. This substitution of values does not eliminate ex post evaluation risk (retroactive adjustments to savings claims) that exists when using custom inputs.

This measure was developed to be applicable to the following program types: Retrofit (RF), New Construction (NC). If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

Conventional or Topping Cycle CHP is defined as an integrated system that is located at or near the building or facility (on-site, on the customer side of the meter) that utilizes a prime mover (reciprocating engine, gas turbine, micro-turbine, fuel cell, boiler/steam turbine combination) for the purpose of generating electricity and useful thermal energy (such as steam, hot water, or chilled water) where the primary function of the facility where the CHP is located is not to generate electricity for use on the grid. An eligible system must demonstrate a minimum total system efficiency of 60% (HHV)[520] with at least 20% of the system's total useful energy output in the form of useful thermal energy on an annual basis.

*Measuring and Calculating Conventional CHP Total System Efficiency:*

CHP efficiency is calculated using the following equation:

$$CHP_{\ Efficiency}(HHV) = \frac{\left[CHP_{thermal}\ \left(\frac{kBtu}{yr}\right) + E_{CHP}\ \left(\frac{kWh}{yr}\right) * 3.412\ \left(\frac{kBtu}{kWh}\right)\right]}{F_{totalCHP}\left(\frac{kBtu}{yr}\right)}$$

Where:

$CHP_{thermal}$ = Useful annual thermal energy output from the CHP system, defined as the annual thermal energy output of the CHP system that is actually recovered and utilized in the facility/process.

$E_{CHP}$ = Useful annual electricity output produced by the CHP system, defined as the annual electric energy output of the CHP system that is actually utilized to replace purchased electricity required to meet the requirements of the facility/process.

$F_{totalCHP}$ = Total annual fuel consumed by the CHP system

For further definition of the terms, please see "Calculation of Energy Savings" Section below.

[520] Higher Heating Value (HHV): refers to the heating value of the fuel and is defined as the total thermal energy available, including the heat of condensation of water vapors,resulting from complete combustion of the fuel versus the Lower Heating Value (LHV) which assumes the heat of condensation is not available

Waste Heat-to-Power or Bottoming Cycle CHP is defined as an integrated system that is located at or near the building or facility (on-site, on the customer side of the meter) that does one of the following:

- Utilizes exhaust heat from an industrial/commercial process to generate electricity (except for exhaust heat from a facility whose primary purpose is the generation of electricity for use on the grid); or
- Utilizes the pressure drop in an industrial/commercial facility to generate electricity through a backpressure steam turbine where the facility normally uses a pressure reducing valve (PRV) to reduce the pressure in their facility; or
- Utilizes the pressure reduction in natural gas pipelines (located at natural gas compressor stations) before the gas is distributed through the pipeline to generate electricity, provided that the conversion of energy to electricity is achieved without using additional fossil fuels.

Since these types of systems utilize waste heat as their fuel, they do not have to meet any specific total system efficiency level (assuming they use no additional fossil fuel in their operation) If additional fuel is used onsite, it should be accounted for using the following methodology:

- Treat the portion of Waste-Heat-to-Power that does not require any additional fuel using the Waste-Heat-to-Power methodology outlined in this document.
- Treat the portion of Waste-Heat-to-Power that requires additional fuel (if natural gas) using the Conventional CHP methodology outlined in this document. If the additional fuel is not natural gas, custom carbon equivalency calculations would be needed – refer to section "Calculation of Energy Savings" for more details.
- Add the energy savings together.

These systems may export power to the grid.

### Definition of Baseline Equipment

Electric Baseline: The baseline facility would be a facility that purchases its electric power from the grid.

Heating Baseline (for CHP applications that displace onsite heat): The baseline equipment would be the boiler/furnace operating onsite, or a boiler/furnace meeting the baseline equipment defined in the High Efficiency Boiler (Section 4.4.10)/Furnace (Section 4.4.11) measures of this TRM.

Cooling Baseline (for CHP applications that displace onsite cooling demands): The baseline equipment would be the chiller (or chillers) operating onsite, or a chiller (or chillers) meeting the definition of baseline equipment defined in the Electric Chiller (Section 4.4.6) measure of this TRM.

Facilities that use biogas or waste gas: Facilities that use (but are not purchasing) biogas or waste gas that is not otherwise used, whether they are using biogas or waste gas only or a combination of biogas or waste gas and natural gas to meet their energy demands are also eligible for this measure. If additional fuel is purchased to power the CHP system, then the additional natural gas should be taken into account using the following methodology:

- Treat the portion of CHP system that does not require any additional fuel, or that requires additional fuel that would otherwise be wasted (e.g. flared), using the Waste-Heat-to-Power methodology outlined in this document.
- Treat the portion of CHP that requires additional fuel (if natural gas) using the Conventional CHP methodology outlined in this document. If the additional fuel is not natural gas, custom carbon equivalency calculations would be needed – refer to section "Calculation of Energy Savings" for more details.
- Add the energy savings together.

Consumption of any biogas or waste gas that would not otherwise being wasted (*e.g.,* flared) will be accounted for in the overall net BTU savings calculations the same as for purchased natural gas.

### Deemed Lifetime of Efficient Equipment

Measure life is a custom assumption, dependent on the technology selected and the system installation.

### DEEMED MEASURE COST

Custom installation and equipment cost will be used. These costs should include the cost of the equipment and the cost of installing the equipment. Equipment costs include, but are not limited to: prime mover, heat recovery system(s), exhaust gas treatment system(s), controls, and any interconnection/electrical connection costs.

The installations costs include labor and material costs such as, but not limited to: labor costs, materials such as ductwork, piping, and wiring, project and construction management, engineering costs, commissioning costs, and other fees.

Measure costs will also include the present value of expected maintenance costs over the life of the CHP system.

### LOADSHAPE

Use Custom Loadshape. The loadshape should be obtained from the actual CHP operation strategy, based on the On-Peak and Off-Peak Energy definitions specified in Table 3.3 of "Section 3.5 Electrical Loadshapes" of the TRM.

### COINCIDENCE FACTOR

Custom coincidence factor will be used. Actual value based on the CHP operation strategy will be used.

## Algorithm

### CALCULATION OF ENERGY SAVINGS

**i) Conventional or Topping Cycle CHP Systems:**

***<u>Step 1: (Calculating Total Annual Source Fuel Savings in Btus)</u>***

The first step is to calculate the total annual source fuel savings associated with the CHP installation, in order to ensure the CHP project produces positive total annual source fuel savings (i.e. reduction in source Btus):

$S_{FuelCHP}$ = Annual fuel savings (Btu) associated with the use of a Conventional CHP system to generate the useful electricity output (kWh, converted to Btu) and useful thermal energy output (Btu) versus the use of the equivalent electricity generated and delivered by the local grid and the equivalent thermal energy provided by the onsite boiler/furnace.

$= (F_{grid} + F_{thermalCHP}) – F_{total\ CHP}$

Where:

$F_{grid}$ = Annual fuel in Btu that would have been used to generate the useful electricity output of the CHP system if that useful electricity output was provided by the local utility grid.

$= E_{CHP} * H_{grid}$

Where:

$E_{CHP}$ = Useful annual electricity output produced by the CHP system, defined as the annual electric energy output of the CHP system that is actually utilized to replace purchased electricity required to meet the requirements of the facility/process. [521]

$= ( CHP_{capacity} * Hours\ ) - E_{Parasitic}$

$CHP_{capacity}$ = CHP nameplate capacity

= Custom input

[521] For complex systems this value may be obtained from a CHP System design/financial analysis study.

Hours = Annual operating hours of the system

= Custom input

$E_{parasitic}$ = The electricity required to operate the CHP system that would otherwise not be required by the facility/process

= Custom input

$H_{grid}$ = Heat rate of the grid in Btu/kWh, based on the average fossil heat rate for the EPA eGRID subregion, adjusted to take into account T&D losses.

For systems operating less than 6,500 hrs per year:

Use the Non-baseload heat rate provided by EPA eGRID for RFC West region for ComEd territory (including independent providers connected to RFC West), and SERC Midwest region for Ameren territory (including independent providers connected to SERC Midwest)[522]. Also include any line losses.

For systems operating more than 6,500 hrs per year:

Use the All Fossil Average heat rate provided by EPA eGRID for RFC West region for ComEd territory (including independent providers connected to RFC West), and SERC Midwest region for Ameren territory (including independent providers connected to SERC Midwest). Also include any line losses.

$F_{thermalCHP}$ = Annual fuel in Btu that would have been used on-site by a boiler/furnace to provide the useful thermal energy output of the CHP system. [523]

= $CHP_{thermal}$ / $Boiler_{eff}$ (or $CHP_{thermal}$ / $Furnace_{eff}$)

$CHP_{thermal}$ = Useful annual thermal energy output from the CHP system, defined as the annual thermal energy output of the CHP system that is actually recovered and utilized in the facility/process.

= Custom input

$Boiler_{eff}$ /$Furnace_{eff}$= Efficiency of the on-site Boiler/Furnace that is displaced by the CHP system or if unknown, the baseline equipment value stated in the High Efficiency Boiler (Section 4.4.10) measure or High Efficiency Furnace (Section 4.4.11) measure in this TRM. .

= Custom input

$F_{total\ CHP}$ = Total fuel in Btus consumed by the CHP system

= Custom input

***Step 2: (Savings Allocation to Program Administrators for Purposes of Assessing Compliance with Energy Savings Goals (Not for Use in Load Reduction Forecasting))***

Savings claims are a function of the electric output of the CHP system ($E_{CHP}$), the used thermal output of the CHP system ($F_{thermalCHP}$), and the CHP system efficiency ($CHP_{Eff}$(HHV)). The percentages of electric output and used

---

[522] These values are subject to regular updates so should be reviewed regularly to ensure the current assumptions are correct. Refer to the latest EPA eGRID data. Current values, based on eGrid 2016 are:

- Non-Baseload RFC West: 10,539 Btu/kWh * (1 + Line Losses)
- Non-Baseload SERC Midwest: 9,968 Btu/kWh * (1 + Line Losses)
- All Fossil Average RFC West: 9,962 Btu/kWh * (1 + Line Losses)
- All Fossil Average SERC Midwest: 9,996 Btu/kWh * (1 + Line Losses)

[523] For complex systems this value may be obtained from a CHP System design/financial analysis study.

thermal output that can be claimed also differ slightly depending on whether the project was included in both electric[524] and gas[525] Energy Efficiency Portfolio Standard (EEPS)[526] efficiency programs, only an electric EEPS program or only a gas EEPS program. The tables below provide the specific percentages of electric and/or thermal output that can be claimed under each of those three scenarios. These percentages apply only to cases in which natural gas is the fuel used by the CHP system. Saving estimates for systems using other fuels should be calculated on a custom basis. If the waste heat recovered from the CHP system is offsetting electric equipment, such as an absorption chiller offsetting an electric chiller, then the net change in electricity consumption associated with the electric equipment should be added to the allocated electric savings.

1) For systems participating in both electric EEPS and gas EEPS programs:

| CHP Annual System Efficiency (HHV) | Allocated Electric Savings | Allocated Gas Savings |
|---|---|---|
| **60%** | 65% of $E_{CHP}$ (kWh) | No gas savings |
| **>60% to 65%** | 65% of $E_{CHP}$ (kWh) + one percentage point increase for every one percentage point increase in CHP system efficiency (max 70% of $E_{CHP}$ in kWh) | No gas Savings |
| **>65%** | 70% of $E_{chp}$ (kWh) | 2.5% of $F_{thermal}$ (useful thermal output of the CHP system) for every one percentage point increase in CHP system efficiency above 65%. |

Example: System with measured annual system efficiency (HHV) of 70%: Electric savings (kWh) = 70% of $E_{CHP}$ measured over 12 months, and Gas savings (therms) = 12.5% of $F_{thermal}$ measured over 12 months (70% - 65% = 5 X 2.5% = 12.5%)

2) For systems participating in only an electric EEPS program:

| CHP Annual System Efficiency (HHV) | Allocated Electric Savings | Allocated Gas Savings |
|---|---|---|
| **60%** | 65% of $E_{CHP}$ (useful electric output of CHP system in kWh) | No gas Savings |
| **Greater than 60%** | 65% + one percentage point increase for every one percentage point increase in CHP system efficiency (no max) | No gas Savings |

Example: System with measured annual fuel use efficiency of 75%: Electric savings (kWh) = 65% + 15% = 80% of $E_{CHP}$ measured over 12 months (15% = 1% for every 1% increase in system efficiency). No gas savings (therms).

3) For systems participating in only a gas EEPS program:

| CHP Annual System Efficiency (HHV) | Allocated Electric Savings | Allocated Gas Savings |
|---|---|---|
| **60% or greater** | No electric savings | 2.5% of Fthermal (useful thermal output of the CHP system) for every one percentage point increase in CHP system efficiency above 60%. |

[524] 220 ILCS 5/8-103; 220 ILCS 5/16-111.5B
[525] 220 ILCS 5/8-104
[526] As used in this measure characterization, EEPS programs are defined as those energy efficiency programs implemented pursuant to Sections 8-103, 8-104, and 16-111.5B of the Illinois Public Utilities Act. Technically, EEPS programs pertain to energy efficiency programs implemented pursuant to 220 ILCS 5/8-103 and 220 ILCS 5/8-104. However, for simplicity in presentation, this measure defines EEPS programs as also including those programs implemented pursuant to 220 ILCS 5/16-111.5B (these programs are funded through the same energy efficiency riders established pursuant to Section 8-103).

Example: System with measured annual system efficiency (HHV) of 70%: No Electric savings (kWh). Gas savings (therms) = 25% of $F_{thermal}$ measured over 12 months (70% - 60% = 10 X 2.5% = 25%)

Conventional or topping cycle CHP systems virtually always require an increase in the use of fuel on-site in order to produce electricity. Different jurisdictions and experts across the country have employed and/or put forward a variety of approaches[527] to address how increased on-site fuel consumption should be reflected in the attribution of electric savings to CHP systems. The approach reflected in the tables above is generally consistent – for CHP systems consuming natural gas – with approaches recently put forward by the Southwest Energy Efficiency Project (SWEEP) and Institute for Industrial Productivity (IIP) that determine reduced electric savings based on the equivalent amount of carbon dioxide generated from the increased fuel used[528].

There are a variety of ways one could treat the potential for gas utilities to claim savings from CHP projects in their EEPS portfolios. For projects in which a natural gas EEPS program is involved, the tables above treat savings from CHP installations in two steps: (1) a fuel-switch from electricity to natural gas (i.e. using more natural gas to eliminate the need to generate as much electricity on the grid); and (2) possible increases in CHP efficiency above a "benchmark" level. When both electric EEPS and natural gas EEPS programs are involved in a project, the program administrator claims all the electricity savings associated with a fuel-switch up to a "benchmark" 65% efficient CHP system. All the savings associated with increasing CHP efficiencies above that benchmark level are allocated to natural gas (e.g. if the CHP efficiency is 75%, the natural gas savings associated with an increase in CHP efficiency from 65% to 75% are allocated to natural gas). That is consistent with the notion that CHP efficiency typically increases primarily by increasing the use of the thermal output of the system (increasing the displacement of baseline gas use). For projects that involve only a natural gas EEPS program, the "benchmark" above which the gas utility can claim savings is lowered to 60%.

ii) **Waste-Heat-to-Power CHP Systems :**

**ELECTRIC ENERGY SAVINGS:**

$$\Delta kWh = E_{CHP}$$

Where:

$E_{CHP}$ = Useful annual electricity output produced by the CHP system, defined as the annual electric energy output of the CHP system that is actually utilized to replace purchased electricity required to meet the requirements of the facility/process.

= Custom input

[527] Approaches range from ignoring the increased gas use entirely (i.e., no "penalty") to applying approximately 40-60% "penalties", depending on the CHP efficiency and based on the equivalent grid kWh that the increased gas use represents.

[528] Consider, for example, a hypothetical CHP system that produces 5 million kWh annually, consumes 50 million kBtu of gas annual to generate that electricity (i.e. electric efficiency of approximately 34.8% HHV), reduces on-site gas use for space heating by 26 million kBtu of gas (i.e. equivalent to approximately 81.5% CHP thermal output utilization displacing gas used in a 70% efficient space heating boiler) and has a total annual CHP efficiency of 70.6% HHV. In this example, the net increase in on-site gas use is 24 million kBtu. At a carbon dioxide emission rate of 53.06 kg/MMBtu for burning natural gas, that translates to an increase in on-site carbon dioxide emissions of 1404 tons per year. At an estimated marginal emission rate of 1.098 tons of carbon dioxide per MWh in Illinois, that is equivalent to electric grid production of approximately 1.28 million kWh, or penalty of about 25.6% of the CHP system's electrical output if a precise calculation of carbon equivalency was utilitized to assign savings. In comparison, the simplified table above would entitle an electric utility to claim savings equal to 75.6% of the electric output (i.e. a penalty of 24.4% of electrical output) if it was the only utility promoting the system. In a gas and electric example, the electric savings claimed would be 70% of the production (a penalty of 30% of the CHP system's electrical output) and 12.5% of the recovered thermal output, equivalent to 2.23 million kBtu. The difference between the electric only scenario and the electric and gas, on the electric side, is 5% of the electric output or 250,000 kWh, which would require 2.45 million kBtu input at an efficiency of 34.8% HHV.

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = CF * CHP_{capacity}$$

Where:

CF = Summer Coincidence factor. This factor should also consider any displaced chiller capacity[529]

= Custom input

$CHP_{Capacity}$ = CHP nameplate capacity

= Custom input

### NATURAL GAS ENERGY SAVINGS:

$$\Delta Therms = F_{thermalCHP} \div 100{,}000$$

Where:

$F_{thermalCHP}$ = Net savings in annual purchased fuel in Btu, if any, that would have been used on-site by a boiler/furnace to provide some or all of the useful thermal energy output of the CHP system[530].

100,000 = Conversion factor for Btu to therms

### WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

### DEEMED O&M COST ADJUSTMENT CALCULATION

Custom estimates of maintenance costs that will be incurred for the life of the measure will be used**.** Maintenance costs vary with type and size of the prime mover. These costs include, but are not limited to:

- Maintenance labor
- Engine parts and materials such as oil filters, air filters, spark plugs, gaskets, valves, piston rings, electronic components, etc. and consumables such as oil
- Minor and major overhauls

For screening purposes, the US EPA has published resource guides that provide average maintenance costs based on CHP technology and system size[531].

### COST-EFFECTIVENESS SCREENING AND LOAD REDUCTION FORECASTING

For the purposes of forecasting load reductions due to CHP projects, changes in site energy use at the customer's meter – reduced consumption of utility provided electricity – adjusted for utility line losses (at-the-busbar savings), customer switching estimates, NTG, and any other adjustment factors deemed appropriate, should be used.

For the purposes of screening a CHP measure application for cost-effectiveness, changes in site energy use – reduced consumption of utility provided electricity and the net change in consumption of fuel – should be used. In general, the benefit and cost components used in evaluating the cost-effectiveness of a CHP project would include at least the following terms:

---

[529] If some or all of the existing electric chiller peak demand is no longer needed due to new waste heat powered chillers (e.g., absorption), the coincidence factor should be adjusted appropriately.

[530] In most cases, it is expected that waste-heat-to-power systems will not provide any new net useful thermal energy output, since the CHP system will be driven by thermal energy that was otherwise being wasted. If additional natural gas or other purchased energy is used onsite, it should be properly accounted for.

[531] "EPA Combined Heat and Power Partnership Resources" Oct 07, 2014, in the document "Catalog of CHP Technologies", US EPA, September 2017, pages 2-16,, 3-14, 4-14, 5-14, and 6-16.

Benefits: $E_{CHP} + \Delta kW + F_{thermal\_CHP}$

Costs: $F_{total\_CHP} + CHP_{COSTS} + O\&M_{COSTS}$

Where:

$CHP_{Costs}$ = CHP equipment and installation costs as defined in the "Deemed Measure Costs" section

$O\&M_{Costs}$ = CHP operations and maintenance costs as defined in the "Deemed O&M Cost Adjustment Calculation" section

**MEASURE CODE: CI-HVC-CHAP-V03-190101**

**REVIEW DEADLINE: 1/1/2022**

## 4.4.33 Industrial Air Curtain

**DESCRIPTION**

This measure applies to buildings with exterior entryways that utilize overhead doors. All other air curtain applications, such as through sliding door entryways or conventional foot-traffic entryways, require custom analysis as air curtain designs must often accommodate other factors that may change their effectiveness.

The use of overhead doors within exterior entryways during the heating season leads to the exfiltration of warm air from the upper portion of the door opening and the infiltration of colder air from the lower portion of the door opening. This results in increase heating energy use to compensate for heat losses every time a door is opened. By reducing heat losses, air curtains can also enhance the physical comfort of employees or customers near the entryway as there will be reduced temperature fluctuations when the door is opened and closed. In addition, in some cases excess heating capacity may be installed in buildings to meet this larger heating load. The addition of air curtains to exterior entryways that currently utilize overhead doors will result in energy savings and enhanced personal comfort, and also possibly in reduced equipment sizing and corresponding costs.

The primary markets for this measure are commercial and industrial facilities with overhead doors in exterior entryways, including but not limited to the following building types: retail, manufacturing, and warehouse (non-refrigerated).

*Limitations*

- For use in conditioned spaces with an overhead door in an exterior entryway. This measure does include other door types such doorways to commercial spaces such as retail.
- This measure should only be applied to spaces in which the overhead door separates a conditioned space and an unconditioned space.
- Installation must follow manufacturer recommendations to attain proper air velocity, discharge angle down to the floor level, and unit position.
- Certain heating systems may not be a good fit for air curtains, such as locations with undersized heating capacity. In these cases, the installation of an air curtain may not effectively reduce heating system cycling given the inappropriately sized heating capacity.
- Buildings with slightly positive to slightly negative (~5 Pa to -10 Pa). For all other scenarios, custom analysis is recommended.
- Measure assumes that wind speeds at near ground level are less than or equal to 12 mph for 90% of the heating or cooling season. For areas with more extreme weather, custom analysis is necessary.
- Note: for cost effectiveness, it is recommended that minimum door open times should be approximately 15 hours per week.[532]

This measure was developed to be applicable to the following program types: NC, RF. If applied to other program types, the measure savings should be verified.

The following methodology is highly complex and requires significant data collection. It is hoped that simplifying steps can be made in future iterations based on continued metering and evaluation of installations. Also the data collected through implementing the measure in the way currently drafted will aid in simplifying efforts at a future date.

**DEFINITION OF EFFICIENT EQUIPMENT**

Overhead air curtains designed for commercial and industrial applications that have been tested and certified in accordance with ANSI/AMCA 220 and installed following manufacturer guidelines. Measure is for standard models without added heating.

[532] Spentzas, Steve, et. al, “1009: Commercial and Industrial Air Curtains – Public Project Report,” Nicor Gas Emerging Technology Program (Oct 2014): 9

### DEFINITION OF BASELINE EQUIPMENT

No air curtain or other currently installed means to effectively reduce heat loss and air mixing during door openings, such as a vestibule or strip curtain.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.[533]

### DEEMED MEASURE COST

The incremental capital cost for overhead air curtains for exterior entryways are as follows, with an added average installation cost approximately equal to the capital cost.[534]

| Door Size | Capital Cost |
|---|---|
| 8'w x 8'h | $3,600 |
| 10'w x 10'h | $4,500 |
| 10'w x 12'h | $5,400 |
| 12'w x 14'h | $8,000 |
| 16'w x 16'h | $13,300 |

### LOADSHAPE

Heating Season: If electric heating, use Commercial Electric Heating Loadshape: C04. Otherwise, N/A

Cooling Season: Commercial Cooling Loadshape C03. Or, if applicable, use Commercial Electric Heating and Cooling Loadshape C05.

### COINCIDENCE FACTOR

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3%[535]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [536]

## Algorithm

### CALCULATION OF ENERGY SAVINGS

The following formulas provide a methodology for estimating cooling load (kWh) and heating load (therm) savings associated with the installation of air curtains on exterior entryways such as a single door or loading bay. This algorithm is based on the assumption that therm savings are directly related to the difference in cooling or heating losses due to infiltration or exfiltration through an entryway before and after the installation of an AMCA certified air curtain. Energy savings are assumed to be the result of a reduction of natural infiltration effects due to wind and thermal forces and follow the calculation methodology outlined by the ASHRAE Handbook.[537] The calculation assumes that the air curtain is appropriately sized and commissioned to be effective in mitigating infiltration of winds

[533] Navigant Consulting Inc, Measures and Assumptions for Demand Side Management (DSM) Planning: Appendix C: Substantiation Sheets, "Air Curtains – Single Door," Ontario Energy Board, (April 2009): C-137.
2014 Database for Energy-Efficient Resources, EUL/RUL (Effective/Remaining Useful Life) Values, February 4, 2014.

[534] Based on manufacturer interviews and air curtain specification sheets.

[535] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility's peak hour is divided by the maximum AC load during the year.

[536]Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year

[537] ASHRAE, "Ventilation and Infiltration," in 2013 ASHRAE Handbook – Fundamentals (2013): Ch 16.1 - 16.37

of up to 12 mph for at a least 90% of the year (based on manufacturer literature and TMY3 wind speed ranges at near ground level for Illinois).[538] Additionally, this measure assumes the HVAC systems are appropriately balanced such that the maximum pressure differential between indoor air and outdoor air is within the range of 5 Pa < ΔP < -10 Pa.[539] Custom analysis is necessary if building pressurization exceeds this range. However, while effectiveness decreases, some studies suggest that air curtains outperform vestibules and single door construction for negatively pressurized buildings with a ΔP of above -30 Pa.[540]

This algorithm allows either actual inputs or provides estimates if actual data is not available. All weather dependent values are derived from TMY3 data for the closest weather station to those locations defined elsewhere in the Illinois TRM (which are based on 30 year climate normals). If TMY3 weather station data was not available for the data used in the Illinois TRM, the next closest weather station was used. It is assumed that weather variations are negligible between the weather stations located within the same region. This approach was followed as the air curtain algorithm has a number of weather dependent variables which are all calculated in relation to the heating season or cooling season as defined by the balance point temperature deemed appropriate for the facility. All weather dependent data is based on TMY3 data and is listed in tables by both climate zone and balance point temperature, which is then normalized to the Illinois TRM climate zoned HDD/CDD definitions unless otherwise noted.

**ELECTRIC ENERGY SAVINGS**

$\Delta$kWhcooling = $[(Q_{tbc} – Q_{tac}) / EER – (HP * 0.7457)] * t_{open} * CD$

$\Delta$kWhHPheating = $[(Q_{tbc} – Q_{tac}) / HSPF – (HP * 0.7457)] * t_{open} * HD$

$\Delta$kWhGasheating = $- (HP * 0.7457) * t_{open} * HD$

Where:

$Q_{tbc}$ = rate of total heat transfer through the open entryway, before air curtain (kBtu/hr)

$Q_{tac}$ = rate of total heat transfer through the open entryway, after air curtain (kBtu/hr)

(see calculation in 'Heat Transfer Through Open Entryway with/without Air Curtain' sections below)

EER = energy efficiency ratio of the cooling equipment (kBtu/kWh)

= Actual. If unknown, use the table C403.2.3(2) in IECC 2012 (or IECC 2015 if through new construction) to assume values based on code estimates.

Note IECC 2018 is scheduled to become effective March 1, 2019 and will become baseline for all New Construction permits from that date.

HP = Input power for air curtain (hp)

= Actual value. If actual value not available, use the following estimates based on manufacturer specs

| Door Size | Fan HP |
|---|---|
| 8'w x 8'h | 1 |
| 10'w x 10'h | 1.5 |
| 10'w x 12'h | 4 |
| 12'w x 14'h | 6 |

[538] National Solar Radiation Data Base – 1991 – 2005 Update: Typical Meteorological Year 3, NREL.

[539] Spentzas, Steve, et. al, "1009: Commercial and Industrial Air Curtains – Public Project Report," Nicor Gas Emerging Technology Program (Oct 2014): 10
Wang, Liangzhu, "Investigation of the Impact of Building Entrance Air Curtain on Whole Building Energy Use," Air Movement and Control International, Inc. (2013). 4

[540] Wang, Liangzhu, "Investigation of the Impact of Building Entrance Air Curtain on Whole Building Energy Use," Air Movement and Control International, Inc. (2013). 4

| Door Size | Fan HP |
|---|---|
| 16'w x 16'h | 12 |

0.7457 = unit conversion factor, brake horsepower to electric power (kW/HP)

$t_{open}$ = average hours per day the door is open (hr/day)

= Actual or user defined estimated value.

CD = cooling days per year, total days in year above balance point temperature (day)

= use table below to select the best value for location[541]

| . | CD (Balance Point Temperature) | | | | |
|---|---|---|---|---|---|
| Climate Zone -Weather Station/City | 45 °F | 50 °F | 55 °F | 60 °F | 65 °F |
| 1 - Rockford AP / Rockford | 194 | 168 | 148 | 124 | 97 |
| 2 - Chicago O'Hare AP / Chicago | 194 | 173 | 153 | 127 | 95 |
| 3 - Springfield #2 / Springfield | 214 | 194 | 174 | 148 | 114 |
| 4 - Belleville SIU RSCH / Belleville | 258 | 229 | 208 | 174 | 138 |
| 5 - Carbondale Southern IL AP / Marion | 222 | 201 | 181 | 158 | 130 |

HSPF = Heating System Performance Factor of heat pump equipment

= Actual. If unknown, use the table C403.2.3(2) in IECC 2012 (or IECC 2015 if through new construction) to assume values based on code estimates.

Note IECC 2018 is scheduled to become effective March 1, 2019 and will become baseline for all New Construction permits from that date.

HD = heating days per year, total days in year above balance point temperature (day)

= use table below to select an appropriate value[542]:

| | HD | | | | |
|---|---|---|---|---|---|
| Climate Zone Weather Station/City | 45 °F | 50 °F | 55 °F | 60 °F | 65 °F |
| 1 -Rockford AP / Rockford | 142 | 160 | 183 | 204 | 228 |
| 2 - Chicago O'Hare AP / Chicago | 150 | 166 | 192 | 219 | 253 |
| 3 - Springfield #2 / Springfield | 125 | 142 | 167 | 194 | 230 |
| 4 - Belleville SIU RSCH / Belleville | 101 | 115 | 134 | 156 | 180 |
| 5 - Carbondale Southern IL AP / Marion | 103 | 123 | 148 | 174 | 205 |

***Heat Transfer Through Open Entryway without Air Curtain (Cooling Season)***

$Q_{tbc}$ = 4.5 * $CFM_{tot}$ *($h_{oc}$ – $h_{ic}$) / (1,000 Btu/kBtu)

Where:

[541] National Solar Radiation Data Base – 1991 – 2005 Update: Typical Meteorological Year 3, NREL.
Note that cooling days (CD) are calculated by first determining its value from the TMY3 data associated with the appropriate weather station as defined by and used elsewhere in the Illinois TRM. Using the TMY3 outdoor air dry bulb hourly data, the annual hours are totaled for every hour that the outdoor air dry bulb temperature is above a designated zero heat loss balance point temperature or base temperature for cooling. For commercial and industrial (C&I) buildings, a base temperature for heating of 55 °F is designated in the Illinois TRM, but building specific base temperatures are recommended for large C&I projects. Additionally, the TRM uses a 30-year normal data for degree-days while the CD calculation was based on TMY3 data; in order to account for this, calculations of CD were also normalized by the ratio of CDD to align the calculated values more closely with the TRM.

[542] Note that Heating Days (HD) are calculated following the same approach outlined in the Cooling Days section.

4.5 = unit conversion factor with density of air: 60 min/hr * 0.075 lbm/ft3 (lb*min/(ft*hr))

$CFM_{tot}$ = Total air flow through entryway (cfm), see calculation below

$h_{oc}$ = average enthalpy of outside air during the cooling season (Btu/lb)

= use the below table to determine the approximate outdoor air enthalpy associated with an indoor temperature setpoint and climate zone.[543]

| | $h_{oc}$ | | |
|---|---|---|---|
| Climate Zone -Weather Station/City | 67 °F | 72 °F | 77 °F |
| 1 -Rockford AP / Rockford | 31.6 | 33.0 | 35.3 |
| 2 - Chicago O'Hare AP / Chicago | 32.0 | 33.6 | 35.4 |
| 3 - Springfield #2 / Springfield | 32.9 | 34.6 | 36.6 |
| 4 - Belleville SIU RSCH / Belleville | 33.5 | 35.0 | 36.4 |
| 5 - Carbondale Southern IL AP / Marion | 34.6 | 36.2 | 37.7 |

$h_{ic}$ = average enthalpy of indoor air, cooling season (Btu/lb)

= use the below table to determine the approximate indoor air enthalpy associated with an indoor temperature setpoint in indoor relative humidity.

| | $h_{ic}$ | | |
|---|---|---|---|
| Relative Humidity (%) | 67 °F | 72 °F | 77 °F |
| 60 | 25.5 | 28.5 | 31.8 |
| 50 | 23.9 | 26.6 | 29.5 |
| 40 | 22.3 | 24.7 | 27.3 |

= an estimate 26.6 Btu/lb associated with the 72 °F and 50% indoor relative humidity case can be used as an approximation if no other data is available. For other indoor temperature setpoints and RH, enthalpies may be interpolated.

The total airflow through the entryway, $CFM_{tot}$, includes both infiltration due to wind as well as thermal forces, as follows:

$CFM_{tot}$ = sqrt[ $(CFM_w)^2$ + $(CFM_t^2)$ ]

Where:

$CFM_w$ = Infiltration due to the wind (cfm)

$CFM_t$ = Infiltration due to thermal forces (cfm)

The infiltration due to the wind is calculated as follows:

$CFM_w$ = $(v_{wc} * C_{wc}) * C_v * A_d$ * (88 fpm/mph)

Where:

$v_{wc}$ = average wind speed during the cooling season based on entryway orientation (mph)

[543] Average enthalpies were estimated following ASHRAE guidelines for perfect gas relationships for dry air associated with hourly TMY3 data. Enthalpies were then averaged for all values associated with a dry-bulb outdoor air temperature that exceeded the indoor air temperature setpoint. Other enthalpy values may be interpolated for indoor air temperature setpoints not represented in the table. Note that while outdoor air enthalpies increase with higher temperature setpoints, the change in enthalpy from indoor to outdoor will decrease.

= use the below table to for the wind speed effects based on climate zone and entryway orientation[544]:

| | Entryway Orientation | | | |
|---|---|---|---|---|
| Climate Zone -Weather Station /City | N | E | S | W |
| 1 -Rockford AP / Rockford | 4.2 | 4.1 | 4.7 | 4.8 |
| 2 - Chicago O'Hare AP / Chicago | 4.7 | 4.5 | 5.4 | 4.6 |
| 3 - Springfield #2 / Springfield | 4.1 | 3.7 | 6.0 | 5.0 |
| 4 - Belleville SIU RSCH / Belleville | 3.3 | 2.7 | 3.8 | 4.2 |
| 5 - Carbondale Southern IL AP / Marion | 3.1 | 2.9 | 4.4 | 3.8 |

$C_{wc}$ = wind speed correction factor due to wind direction in cooling season, (%)

= because wind direction is not constant, a wind speed correction factor is used to adjust for the amount of time during the cooling season prevailing winds can be expected to impact the entryway. Use the following table to determine the correct wind speed correction factor for cooling applications.

| | Entryway Orientation | | | |
|---|---|---|---|---|
| Climate Zone -Weather Station/City | N | E | S | W |
| 1 -Rockford AP / Rockford | 0.18 | 0.13 | 0.30 | 0.31 |
| 2 - Chicago O'Hare AP / Chicago | 0.18 | 0.17 | 0.36 | 0.26 |
| 3 - Springfield #2 / Springfield | 0.17 | 0.12 | 0.46 | 0.21 |
| 4 - Belleville SIU RSCH / Belleville | 0.21 | 0.15 | 0.35 | 0.16 |
| 5 - Carbondale Southern IL AP / Marion | 0.18 | 0.15 | 0.37 | 0.11 |

Note that correction factors do not add up to 1 (100%). This is attributed to periods of calm winds.

$C_v$ = effectiveness of openings,

= 0.3, assumes diagonal wind[20]

$A_d$ = area of the doorway ($ft^2$)

= user defined

The infiltration due to thermal forces is calculated as follows:

$CFM_t = A_d * C_{dc} * (60 \text{ sec/min}) * \text{sqrt}[2 * g * H/2 * (T_{oc} - T_{ic}) / (459.7 + T_{oc})]$

Where:

$C_{dc}$ = the discharge coefficient during the cooling season[545]

$= 0.4 + 0.0025 * |T_{ic} – T_{oc}|$

= 0.42, Illinois average at indoor air temp of 72°F

Note, values for $C_{dc}$ show little variation due to balance point temperature, indoor air temperature, and climate zone. As such, if estimating results, the Illinois average value may be used as a simplification.

g = acceleration due to gravity

= 32.2 ft/sec$^2$

[544] Average wind speeds are calculated based on the TMY3 wind speed data. Because this data is collected at an altitude of 33 ft, wind speed is approximated for a 5 ft level based on ASHRAE Handbook guidelines using the urban/suburban parameters for adjusting wind speed based on altitude (⍰ = 1200, ⍰ = 0.22).
ASHRAE, “Airflow Around Buildings,” in 2013 ASHRAE Handbook – Fundamentals (2013): p 24.3

[545] ASHRAE, “Ventilation and Infiltration,” in 2013 ASHRAE Handbook – Fundamentals (2013): p 16.13

H = the height of the entryway (ft)

= user input

$T_{ic}$ = Average indoor air temperature during cooling season

= User input, can assume indoor cooling temperature set-point

$T_{oc}$ = Average outdoor temp during cooling season (°F)

= the average outdoor temperature is dependent on the CD period and zone. As such, the following table may be used for average outdoor temperature during the cooling period[546]:

| | $T_{oc}$ | | | | |
|---|---|---|---|---|---|
| Climate Zone Weather Station/City | 62 °F | 67 °F | 72 °F | 77 °F | 82 °F |
| 1 -Rockford AP / Rockford | 72.9 | 76.0 | 79.2 | 82.5 | 85.5 |
| 2 - Chicago O'Hare AP / Chicago | 72.9 | 76.0 | 79.4 | 82.8 | 85.5 |
| 3 - Springfield #2 / Springfield | 73.7 | 76.7 | 79.9 | 83.4 | 86.4 |
| 4 - Belleville SIU RSCH / Belleville | 74.9 | 77.7 | 81.0 | 84.3 | 86.9 |
| 5 - Carbondale Southern IL AP / Marion | 75.1 | 77.7 | 80.9 | 84.7 | 87.4 |

459.7 = conversion factor from °F to °R

= calculation requires absolute temperature for values not calculated as a difference of temperatures.

***Heat Transfer Through Open Entryway with Air Curtain (Cooling Season)***

$Q_{tac}$ = $Q_{tbc}$ * (1 – E)

Where:

E = the effectiveness of the air curtain (%)

= 0.60[547]

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = (ΔkWh$_{cooling}$ / (CD *24)) * CF

Where:

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3%[548]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [549]

[546] Based on binned data from TMY3 & adjusted bracketed thermostat setpoint temperatures. Interpolate other values as needed.
[547] Assumed conservative estimate based on referenced study results and ASHRAE 2004 effectiveness range of 60-80% for air curtains. Jaramillo, Julian, et. Al. "Application of Air Curtains in Refrigerated Chambers," International Refrigeration and Air-Conditioning Conference, Purdue University e-Pubs (July 14-17, 2008).
ASHRAE, "Room Air Distribution Equipment," in 2004 ASHRAE Handbook – HVAC Systems and Equipment (2004): p 17.8
[548] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility's peak hour is divided by the maximum AC load during the year.
[549]Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year

## NATURAL GAS SAVINGS

Natural gas savings, ∆therms, associated with reduced infiltration through an entryway during the heating season are calculated by determining the difference between heat loss through the entryway before and after the installation of the air curtain.

$$\Delta therms = (Q_{bc} - Q_{ac}) * t_{open} * HD / \eta$$

Where:

$Q_{bc}$ = rate of sensible heat transfer through the open entryway, before air curtain (therm/hr)

$Q_{ac}$ = rate of sensible heat transfer through the open entryway, after air curtain (therm/hr)

$t_{open}$ = average hours per day the door is open (hr/day)

= Actual or estimated user input value

HD = heating days per year, total days in year above balance point temperature (day)

= use table below to select an appropriate value[550]:

| Climate Zone - Weather Station/City | HD | | | | |
|---|---|---|---|---|---|
| | 45 °F | 50 °F | 55 °F | 60 °F | 65 °F |
| 1 -Rockford AP / Rockford | 142 | 160 | 183 | 204 | 228 |
| 2 - Chicago O'Hare AP / Chicago | 150 | 166 | 192 | 219 | 253 |
| 3 - Springfield #2 / Springfield | 125 | 142 | 167 | 194 | 230 |
| 4 - Belleville SIU RSCH / Belleville | 101 | 115 | 134 | 156 | 180 |
| 5 - Carbondale Southern IL AP / Marion | 103 | 123 | 148 | 174 | 205 |

η = efficiency of heating equipment

= Actual. If unknown, assume 0.8

***Heat Transfer Through Open Entryway without Air Curtain (Heating Season)***

$$Q_{bc} = (1.08\ Btu/(hr*°F*cfm)) * CFM_{tot} * (T_{ih} – T_{oh}) / (100,000\ Btu/therm)$$

Where:

1.08 = sensible heat transfer coefficient (specific heat of air and unit conversions)

$CFM_{tot}$ = Total air flow through entryway (cfm)

$T_{ih}$ = Average indoor air temperature during heating season

= User input, can assume indoor heating temperature set-point

$T_{oh}$ = Average outdoor temp during heating season (°F)

= use table below, based on binned data from TMY3 & balance point temperature

| Climate Zone -Weather Station/City | Avg Outdoor Air Temp - Heating Season | | | | |
|---|---|---|---|---|---|
| | 45 °F | 50 °F | 55 °F | 60 °F | 65 °F |
| 1 -Rockford AP / Rockford | 26.3 | 28.8 | 31.6 | 34.2 | 37.3 |
| 2 - Chicago O'Hare AP / Chicago | 29.4 | 31.2 | 34.0 | 36.8 | 40.3 |
| 3 - Springfield #2 / Springfield | 29.4 | 31.5 | 34.6 | 37.7 | 41.6 |
| 4 - Belleville SIU RSCH / Belleville | 31.7 | 33.6 | 36.2 | 39.2 | 42.3 |

[550] Note that Heating Days (HD) are calculated following the same approach outlined in the Cooling Days section.

| | Avg Outdoor Air Temp - Heating Season | | | | |
|---|---|---|---|---|---|
| Climate Zone -Weather Station/City | 45 °F | 50 °F | 55 °F | 60 °F | 65 °F |
| 5 - Carbondale Southern IL AP / Marion | 32.5 | 34.9 | 37.8 | 40.7 | 44.0 |

The total airflow through the entryway, $CFM_{tot}$, includes both infiltration due to wind as well as thermal forces, as follows:

$CFM_{tot}$ = sqrt[ $(CFM_w)^2 + (CFM_t^2)$ ]

Where:

$CFM_w$ = Infiltration due to the wind (cfm)

$CFM_t$ = Infiltration due to thermal forces (cfm)

The infiltration due to the wind is calculated as follows:

$CFM_w = (v_{wh} * C_{wh}) * C_v * A_d$ * (88 fpm/mph)

Where:

$v_{wh}$ = average wind speed during the heating season (mph)

= similar to cooling season wind speed assumptions, use the following table to determined average wind speed based on entryway orientation:

| | Entryway Orientation | | | |
|---|---|---|---|---|
| Climate Zone -Weather Station/ City | N | E | S | W |
| 1 -Rockford AP / Rockford | 5.0 | 4.6 | 4.9 | 5.6 |
| 2 - Chicago O'Hare AP / Chicago | 5.5 | 5.2 | 4.9 | 5.1 |
| 3 - Springfield #2 / Springfield | 5.0 | 4.9 | 5.3 | 5.1 |
| 4 - Belleville SIU RSCH / Belleville | 4.3 | 3.4 | 3.5 | 5.3 |
| 5 - Carbondale Southern IL AP / Marion | 4.6 | 3.2 | 4.2 | 4.4 |

$C_{wh}$ = wind speed correction factor due to wind direction in heating season, (%)

= because wind direction is not constant, a wind speed correction factor is used to adjust for the amount of time during the heating season prevailing winds can be expected to impact the entryway. Use the following table to determine the correct wind speed correction factor for the heating applications.

| | Entryway Orientation | | | |
|---|---|---|---|---|
| Climate Zone -Weather Station/ City | N | E | S | W |
| 1 -Rockford AP / Rockford | 0.18 | 0.13 | 0.30 | 0.31 |
| 2 - Chicago O'Hare AP / Chicago | 0.21 | 0.10 | 0.26 | 0.39 |
| 3 - Springfield #2 / Springfield | 0.21 | 0.14 | 0.27 | 0.34 |
| 4 - Belleville SIU RSCH / Belleville | 0.31 | 0.15 | 0.22 | 0.29 |
| 5 - Carbondale Southern IL AP / Marion | 0.31 | 0.11 | 0.27 | 0.18 |

Note that correction factors do not add up to 1 (100%). This is attributed to periods of calm winds.

$C_v$ = effectiveness of openings,

= 0.3, assumes diagonal wind[24]

$A_d$ = area of the doorway ($ft^2$)

= user input

The infiltration due to thermal forces is calculated as follows:

$CFM_t$ = $A_d$ * $C_{dh}$ * (60 sec/min) * sqrt[2 * g * H/2 * ($T_{ih}$ – $T_{oh}$) / (459.7 + $T_{ih}$)]

Where:

$C_{dh}$ = the discharge coefficient during the heating season

= 0.4 + 0.0025 * $|T_{ih} – T_{oh}|$

= 0.49, Illinois average at indoor air temp of 72°F

Note, values for $C_{dh}$ show little variation due to balance point temperature, indoor air temperature, and climate zone. As such, if estimating results, the Illinois average value may be used as a simplification.

g = acceleration due to gravity

= 32.2 ft/sec$^2$

H = the height of the entryway (ft)

= user defined

***Heat Transfer Through Open Entryway without Air Curtain (Heating Season)***

$Q_{ac}$ = $Q_{bc}$ * (1 – E)

Where:

E = the effectiveness of the air curtain (%)

= 0.60[551]

### WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION

N/A

### DEEMED O&M COST ADJUSTMENT CALCULATION

The air curtain would need to be regularly serviced and commissioned to ensure that it is appropriately operating. This is estimated at a cost of $150[552].

### MEASURE CODE: CI-HVC-AIRC-V02-190101

### REVIEW DEADLINE: 1/1/2022

[551] Assumed conservative estimate based on referenced study results and ASHRAE 2004 effectiveness range of 60-80% for air curtains. Jaramillo, Julian, et. Al. "Application of Air Curtains in Refrigerated Chambers," International Refrigeration and Air-Conditioning Conference, Purdue University e-Pubs (July 14-17, 2008).
ASHRAE, "Room Air Distribution Equipment," in 2004 ASHRAE Handbook – HVAC Systems and Equipment (2004): p 17.8

[552] Assumes approximately 1 hour of maintenance (include cleaning out filters, greasing, and checking that the designed angle of attack on the blower nozzle is at the designed position) based on manufacturer inpur and product spec sheets.

## 4.4.34 Destratification Fan

### DESCRIPTION

This measure applies to buildings with high bay ceiling construction without fans currently installed for the purpose of destratifying air. There is also a separate measure for destratification fans as applied to agricultural settings ("High Volume Low Speed Fans"). All other destratification fan applications require custom analysis.

Air stratification leads to higher temperatures at the ceiling and lower temperatures at the ground. During the heating season, destratification fans improve air temperature distribution in a space by circulating warmer air from the ceiling back down to the floor level, thereby enhancing comfort and saving energy. Energy savings are realized by a reduction of heat loss through the roof-deck and walls as a result of a smaller temperature differential between indoor temperature and outdoor air.

Note that further, but limited, empirical evidence suggests that improved air mixing due to destratification would also result in shorter heating system runtimes due to warmer air reaching the thermostat level sooner, and possibly even allow a facility to lower the thermostat set point while maintaining a similar level of occupant comfort. This is supported by measured data in which an increase in temperatures was observed at the thermostat (5 foot level) level when air is destratified, resulting in an approximate temperature increase at the 5 foot level in the range of 1 - 3°F[553]. This measure does not currently attempt to quantify the potential impacts of air mixing from destratification; however, it should be noted that additional therms savings may be possible.

This measure was developed to be applicable to the following program types: NC, RF. If applied to other program types, the measure savings should be verified.

*Limitations*

- For use in conditioned, high bay structures. Recommended minimum ceiling height of 20 ft.
- This measure should only be applied to spaces in which the ceiling is subject to heat loss to outdoor air (i.e., single story or top floor spaces) and where there is sufficient space to allow for appropriate spacing of the fans. Other applications require custom analysis.
- Installation must follow manufacturer recommendations sufficient to effectively destratify the entire space. Please see calculation of effective area, $A_{eff}$, in the therms savings algorithm as a check if this criteria is met. Otherwise, custom calculation is necessary.
- Measure does not currently support facilities with night setbacks on heating equipment. Custom analysis is needed in this case.
- Certain heating systems may not be a good fit for destratification fans, such as locations with: high velocity vertical throw unit heaters, radiant heaters, and centralized forced air systems. In these cases, measured evidence of stratification should be confirmed and custom analysis may be necessary.

### DEFINITION OF EFFICIENT EQUIPMENT

High Volume, Low Speed (HVLS) fans with a minimum diameter of 14 ft with Variable Speed Drive (VSD) installed[554].

Note that bell-shaped fans are currently excluded from this measure due to limited validation of the technology available. Further verification of effectiveness compared to HVLS is needed. A manufacturer of bell shaped fans indicates that four bell-shaped fans provide an equivalent effective area as a typical HVLS fan. However, there is a need for further review of bell shaped fan field test data supporting manufacturer claims regarding comparable effectiveness to HVLS technologies.

[553] Kosar, Doug, "1026: Destratification Fans – Public Project Report," Nicor Gas, Emerging Technology Program (Oct 2014): 16
[554] Ibid.

### DEFINITION OF BASELINE EQUIPMENT

No destratification fans or other means to effectively mix indoor air.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 10 years[555]

### DEEMED MEASURE COST

Measure cost = [incremental cost of HVLS fans] + [installation costs (including materials and labor)]

The incremental capital cost for HVLS fans are as follows[556]:

| Fan Diameter (ft) | Incremental Cost |
|---|---|
| 14 | $6,600 |
| 16 | $6,650 |
| 18 | $6,700 |
| 20 | $6,750 |
| 22 | $6,800 |
| 24 | $6,850 |

Since installation cost is depended on a variety of factors, this is a custom entry. Actual costs should be used.

### LOADSHAPE

Loadshape C04: Commercial Electric Heating.

### COINCIDENCE FACTOR

N/A due to no savings attributable to cooling during the summer peak period.

## Algorithm

### CALCULATION OF SAVINGS

The following formulas provide a methodology for estimating heating load savings associated with destratification fan use. This algorithm is based on the assumption that savings are directly related to the difference in heat loss through the envelope before and after destratification.

### ELECTRIC ENERGY SAVINGS

The algorithm for this measure was developed for natural gas heating applications, however, for electric heating applications, the same methodology presented in the Natural Gas Savings Section may be used with the standard conversion factor from therms to kWh of 29.31 kWh/therm and an equipment efficiency as follows:

| System Type | Age of Equipment | HSPF Estimate | η (Effective COP Estimate) (HSPF/3.413) |
|---|---|---|---|
| Heat Pump | Before 2006 | 6.8 | 2.0 |
| | 2006 - 2014 | 7.7 | 2.3 |
| | 2015 on | 8.2 | 2.40 |

555 Consistent with both 2008 Database for Energy-Efficient Resources, EUL/RUL (Effective/Remaining Useful Life) Values, October 10, 2008 and GDS Associates, Inc, "Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures," New England Stat Program Working Group (June 2007), p30.

556 Costs were obtained from manufacturer interviews and are based off of average or typical prices for base model HVLS fans. Costs include materials and labor to install the fans and tie fans into an existing electrical supply located near the fan.

| System Type | Age of Equipment | HSPF Estimate | η (Effective COP Estimate) (HSPF/3.413) |
|---|---|---|---|
| Resistance | N/A | N/A | 1 |

Regardless of how the building is heated, the energy consumption of the fans must be accounted for. If the building is electrically heated, fan energy shall be subtracted from the savings as calculated above. If the building is heated with natural gas, this shall represent an electric penalty, i.e., an increase in consumption. This is calculated as follows:

ΔkWh = - ($W_{fan}$ * $N_{fan}$) * $t_{eff}$

$W_{fan}$ = fan input power (kW)

$N_{fan}$ = number of fans

$t_{eff}$ = effective annual operation time, based on balance point temperature (hr)

= see table below in Natural Gas Savings section for further detail

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

N/A

**NATURAL GAS ENERGY SAVINGS**

ΔTherms = [(Δ$Q_r$ + Δ$Q_w$) * $t_{eff}$] / (100,000 * η)

Where:

Δ$Q_r$ = the heat loss reduction through the roof due to the destratification fan (Btu/hr)

= See calculation section below

Δ$Q_w$ = the heat loss reduction through the exterior walls due to destratification fan (Btu/hr)

= See calculation section below

$t_{eff}$ = effective annual operation time, based on balance point temperature (hr)

= use table below to select an appropriate value[557]:

| Climate Zone -Weather Station/City | $t_{eff}$ | | | | |
|---|---|---|---|---|---|
| | 45 °F | 50 °F | 55 °F | 60 °F | 65 °F |
| 1 -Rockford AP / Rockford | 3810 | 4226 | 4880 | 5571 | 6436 |
| 2 - Chicago O'Hare AP / Chicago | 3593 | 3986 | 4603 | 5254 | 6070 |
| 3 - Springfield #2 / Springfield | 3038 | 3370 | 3891 | 4442 | 5131 |
| 4 - Belleville SIU RSCH / Belleville | 2243 | 2488 | 2873 | 3280 | 3789 |
| 5 - Carbondale Southern IL AP / Marion | 2271 | 2519 | 2909 | 3320 | 3836 |

100,000 = conversion factor (1 therm = 100,000 Btu)

η = thermal efficiency of heating equipment

[557] These were calculated at various base temperatures using TMY3 data and adjusted to make consistent with the 30 year normal data used elsewhere. For more information see 'Destratification Fan Workpaper'; Robert Irmiger, Gas Technology Institute, 9/6/2015.

= Actual. If unknown assume 0.8.

EXAMPLE:

For a warehouse facility located in Rockford, IL, installing destratification fans could reduce heat loss through the roof of 95,000 Btu/hr and a reduced heat loss through the wall of 51,228 Btu/hr. Assuming a balance point of 55°F the therms savings for the facility would be estimated as:

$\Delta Therms = [(\Delta Q_r + \Delta Q_w) * t_{eff}] / (100{,}000 * \eta)$

$= [(95{,}000\ Btu/hr + 51{,}282\ Btu/hr) * 4880\ hr] / [(100{,}000\ Btu/therm) * 0.8)]$

$= 8{,}923$ therms

***Heat loss reduction through the roof***

$\Delta Q_r = Q_{r,s} - Q_{r,d}$

$= (1/R_r) * A_r * [(T_{r,s} - T_{oa}) - (T_{r,d} - T_{oa})]$

$= (1/R_r) * A_r * (T_{r,s} - T_{r,d})$

Where:

$Q_{r,s}$ = roof heat loss for stratified space

$Q_{r,d}$ = roof heat loss for destratified space

$R_r$ = overall thermal resistance through the roof (hr * ft$^2$ * °F / Btu)

= Actual or estimated based on construction type. If unknown, assume the following:

| Thermal Resistance Factor (R-Factor) for Roof | Retrofit[558] | New Construction[559] |
|---|---|---|
| $R_r$ | 15.0 (hr * ft$^2$ * °F / Btu) | 30.0 (hr * ft$^2$ * °F / Btu) |

$A_r$ = roof area (ft$^2$)

= user input

= can be approximated with floor area

$T_{oa}$ = outside air temperature, note: therm savings calculations are actually independent of outside air because this term drops out of the heat loss reduction equation

$T_{r,s}$ = indoor temperature at roof deck, stratified case (°F)

= Actual. If unknown, use the following equation

$= m_s * h_r + T_{f,s}$

$h_r$ = ceiling height/roof deck (ft)

$m_s$ = estimated heat gain per foot elevation, stratified case (°F/ft)

= 0.8 °F/ft

[558] Professional judgement was used to address older vintage structures and an estimate of 50% of current code standard was used.

[559] ANSI/ASHRAE/IESNA Standard 90.1-2016, "Energy Standard for Buildings Except Low-Rise Residential Buildings," ASHRAE Standard (20016): Table 5.5-4 and Table 5.5-5

= Professional judgement used to define value based on result from a Nicor Gas ETP Pilot field testing results and the Ansley article[560,561]. Estimates from these sources fall on the conservative side of the industry rule of thumb range of 1-2 °F/ft heat gain.

$T_{f,s}$ = estimated floor temperature, stratified case (°F)

= $T_{tstat} - m_s * h_{tstat}$

= $T_{tstat}$ – 4 °F

$T_{tstat}$ = temperature set point at the thermostat

$h_{tstat}$ = vertical distance between the floor and the thermostat, assumed 5ft

$T_{r,d}$ = indoor temp at roof, destratified case

= actual value, or may be estimated using the following:[562,563]

= $T_{tstat}$ + 1 °F

EXAMPLE:

For a 50,000 ft² warehouse built in 1997 with 30 ft ceilings and a thermostat set point of 65 °F. No further measured values available.

$$\Delta Q_r = (1/R_r) * A_r * (T_{r,s} - T_{r,d}) = (1/R_r) * A_r * [(m_s * h_r + T_{tstat} - 4\ °F) - (T_{tstat} + 1\ °F)]$$

$$= (1/R_r) * A_r * [(0.8°F/ft * h_r) - 5\ °F]$$

$$= 1/(10\ hr * ft^2 * °F / Btu) * (50{,}000\ ft^2) * [(0.8°F/ft * 30\ ft) - 5\ °F]$$

$$= 95{,}000\ Btu/hr$$

***Heat loss reduction through exterior walls***

Note: a conservative estimate for therms savings would neglect the impact of heat loss through the walls. However, Ansley suggests that estimates based on the roof deck losses alone underestimate actual savings by up to 46%.[564]

$$\Delta Q\_w = Q_{w,s} - Q_{w,d}$$

$$= (1/R_w) * A_w * (T_{w,s} - T_{w,d})$$

Where:

$R_w$ = overall thermal resistance through the exterior walls (hr * ft²* °F / Btu)

= Actual or estimated based on construction type[565]. If unknown, assume the following

[560] Kosar, Doug, "1026: Destratification Fans – Public Project Report," Nicor Gas, Emerging Technology Program (Oct 2014): 10-11. Field testing results indicated approximately 0.6 oF/ft for a garden center.

[561] Aynsley, Richard, "Saving Heating Costs in Warehouses," ASHRAE Journal (Dec 2005): 48. Identifies a 0.8 oF/ft gain.

[562] 12. Kosar, Doug, "1026: Destratification Fans – Public Project Report," Nicor Gas, Emerging Technology Program (Oct 2014): 10-11. Field testing results indicated approximately 0.6 oF/ft for a garden center.

[563] 13. Aynsley, Richard, "Saving Heating Costs in Warehouses," ASHRAE Journal (Dec 2005): 48.

[564] Aynsley, Richard, "Saving Heating Costs in Warehouses," ASHRAE Journal (Dec 2005): 51

[565] Because heat loss through the walls is estimated using the average space temperature pre- and post- destratification. There are a number of factors that can impact the average space temperature causing deviations from estimates of many degrees in some cases. As such, it is recommended that a conservative value for the thermal resistance through the walls, $R_w$, be used. A recommended method for determining $R_w$ would be to use the highest R-value for the wall space, neglecting lower R-values associated with windows, thermal bridges, etc.

| Thermal Resistance Factor (R-Factor) for Wall | Retrofit[566] | New Construction[567] (2010 or newer) |
|---|---|---|
| $R_w$ | 6.5 (hr * ft$^2$ * $^oF$ / Btu) | 13.0 (hr * ft$^2$ * $^oF$ / Btu) |

$A_w$ = area of exterior walls (ft$^2$)

= user input

$T_{w,s}$ = average indoor air temperature for wall heat loss, stratified case

= If actual $T_{r,s}$ measurement is available[568]

$= [(T_{r,s} * h_a) + (T_{tstat} * h_b)] / h_r$

$h_a$ = vertical distance between the heat source and the ceiling

$h_b$ = vertical distance between the floor and the heat source

= Otherwise, use the linear stratification equation at average space height, see definition above.

$= m_s * (h_r / 2) + T_{f,s}$

$= m_s * (h_r / 2) + (T_{tstat} – 4)$

$T_{w,d}$ = average indoor air temperature for wall heat loss, destratified case

$= T_{tstat} + 0.5$

= conservative estimate using engineering judgment based on the same assumption used for $T_{r,f}$ estimate.

**EXAMPLE:**

For a 50,000 ft$^2$ warehouse built in 1997 with 1200 ft length of perimeter wall and 30 ft ceilings and a thermostat set point of 65 $^oF$ and a measured temperature at the ceiling of 85 $^oF$ and unit heaters located 10 feet from the roof:

$\Delta Q_w = (1/R_w) * A_w * (T_{w,s} – T_{w,d})$

$= (1/R_w) * A_w * [(([(T_{r,s} * h_a) + (T_{tstat} * h_b)] / h_r) – (T_{tstat} + 0.5\ ^oF)]$

$= 1/(6.5\ hr*ft^2*^oF/Btu) * (1200 * 30) * [(([(85^oF * 10ft) + (65\ ^oF * 20ft)] / 30ft) – (65 + 0.5\ ^oF)]$

$= 1/(6.5\ hr*ft^2*^oF/Btu) * (36{,}000ft^2) * (71.7\ ^oF – 65.5\ ^oF)$

= 34,338 Btu/hr

***Measure eligibility check***

Use the following algorithm to verify a fan system is sufficiently sized to destratify air across the entire area.

Effective area, $A_{eff}$, is the area over which a fan or a group of fans can be expected to effectively destratify a space. If $A_{eff}$ is less than the roof area, $A_r$, a custom analysis approach should be followed to account for the change in the effectiveness of the system. In lieu of more detailed studies, effective area is defined

[566] ANSI/ASHRAE/IESNA 100-1995, “Energy Conservation in Existing Buildings,” ASHRAE Standard (1995). Additionally, professional judgement was used to address older vintage structure prior to adoption of the 1995 standard and an estimate of 50% of current code standard was used.
[567] ANSI/ASHRAE/IESNA Standard 90.1-2007, “Energy Standard for Buildings Except Low-Rise Residential Buildings,” ASHRAE Standard (2007): Table 5.5-4 and Table 5.5-5
[568] Aynsley, Richard, “Saving Heating Costs in Warehouses,” ASHRAE Journal (Dec 2005): 48

based on the measured results from an Enbridge Gas field study in which the area a fan was expected to effectively destratify was equal to 5 times the fan diameter[569]. Effective area, is calculated as follows:

$A_{eff} = [\pi * (5*D_{fan})^2) / 4] * N_{fan}$

$= 6.25 * \pi * D_{fan}^2 * N_{fan}$

Where:

$A_{eff}$ = the effective area fan area on the floor ($ft^2$)

$D_{fan}$ = fan diameter

$N_{fan}$ = the number of fans

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-HVC-DSFN-V03-190101**

**REVIEW DEADLINE: 1/1/2021**

[569] Enbridge Gas Distribution, Inc., "Big Fans Deliver Big Bonus," (Aug 2007). Additionally, multiple utilities have adopted this definition in their programs in including Enbridge Gas and Consumers Energy.

## 4.4.35 Economizer Repair and Optimization

### DESCRIPTION

Economizers are designed to use unconditioned outside air (OSA) instead of mechanical cooling to provide cooling when exterior conditions permit. When the OSA temperature is less than the changeover temperature (determined by a static setpoint or a reference return air sensor) up to 100% OSA is supplied to help meet the facility's cooling needs, thus reducing mechanical cooling energy and saving energy. An economizer that is not working or is not properly adjusted can waste energy and cause comfort issues. This HVAC Economizer Optimization measure involves the repair and optimization of common economizer problems such as adjusting changeover setpoint, repairing damper motors & linkages and replacing non-working sensors and/or controllers. These repairs and adjustments result in proper operation which maximizes both occupant comfort and energy savings.

This measure is only appropriate for single zone packaged rooftop units. Custom calculations are required for savings for multi-zone systems.

In general the HVAC Economizer Optimization measure may involve both repair and/or optimization;

**Economizer Repair** – The Economizer repair work is preformed to ensure that the existing economizer is working properly. This allows the system to take advantage of free cooling and ensure that the system is not supplying an excess amount of outside air (OSA) during non-economizing periods.

- **Replace Damper Motor** – If the existing damper motor is not operational, the unit will be replaced with a functioning motor to allow proper damper modulation.
- **Repair Damper linkage** – If the existing linkage is broken or not adjusted properly, the unit will be replaced or adjusted to allow proper damper modulation.
- **Repair Economizer Wiring** – If the existing economizer is not operational due to a wiring issue, the issue will be repaired to allow proper economizer operation.
- **Reduce Over Ventilation** – If the unit is supplying excess OSA, the OSA damper position will be adjusted to meet minimum ventilation requirements.
- **Economizer Sensor Replacement** – If the unit is equipped with a nonadjustable dry bulb (i.e. snapdisk) or malfunctioning analog sensor, the sensor is replaced with a new selectable sensor.
- **Economizer Control Replacement** – If the existing economizer controller is not operational, the unit will be replaced or upgraded to allow for proper economizer operation.

**Economizer Optimization**- The economizer optimization work is preformed to ensure that the existing economizer system is set up properly to maximize use of free cooling for units located in a particular climate zone.

- **Economizer Changeover Setpoint Adjustment** – If the unit is equipped with a fully operational economizer, the controller is adjusted to the appropriate changeover setpoint based on ASHRAE 90.1 (Figure 1 - *Table 6.5.1.1.3 High-Limit Shutoff Control Settings for Air Economizers)* for the corresponding climate zone.
- **Enable Integrated Operation** – If the unit is equipped with a fully operational economizer and is not set up to allow a minimum of two stages of cooling (1st stage – Economizer Only & 2nd Stage – Economizer & Mechanical cooling), the unit will be wired to allow two stage cooling

This measure was developed to be applicable to the following program types: RF, DI.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

The efficient equipment condition is defined by fully functional economizer that is programmed to meet ASHRAE 90.1 economizer changeover setpoint requirements for the facility's climate zone and changeover control type (Figure 1 - Table 6.5.1.1.3 High-Limit Shutoff Control Settings for Air Economizers)[570].

[570] ASHRAE, Standard 90.1-2013

**Figure 1 – Baseline ASHRAE High-Limit Shutoff Control Settings**

**TABLE 6.5.1.1.3 High-Limit Shutoff Control Settings for Air Economizers[b]**

| Control Type | Allowed Only in Climate Zone at Listed Setpoint | Required High-Limit Setpoints (Economizer Off When): Equation | Description |
|---|---|---|---|
| Fixed dry-bulb temperature | 1b, 2b, 3b, 3c, 4b, 4c, 5b, 5c, 6b, 7, 8 | $T_{OA} > 75°F$ | Outdoor air temperature exceeds 75°F |
| | 5a, 6a | $T_{OA} > 70°F$ | Outdoor air temperature exceeds 70°F |
| | 1a, 2a, 3a, 4a, | $T_{OA} > 65°F$ | Outdoor air temperature exceeds 65°F |
| Differential dry-bulb temperature | 1b, 2b, 3b, 3c, 4b, 4c, 5a, 5b, 5c, 6a, 6b, 7, 8 | $T_{OA} > T_{RA}$ | Outdoor air temperature exceeds return air temperature |
| Fixed enthalpy with fixed dry-bulb temperature | All | $h_{OA} > 28$ Btu/lb[a] or $T_{OA} > 75°F$ | Outdoor air enthalpy exceeds 28 Btu/lb[a] of dry air[a] or outdoor air temperature exceeds 75°F |
| Differential enthalpy with fixed dry-bulb temperature | All | $h_{OA} > h_{RA}$ or $T_{OA} > 75°F$ | Outdoor air enthalpy exceeds return air enthalpy or outdoor air temperature exceeds 75°F |

a. At altitudes substantially different than sea level, the fixed enthalpy limit shall be set to the enthalpy value at 75°F and 50% RH. As an example, at approximately 6000 ft elevation, the fixed enthalpy limit is approximately 30.7 Btu/lb.

b. Devices with selectable rather than adjustable setpoints shall be capable of being set to within 2°F and 2 Btu/lb of the setpoint listed.

**Figure 2 – ASHRAE Climate Zone Map**

NORMATIVE APPENDIX B
CLIMATE ZONES FOR U.S. STATES AND COUNTIES

This normative appendix provides the climate zones for U.S. states and counties. Figure B-1 contains the county-level climate zone map for the United States. Table B-1 lists each state and major counties within the state and shows the climate number and letter for each county listed.

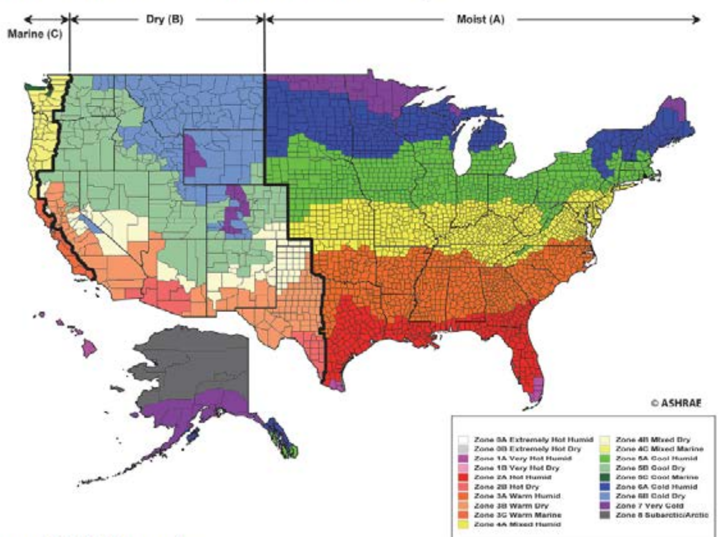



FIGURE B-1 Climate zones for United States counties.

### Definition of Baseline Equipment

The baseline for this measure is an existing economizer installed on a packaged single zone rooftop HVAC unit. The existing economizer system is currently not operating as designed due to mechanical and/or control problems, and/or is not optimally adjusted.

### Deemed Lifetime of Efficient Equipment

The measure life is assumed to be 5 years[571].

571 DEER 2014 (DEER2014 EUT Table D08 v2.05)

### DEEMED MEASURE COST

The cost for this measure can vary considerably depending upon the existing condition of the economizer and the work required to achieve the required efficiency levels. Measure cost should be determined on a site-specific basis.

### LOADSHAPE

Loadshape C03 - Commercial Cooling

### COINCIDENCE FACTOR

N/A

## Algorithm

### CALCULATION OF ENERGY SAVINGS

The savings calculation methodology uses a regression equation to calculate the energy savings for a variety of common situations[572]. The equation variables are limited to the ranges listed; if the actual conditions fall outside of these ranges custom calculations are required.

### ELECTRIC ENERGY SAVINGS

ΔkWh = [Baseline Energy Use (kWh/Ton) – Proposed Energy Use (kWh/Ton)] * Cooling Capacity (Tons)

The following equations are used to calculate baseline and proposed electric energy use[573].

**Electric Energy Use Equations (kWh / ton)**

| Building Type | Changeover Type | Equation |
|---|---|---|
| Assembly | Fixed Dry-Bulb (DB) | cz+CSP*-2.021+EL*-16.362+OAn*1.665+OAx*-3.13 |
| | Dual Temperature Dry-Bulb (DTDB) | cz+EL*-11.5+OAn*1.635+OAx*-2.817 |
| | Dual Temperature Enthalpy (DTEnth) | cz+EL*-17.772+OAn*1.853+OAx*-3.044 |
| | Fixed Enthalpy (Enth) | cz+CSP*-5.228+EL*-17.475+OAn*1.765+OAx*-3.003 |
| | Analog ABCD Economizers (ABCD) | cz+CSP*-2.234+EL*-16.394+OAn*1.744+OAx*-3.01 |
| Convenience Store | DB | cz+CSP*-3.982+EL*-27.508+OAn*2.486+OAx*-4.684 |
| | DTDB | cz+EL*-20.798+OAn*2.365+OAx*-3.773 |
| | DTEnth | cz+EL*-30.655+OAn*2.938+OAx*-4.461 |
| | Enth | cz+CSP*-8.648+EL*-25.678+OAn*2.092+OAx*-3.754 |
| | ABCD | cz+CSP*-3.64+EL*-24.927+OAn*2.09+OAx*-3.788 |
| Office - Low Rise | DB | cz+CSP*-0.967+EL*-6.327+OAn*2.87+OAx*-1.047 |
| | DTDB | cz+OAn*2.968+OAx*-0.943 |
| | DTEnth | cz+EL*-9.799+OAn*3.106+OAx*-1.085 |
| | Enth | cz+CSP*-2.773+EL*-7.392+OAn*2.941+OAx*-0.974 |
| | ABCD | cz+CSP*-1.234+EL*-7.229+OAn*2.936+OAx*-0.995 |
| | DB | cz+CSP*-1.131+OAn*3.542+OAx*-1.01 |

[572] For more information on methodology, please refer to workpaper submitted by CLEAResult titled "CLEAResult_Economizer Repair_151020_Finalv2.doc". Note that the original ComEd eQuest models were used in the analysis, rather than the VEIC developed models used elsewhere. VEIC do not consider this a significant issue as adjustments from the ComEd models were focused on calibrating EFLH values, not to overall energy use metrics. We also believe using the ComEd models is likely more conservative. It may be appropriate to update the analysis with the updated models at a later time.

[573] This approach allows the savings estimate to account for the operational attributes of the baseline as well as the proposed case, yielding a better estimate than an approach that assumes a particular baseline or proposed energy use to determine savings.

| Building Type | Changeover Type | Equation |
|---|---|---|
| Religious Facility | DTDB | cz+EL*-10.198+OAn*4.056+OAx*-1.279 |
| | DTEnth | cz+OAn*3.775+OAx*-1.031 |
| | Enth | cz+CSP*-2.13+OAn*3.317+OAx*-0.629 |
| | ABCD | cz+CSP*-0.95+OAn*3.313+OAx*-0.647 |
| Restaurant | DB | cz+CSP*-2.243+EL*-21.523+OAx*-1.909 |
| | DTDB | cz+EL*-14.427+OAn*0.295+OAx*-1.451 |
| | DTEnth | cz+EL*-25.99+OAn*0.852+OAx*-1.951 |
| | Enth | cz+CSP*-4.962+EL*-16.868+OAn*-0.12+OAx*-1.418 |
| | ABCD | cz+CSP*-2.115+EL*-16.15+OAn*-0.125+OAx*-1.432 |
| Retail - Department Store | DB | cz+CSP*-1.003+OAn*3.765+OAx*-0.938 |
| | DTDB | cz+OAn*3.688+OAx*-0.676 |
| | DTEnth | cz+OAn*4.081+OAx*-1.072 |
| | Enth | cz+CSP*-2.545+OAn*3.725+OAx*-0.788 |
| | ABCD | cz+CSP*-1.175+OAn*3.708+OAx*-0.809 |
| Retail - Strip Mall | DB | cz+CSP*-1.192+EL*-5.62+OAn*3.353+OAx*-1.142 |
| | DTDB | cz+OAn*3.355+OAx*-0.915 |
| | DTEnth | cz+EL*-9.202+OAn*3.642+OAx*-1.215 |
| | Enth | cz+CSP*-2.997+EL*-5.938+OAn*3.312+OAx*-0.964 |
| | ABCD | cz+CSP*-1.36+EL*-5.884+OAn*3.3+OAx*-0.987 |

Where:

CZ = Climate Zone Coefficient

= Depends on Building Type and Changover Type (see table below)

| | | Electric Climate Zone Coefficients | | | | |
|---|---|---|---|---|---|---|
| Building Type | Changeover Type | CZ1 (Rockford) | CZ2 (Chicago) | CZ3 (Springfield) | CZ4 (Belleville) | CZ5 (Marion) |
| Assembly | DB | 874.07 | 886.73 | 1043.38 | 1071.48 | 1072.20 |
| | DTDB | 698.45 | 711.89 | 870.13 | 899.51 | 903.10 |
| | DTEnth | 702.06 | 715.42 | 873.43 | 902.76 | 906.50 |
| | Enth | 851.95 | 865.43 | 1020.65 | 1047.10 | 1053.32 |
| | ABCD | 884.19 | 897.63 | 1053.12 | 1080.58 | 1086.35 |
| Convenience Store | DB | 1739.12 | 1787.09 | 2128.78 | 2206.65 | 2245.93 |
| | DTDB | 1389.28 | 1436.30 | 1780.99 | 1863.45 | 1904.89 |
| | DTEnth | 1398.42 | 1446.82 | 1789.71 | 1869.89 | 1912.59 |
| | Enth | 1643.51 | 1691.34 | 2032.83 | 2112.21 | 2157.63 |
| | ABCD | 1692.80 | 1740.62 | 2082.35 | 2162.73 | 2207.68 |
| Office - Low Rise | DB | 674.06 | 687.17 | 899.17 | 993.84 | 989.16 |
| | DTDB | 583.62 | 597.02 | 811.39 | 907.61 | 903.58 |
| | DTEnth | 588.94 | 602.11 | 816.02 | 912.49 | 908.26 |
| | Enth | 668.83 | 682.23 | 893.61 | 987.52 | 986.59 |
| | ABCD | 690.27 | 703.52 | 915.27 | 1009.94 | 1008.59 |
| Religious Facility | DB | 613.26 | 630.50 | 853.53 | 923.99 | 931.74 |
| | DTDB | 518.40 | 535.45 | 760.76 | 832.57 | 840.72 |
| | DTEnth | 513.59 | 531.20 | 756.26 | 829.13 | 837.26 |
| | Enth | 576.94 | 594.17 | 817.64 | 888.37 | 897.18 |

| Building Type | Changeover Type | Electric Climate Zone Coefficients CZ1 (Rockford) | CZ2 (Chicago) | CZ3 (Springfield) | CZ4 (Belleville) | CZ5 (Marion) |
|---|---|---|---|---|---|---|
| | ABCD | 593.78 | 611.04 | 834.69 | 905.83 | 914.27 |
| Restaurant | DB | 1397.27 | 1430.45 | 1763.21 | 1837.63 | 1872.18 |
| | DTDB | 1191.82 | 1225.12 | 1558.32 | 1633.95 | 1669.13 |
| | DTEnth | 1192.84 | 1226.77 | 1559.41 | 1635.13 | 1671.11 |
| | Enth | 1343.56 | 1377.52 | 1710.11 | 1783.66 | 1821.67 |
| | ABCD | 1373.72 | 1407.70 | 1740.43 | 1814.74 | 1852.55 |
| Retail - Department Store | DB | 717.89 | 730.07 | 968.85 | 1034.78 | 1035.06 |
| | DTDB | 628.83 | 641.70 | 883.37 | 951.09 | 951.33 |
| | DTEnth | 629.35 | 641.90 | 882.84 | 951.33 | 951.44 |
| | Enth | 705.06 | 717.99 | 956.42 | 1020.57 | 1024.45 |
| | ABCD | 728.60 | 741.47 | 980.19 | 1045.30 | 1048.57 |
| Retail - Strip Mall | DB | 800.69 | 818.68 | 1070.39 | 1129.87 | 1133.84 |
| | DTDB | 692.97 | 711.31 | 965.63 | 1026.68 | 1030.41 |
| | DTEnth | 698.12 | 716.34 | 970.06 | 1031.78 | 1035.72 |
| | Enth | 784.54 | 803.35 | 1054.37 | 1112.72 | 1120.74 |
| | ABCD | 810.10 | 828.86 | 1080.11 | 1139.39 | 1146.95 |

CSP = Economizer Changeover Setpoint (°F or Btu/lb) (actual in ranges below)

| Economizer Control Type | | Economizer Changeover Setpoint |
|---|---|---|
| Dry-Bulb | | 60°F - 80°F |
| Dual Temperature Dry-Bulb | | 0°F -5°F delta |
| Dual Temperature Enthalpy | | 0 Btu/lb -5 Btu/lb delta |
| Enthalpy | | 18 Btu/lb – 28 Btu/lb |
| Analog ABCD Economizers | A | 73°F |
| | B | 70°F |
| | C | 67°F |
| | D | 63°F |
| | E | 55°F |

EL = Integrated Economizer Operation (Economizer Lockout)

= 1 for Economizer w/ Integrated Operation (Two Stage Cooling)

= 0 for Economizer w/ out Integrated Operation (One Stage Cooling)

Oan = Minimum Outside Air (% OSA)[574]

= Actual. Must be between 15% -70%. If unknown assume

Functional Economizer – 30%
Non functional Economizer (Damper failed closed) – 15%
Non functional Economizer (Damper failed open) - 30% (Assume Minimum Ventilation (Three Fingers)[575])

Oax = Maximum Outside Air (%)[i]

[574] DNV GL, "HVAC Impact Evaluation Final Report WO32 HVAC – Volume 1: Report," California Public Utilities Commission, Energy Division, HVAC Commercial Quality Maintenance (CQM) (1/28/14)
[575] Technician rule of thumb taken from CPUC 'HVAC Impact Evaluation Final Report', WO32, 28Jan 2015, p18.

= Actual. Must be between 15% -70%. If unknown assume

Functional Economizer – 70%
Non functional Economizer (Damper failed closed) – 15%
Non functional Economizer (Damper failed open) –– 30% (Assume Minimum Ventilation (Three Fingers))

**EXAMPLE**

A low rise office building in Rockford (Climate Zone 1) is heated and cooled with a packaged Gas (92 kBtu output) / DX (5 Ton) RTU. The RTU is equipped with a fixed dry-bulb outside air economizer and is programed for integrated operation. When the technician inspects the RTU they find that the changeover setpoint is programmed to 62°F, which does not meet ASHRAE economizer high limit shut off air economizer recommendations. After further investigation it is found that the OSA damper motor is not operational and is providing 30% outside air.

The technician replaces the damper motor and allow for proper OSA damper modulation (30% Min OSA & 70% Max OSA). They also adjust the fixed dry-bulb changeover setpoint to meet the ASHRAE economizer high limit shut off air economizer recommendation of 70°F.

ΔkWh = [Baseline Energy Use (kWh/Ton) – Proposed Energy Use (kWh/Ton)] * Cooling Capacity (Tons)

Baseline Energy Use (kWh/Ton) = Equation for Office Low Rise

= cz+CSP*-0.967+EL*-6.327+OAn*2.87+OAx*-1.047

= 674.06+62*-0.967+0*-6.327+30*2.87+30*-1.047

= 668.8 kWh/Ton

Proposed Energy Use (kWh/Ton) = Equation for Office Low Rise

= cz+CSP*-0.967+EL*-6.327+OAn*2.87+OAx*-1.047

= 674.06+70*-0.967+0*-6.327+ 30*2.87+70*-1.047

= 619.2 kWh/Ton

ΔkWh = [668.8 (kWh/Ton) – 619.2 (kWh/Ton)] * 5 Tons

= 49.6 kWh/Ton * 5 Tons

= 248.08 kWh

### Summer Coincident Peak Demand Savings

N/A - It is assumed that repair or optimization of the economizer will not typically have a significant impact summer peak demand.

### Natural Gas Savings

ΔTherms = [Baseline Energy Use (Therms/kBtuh) – Proposed Energy Use (Therms/kBtuh)] * Output Heating Capacity (kBtuh)

The following equations are used to calculate baseline and proposed electric energy use.

**Natural Gas Energy Use Equations (therms / kbtu output)**

| Building Type | Changeover Type | Equation |
|---|---|---|
| Assembly | Fixed Dry-Bulb (DB) | cz+OAn*0.0853 |
| | Dual Temperature Dry-Bulb (DTDB) | cz+OAn*0.0866 |
| | Dual Temperature Enthalpy (DTEnth) | cz+OAn*0.0866 |
| | Fixed Enthalpy (Enth) | cz+OAn*0.0855 |
| | Analog ABCD Economizers (ABCD) | cz+OAn*0.0855 |
| Convenience Store | DB | cz+OAn*0.26 |

| Building Type | Changeover Type | Equation |
|---|---|---|
| | DTDB | cz+OAn*0.263 |
| | DTEnth | cz+OAn*0.263 |
| | Enth | cz+OAn*0.261 |
| | ABCD | cz+OAn*0.261 |
| Office - Low Rise | DB | cz+OAn*0.3 |
| | DTDB | cz+OAn*0.301 |
| | DTEnth | cz+OAn*0.301 |
| | Enth | cz+OAn*0.3 |
| | ABCD | cz+OAn*0.3 |
| Religious Facility | DB | cz+OAn*0.35 |
| | DTDB | cz+OAn*0.348 |
| | DTEnth | cz+OAn*0.348 |
| | Enth | cz+OAn*0.349 |
| | ABCD | cz+OAn*0.349 |
| Restaurant | DB | cz+OAn*0.0867 |
| | DTDB | cz+OAx*-0.038+OAn*OAx*0.00149 |
| | DTEnth | cz+OAx*-0.038+OAn*OAx*0.00149 |
| | Enth | cz+OAn*0.0878 |
| | ABCD | cz+OAn*0.0878 |
| Retail - Department Store | DB | cz+OAn*0.319 |
| | DTDB | cz+OAn*0.318 |
| | DTEnth | cz+OAn*0.318 |
| | Enth | cz+OAn*0.318 |
| | ABCD | cz+OAn*0.318 |
| Retail - Strip Mall | DB | cz+OAn*0.215 |
| | DTDB | cz+OAn*0.216 |
| | DTEnth | cz+OAn*0.216 |
| | Enth | cz+OAn*0.215 |
| | ABCD | cz+OAn*0.215 |

Where:

CZ = Climate Zone Coefficient

= Depends on Building Type and Changover Type (see table below)

| | | Natural Gas Climate Zone Coefficients | | | | |
|---|---|---|---|---|---|---|
| Building Type | Changeover Type | CZ1 (Rockford) | CZ2 (Chicago) | CZ3 (Springfield) | CZ4 (Belleville) | CZ5 (Marion) |
| Assembly | DB | -0.03 | -0.55 | -1.06 | -1.28 | -1.71 |
| | DTDB | -0.02 | -0.57 | -1.11 | -1.34 | -1.79 |
| | DTEnth | -0.02 | -0.57 | -1.11 | -1.34 | -1.79 |
| | Enth | -0.03 | -0.55 | -1.06 | -1.29 | -1.72 |
| | ABCD | -0.03 | -0.55 | -1.06 | -1.29 | -1.72 |
| Convenience Store | DB | 2.95 | 0.50 | -1.48 | -2.96 | -5.56 |
| | DTDB | 3.06 | 0.52 | -1.56 | -3.11 | -5.81 |
| | DTEnth | 3.06 | 0.52 | -1.56 | -3.11 | -5.81 |
| | Enth | 2.96 | 0.50 | -1.49 | -2.98 | -5.59 |

| | | Natural Gas Climate Zone Coefficients | | | | |
|---|---|---|---|---|---|---|
| Building Type | Changeover Type | CZ1 (Rockford) | CZ2 (Chicago) | CZ3 (Springfield) | CZ4 (Belleville) | CZ5 (Marion) |
| | ABCD | 2.96 | 0.50 | -1.49 | -2.98 | -5.59 |
| Office - Low Rise | DB | 5.83 | 3.02 | 0.46 | -0.92 | -4.13 |
| | DTDB | 5.98 | 3.08 | 0.41 | -1.03 | -4.36 |
| | DTEnth | 5.98 | 3.08 | 0.41 | -1.03 | -4.36 |
| | Enth | 5.85 | 3.03 | 0.46 | -0.93 | -4.16 |
| | ABCD | 5.85 | 3.03 | 0.46 | -0.93 | -4.16 |
| Religious Facility | DB | 9.23 | 6.71 | 3.75 | 2.40 | -0.80 |
| | DTDB | 9.41 | 6.83 | 3.77 | 2.39 | -0.86 |
| | DTEnth | 9.41 | 6.83 | 3.77 | 2.39 | -0.86 |
| | Enth | 9.25 | 6.73 | 3.75 | 2.40 | -0.80 |
| | ABCD | 9.25 | 6.73 | 3.75 | 2.40 | -0.80 |
| Restaurant | DB | 8.30 | 6.54 | 4.94 | 4.00 | 1.95 |
| | DTDB | 10.51 | 8.71 | 7.07 | 6.10 | 4.00 |
| | DTEnth | 10.51 | 8.71 | 7.07 | 6.10 | 4.00 |
| | Enth | 8.28 | 6.51 | 4.91 | 3.96 | 1.90 |
| | ABCD | 8.28 | 6.51 | 4.91 | 3.96 | 1.90 |
| Retail - Department Store | DB | 8.20 | 5.86 | 3.19 | 1.25 | -2.59 |
| | DTDB | 8.35 | 5.94 | 3.18 | 1.18 | -2.75 |
| | DTEnth | 8.35 | 5.94 | 3.18 | 1.18 | -2.75 |
| | Enth | 8.21 | 5.87 | 3.18 | 1.24 | -2.61 |
| | ABCD | 8.21 | 5.87 | 3.18 | 1.24 | -2.61 |
| Retail - Strip Mall | DB | 6.40 | 4.35 | 2.07 | 0.49 | -2.18 |
| | DTDB | 6.51 | 4.38 | 2.03 | 0.39 | -2.34 |
| | DTEnth | 6.51 | 4.38 | 2.03 | 0.39 | -2.34 |
| | Enth | 6.41 | 4.35 | 2.06 | 0.48 | -2.20 |
| | ABCD | 6.41 | 4.35 | 2.06 | 0.48 | -2.20 |

**EXAMPLE**

A low rise office building in Rockford (Climate Zone 1) is heated and cooled with a packaged Gas (92 kBtu output) / DX (5 Ton) RTU. The RTU is equipped with a fixed dry-bulb outside air economizer and is programed for integrated operation. When the technician inspects the RTU they find that the changeover setpoint is programmed to 62°F, which does not meet ASHRAE economizer high limit shut off air economizer recommendations. After further investigation it is found the OSA damper motor is not operational and is providing 30% outside air.

The technician replaces the damper motor and allow for proper OSA damper modulation (30% Min OSA & 70% Max OSA). They also adjust the fixed dry-bulb changeover setpoint to meet the ASHRAE economizer high limit shut off air economizer recommendation of 70°F.

ΔTherms = [Baseline Energy Use (Therms/kBtuh) – Proposed Energy Use(Therms/kBtuh)] * Output Heating Capacity (kBtuh)

Baseline Energy Use (Therms/kBtuh) = Equation for Office Low Rise

= cz+OAn*0.3
= 5.83+30*.3
=14.8 Therms/kBtuh output

Proposed Energy Use (Therms/kBtuh) = Equation for Office Low Rise

= cz+OAn*0.3
= 5.83+30*.3
=14.8 Therms/kBtuh output

ΔTherms = [14.8(Therms/kBtuh output) – 14.8 (Therms/kBtuh output)] * 92kBtuh output

= 0.0 (Therms/kBtuh output) * 92kBtuh output

= 0 Therms

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-HVC-ECRP-V03-180101**

**REVIEW DEADLINE: 1/1/2023**

## 4.4.36 Multi-Family Space Heating Steam Boiler Averaging Controls

### Description

This measure covers multi-family space heating boiler averaging controls. Temperature sensors are placed in interior spaces to monitor the average temperature of the building. At minimum a sensor must be placed at each corner and at one central location. Additionally, a temperature sensor must monitor the outside air temperature. These sensors shall provide data to the averaging controls. The averaging controls will adjust the boiler operation based upon an average of the indoor sensors and the outside air temperature. These controls shall also incorporate a night-time setback capability. Buildings utilizing thermostatic radiator valves, or other modulating control valves or sequences to control the temperature in individual spaces are not eligible.

This measure was developed to be applicable to the following program types: RF.

### Definition of Efficient Equipment

To qualify the boiler(s) must incorporate an averaging control system utilizing at least 4 indoor sensors and 1 outdoor sensor. The controls shall have the capability to incorporate a nighttime setback throughout the building.

### Definition of Baseline Equipment

The baseline is a boiler system without averaging controls or other steam supply modulating controls. Current boiler control system can utilize a single thermostat or aquastat and timer.

### Deemed Lifetime of Efficient Equipment

The measure life for the domestic hot water boilers is 20 years.[576]

### Deemed Measure Cost

As a retrofit measure, the actual installed cost should be used for screening purposes. A deemed retrofit measure cost of $5,060[577] can be used if the actual installed cost is unknown.

### Loadshape

N/A

### Coincidence Factor

N/A

**Algorithm**

### Calculation of Savings

### Electric Energy Savings

N/A

### Summer Coincident Peak Demand Savings

N/A

[576] The Brooklyn Union Gas Company, High Efficiency Heating and Water and Controls, Gas Energy Efficiency Program Implementation Plan.

[577] NREL, "Steam Balancing and Tuning for Multifamily Residential Buildings in Chicagoland-Second Year of Data Collection", August 2013.

**NATURAL GAS ENERGY SAVINGS**

$$\Delta Therms = Capacity \times EFLH \times SF / 100{,}000$$

Where:

Capacity = Boiler gas input size (Btu/h)

= Actual

EFLH = Effective Full Load Hours for heating are provided in section 4.4. HVAC End Use

SF = Savings Factor

= 10.2%[578] or custom if savings can be substantiated

100,000 = converts Btu/h to therm

For Example:

A 1,000,000 btu/h steam boiler in a Mid-Rise Multi-Family building in Chicago has averaging controls installed.

ΔTherms = 1,000,000 x 1,685 x 0.102 / 100,000

= 1,719 therms

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-HVC-SBAC-V02-190101**

**REVIEW DEADLINE: 1/1/2023**

[578] "Steam Balancing and Tuning for Multifamily Residential Buildings in Chicagoland-Second Year of Data Collection", NREL, August 2013, states that test buildings with steam balancing measures saved an average of 10.2%. The energy savings estimate assumes additional system balancing through the installation of large capacity air vents on steam main lines and the replacement of radiator vents. This work is assumed to be done in concert with any system being retrofitted with averaging controls.

## 4.4.37 Unitary HVAC Condensing Furnace

### Description

Condensing furnaces recover energy in combustion exhaust flue gasses that would otherwise simply be vented to the atmosphere, making them more efficient than non-condensing furnaces. This measure applies to a constant volume (CV), dedicated outside air system (DOAS), make-up air system (MUAS), or any unitary HVAC system that is utilizing an indirect gas fired process to heat 100% OA to provide ventilation or make-up air to commercial and industrial (C&I) building spaces. The unitary package must contain an indirect gas-fired, warm air furnace section, but the unitary package can be with or without an electric air conditioning section. The unitary package can be either a single package or split system that is applied indoors (non-weatherized) or outdoors (weatherized).

This measure excludes demand control ventilation, condensing unit heaters, and high efficiency (condensing) furnaces with annual fuel utilization efficiency (AFUE) ratings (for furnaces with less than 225,000 Btu/hr input capacity), which are covered by other measures for the C&I sector in the Technical Reference Manual (TRM)[579].

This measure was developed to be applicable to the following program types: TOS, NC. If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

To qualify for this measure, the efficient unitary equipment must contain a condensing, warm air furnace with a natural gas thermal efficiency (TE) rating of 90% or higher, or alternatively, the unitary package must have equipment nameplate information for natural gas that identifies a heating output and heating input rating that has an output over input ratio of 0.90 or higher. These ratings must be certified by a recognized testing laboratory in accordance with American National Standards Institute (ANSI) Standard Z21.47 for Gas-Fired Central Furnaces[580]. The furnace must be vented and condensate disposed of in accordance with the equipment manufacturer installation instructions and applicable codes.

### Definition of Baseline Equipment

The baseline equipment is expected to be unitary equipment that contains a non-condensing, warm air furnace with a natural gas thermal efficiency (TE) rating of 80%, or alternatively, the unitary package will have equipment nameplate information for natural gas that identifies a heating output and heating input rating that has an output over input ratio of 0.80. These ratings must be certified by a recognized testing laboratory in accordance with American National Standards Institute (ANSI) Standard Z21.47 for Gas-Fired Central Furnaces.

Note the current Department of Energy (DOE) federal minimum efficiency standard is 80% for 225,000 Btu/hr and higher input capacity furnaces per the Energy Conservation Standard for Commercial Warm Air Furnaces[581]. In the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) Standard 90.1 Energy Standard for Buildings Except Low-Rise Residential Buildings[582] that minimum TE requirement is extended below 225,000 Btu/hr input capacity to require all commercial warm air furnaces and combination warm air furnace/air conditioning units to meet the minimum 80% TE.

Note: new Federal Standards applicable to all gas furnaces become effective January 1, 2023.

[579] Illinois Statewide Technical Reference Manual (TRM), Version 4.0 (effective June 1, 2015), 2015.
[580] American National Standards Institute (ANSI), ANSI Z21.47 Standard for Central Gas-Fired Central Furnaces, 2012.
[581] Department of Energy (DOE), Commercial Warm Air Furnace Standard DOE 10 CFR, Part 431, Subpart D – Commercial Warm Air Furnaces, 2004.
[582] American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE), ASHRAE Standard 90.1 Energy Standard for Buildings Except Low-Rise Residential Buildings, 2013.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years, which is consistent with the established TRM measure life for single-package and split system unitary air conditioners, since in colder climates these unitary packages typically contain a gas-fired, warm air furnace section, with an electric air conditioning section.

### DEEMED MEASURE COST

The actual incremental equipment and installation costs should be used, if available. If not, the incremental cost of $5.42 per 1000 Btu/hr of output capacity should be used for the condensing furnace equipment (as part of a unitary package) and its installation (including the combustion condensate drainage and disposal system). This incremental cost is from the DOE Technical Support Document for the Notice of Proposed Rulemaking (NOPR) for the Commercial Warm Air Furnace Standard[583]. Per the DOE documentation, it is based on their representative 250,000 Btu/hr input capacity furnace at a 92% TE.

### LOADSHAPE

Loadshape C23 - Commercial Ventilation

### COINCIDENCE FACTOR

The coincidence factor is assumed to be 1.0 – that is, building ventilation will always be provided during peak periods.

## Algorithm

### CALCULATION OF SAVINGS

The following methodology provides formulas for estimating gas heating savings associated with condensing furnaces in unitary HVAC packages when applied as a CV, DOAS, MUAS, or any RTU that is indirectly heating 100% outside air (OA). These types of HVAC systems typically run continuously during the HVAC operating schedule to provide building ventilation and maintain indoor air quality or to compensate for exhaust and maintain neutral or slightly positive building pressurization. The algorithm estimates the gas use reduction resulting from utilizing condensing heating of 90% or higher thermal efficiency (TE) in place of the federal minimum TE of 80% (or other user defined baseline TE) for commercial warm air furnaces.

The methodology provides a representative group of operating schedules for the market sector applications highlighted earlier based on DOE commercial reference building models[584]. Heating loads during the operating schedule are determined based on hourly differences between a range of supply air (SA) heated to temperatures and the OA temperature using Typical Meteorological Year (TMY3)[585] weather data. These hourly heating loads are generated for all hours when the OA temperature is below the base temperature of 55 °F for heating in C&I settings per the TRM. To accommodate the variability in heating base temperatures in C&I settings, these hourly heating loads are also generated for base temperatures of 45 °F and 65 °F for heating. The hourly heating loads are then summed for the entire year. The annual heating loads are calculated in this manner for the climate zone 2 weather station (Chicago O'Hare Airport), which is then normalized to its National Climatic Data Center (NCDC)[586] 30 year (1981-2010) weather average by multiplying by the heating degree day (HDD) ratio of the NCDC/TRM HDD55 over the TMY3 HDD55 (HDD at base temperature of 55 °F), and likewise for the annual heating loads for HDD45 (HDD at base temperature of 45 °F) and HDD65 (HDD at base temperature of 65 °F), using the values in Table 1 and Table 2. Since detailed hourly weather data is not available for all 5 of the TRM climate zone weather stations, the annual heating loads for the other climate zones are determined by multiplying the climate zone 2 annual heating loads by the ratio of the other climate zone NCDC HDD over the climate zone 2 NCDC HDD, using the values in Table 1.

[583] Department of Energy (DOE), Rulemaking for Commercial Warm Air Furnace Standard, Technical Support Document 2015.
[584] Department of Energy (DOE) National Renewable Energy Laboratory, Commercial Reference Building Models of the National Building Stock, 2011.
[585] Department of Energy (DOE) National Renewable Energy Laboratory, Users Manual for TMY3 Data Sets, 2008.
[586] National Climatic Data Center, 1981-2010 Climate Normals, 2015.

These annual heating loads on a per unit airflow basis are then used in conjunction with the actual airflow of the 100% OA system and its condensing efficiency to calculate the gas heating savings versus the baseline (non-condensing) heating efficiency. This measure results in additional electric use by the unitary HVAC package due to the additional pressure drop of the condensing heat exchanger of the warm air furnace section.

**Table 1. NCDC/TRM HDD Values for All Climate Zones**

| Climate Zone - Weather Station/City | NCDC 30 Year Average HDD45[8] | NCDC 30 Year Average HDD55[1,8] | NCDC 30 Year Average HDD65[8] |
|---|---|---|---|
| 1 - Rockford AP / Rockford | 2495 | 4272 | 6569 |
| 2 - Chicago O'Hare AP / Chicago | 2263 | 4029 | 6340 |
| 3 - Springfield #2 / Springfield | 1812 | 3406 | 5495 |
| 4 - Belleville SIU RSCH / Belleville | 1197 | 2515 | 4379 |
| 5 - Carbondale Southern IL AP / Marion | 1183 | 2546 | 4477 |

**Table 2. TMY3 HDD Values for Climate Zone 2**

| Climate Zone - Weather Station/City | TMY3 HDD45[7] | TMY3 HDD55[7] | TMY3 HDD65[7] |
|---|---|---|---|
| 2 - Chicago O'Hare AP / Chicago | 2422 | 4188 | 6497 |

### ELECTRIC ENERGY SAVINGS

As noted previously, this measure results in additional SA fan electric use by the unitary HVAC system due to the additional pressure drop of the condensing heat exchanger of the warm air furnace section.

$\Delta kWh = - (t_{FAN} * cfm * \Delta P) / (\eta_{FAN/MOTOR} * 8520)$

Where:

$t_{FAN}$ = annual fan runtime (hr), refer to Tables 1 through 4

cfm = airflow (cfm), use actual or rated system airflow

$\Delta P$ = incremental pressure drop (inch W.G.), assume 0.15 if actual value not known

$\eta_{FAN/MOTOR}$ = combined fan and motor efficiency, assume 0.60 if actual value not known

8520 = conversion factor (fan horsepower – HP – calculation constant of 6356 for standard air conditions adjusted by 1 HP = 0.746 kW, or 6356/ 0.746 = 8520 for this kW calculation)

**EXAMPLE:**

For a "big box" retail store operating 24 hours a day and 7 days a week (8760 hours per year) with a 5000 cfm DOAS that has an incremental pressure drop of 0.15 inch W.G. and a combined fan and motor efficiency of 0.6 has annual kWh savings of:

$\Delta kWh = - (t_{FAN} * cfm * \Delta P) / (\eta_{FAN/MOTOR} * 8520)$

$= - (8760 * 5000 * 0.15) / (0.6 * 8520)$

$= - 1285$ kWh

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

The additional SA fan electric use by the unitary HVAC system will typically result in a modest electric demand increase.

$\Delta kW = (\Delta kWh / t_{FAN}) * CF$

Where:

CF = 1.0

**EXAMPLE:**

Continuing the previous example:

$\Delta kW = (\Delta kWh / t_{FAN}) * CF$

$= (- 1285 / 8760) * 1.0$

$= - 0.15$ kW

**NATURAL GAS ENERGY SAVINGS**

$\Delta Therms = [Q_{OA} * cfm * (1/TE_{NC} - 1/TE_C)] / 100{,}000$

Where:

$Q_{OA}$ = annual outside air (OA) heating load per cfm of OA (Btu/cfm)

First, select the most representative operating schedule for the application from among the four (4) scenarios listed below and its set of three (3) applicable tables. Second, select the table in that set with the most representative HDD base temperature – the base temperature for OA below which heating is required. If that base temperature is not readily determined, select the TRM default base temperature of 55 °F (HDD55) for heating in C&I settings. Third, select the climate zone within that table. Fourth, select an appropriate heated to supply air (SA) temperature within that table. Use the resulting $Q_{OA}$ value, with linear interpolation allowed between SA temperatures.

The four (4) scenarios available are indicative of the following building applications and operating schedules:

1. 24 hour a day and 7 day a week (24/7) operation, with HVAC operating schedule of 8760 hours per year, typical of large retail stores with DOAS, hotel/multifamily buildings with corridor MUAS, and healthcare facilities with DOAS. Use Table 3 through Table 5.
2. 6:00 AM to 1:00 AM every day operation, with HVAC operating schedule of 7300 hours per year, typical of full service and quick service restaurants with kitchen MUAS. Use Table 6 through Table 8.
3. 7:00 AM to 9:00 PM Monday-Friday, 7:00 AM to 10:00 PM Saturday, and 9:00 AM to 7:00 PM Sunday operations, with HVAC operating schedule of 5266 hours per year, typical of non-24/7 retail stores with DOAS. Use Table 9 through Table 11.
4. 7:00 AM to 9:00 PM Monday-Friday operation, with HVAC operating schedule of 3911 hours per year, typical of school buildings with DOAS. Use Table 12 through Table 14.

$TE_{NC}$ = non-condensing thermal efficiency (TE), use federal minimum TE of 80% (0.80) or actual TE if known

$TE_C$ = condensing thermal efficiency (TE), use actual TE or if unknown assume 90% (0.90)

100,000 = conversion factor (1 therm = 100,000 Btu)

**EXAMPLE:**

Continuing the previous example, for a climate zone 2 (Chicago O'Hare AP / Chicago) application using a 90% TE condensing DOAS with a supply air temperature from the DOAS of 95 °F:

$\Delta Therms = [Q_{OA} * cfm * (1/TE_{NC} - 1/TE_{C})]/ 100,000$

$= 303,268 * 5,000 * (1/0.80 – 1/0.90)/100,000$

$= 2,106$ therms

8760 Hour Annual Operation Scenario

**Table 3. 8760 Hour Annual Operation Scenario for HDD45**

| Supply Air Fan Runtime = 8760 Hours | $Q_{oa}$ (Annual Btu/cfm) At Supply Air Temperature Of | | | |
|---|---|---|---|---|
| Climate Zone - Weather Station/City | 75°F | 85°F | 95°F | 105°F |
| 1 - Rockford AP / Rockford | 189,343 | 230,897 | 272,451 | 314,004 |
| 2 - Chicago O'Hare AP / Chicago | 171,737 | 209,427 | 247,116 | 284,806 |
| 3 - Springfield #2 / Springfield | 137,511 | 167,689 | 197,868 | 228,046 |
| 4 - Belleville SIU RSCH / Belleville | 90,839 | 110,775 | 130,711 | 150,647 |
| 5 - Carbondale Southern IL AP / Marion | 89,777 | 109,479 | 129,182 | 148,885 |

**Table 4. 8760 Hour Annual Operation Scenario for HDD55**

| Supply Air Fan Runtime = 8760 Hours | $Q_{oa}$ (Annual Btu/cfm) At Supply Air Temperature Of | | | |
|---|---|---|---|---|
| Climate Zone - Weather Station/City | 75°F | 85°F | 95°F | 105°F |
| 1 - Rockford AP / Rockford | 216,145 | 268,852 | 321,559 | 374,266 |
| 2 - Chicago O'Hare AP / Chicago | 203,850 | 253,559 | 303,268 | 352,977 |
| 3 - Springfield #2 / Springfield | 172,329 | 214,351 | 256,374 | 298,397 |
| 4 - Belleville SIU RSCH / Belleville | 127,248 | 158,278 | 189,307 | 220,337 |
| 5 - Carbondale Southern IL AP / Marion | 128,817 | 160,229 | 191,641 | 223,053 |

**Table 5. 8760 Hour Annual Operation Scenario for HDD65**

| Supply Air Fan Runtime = 8760 Hours | $Q_{oa}$ (Annual Btu/cfm) At Supply Air Temperature Of | | | |
|---|---|---|---|---|
| Climate Zone - Weather Station/City | 75°F | 85°F | 95°F | 105°F |
| 1 - Rockford AP / Rockford | 239,158 | 308,050 | 376,942 | 445,834 |
| 2 - Chicago O'Hare AP / Chicago | 230,820 | 297,311 | 363,802 | 430,292 |
| 3 - Springfield #2 / Springfield | 200,056 | 257,685 | 315,314 | 372,943 |
| 4 - Belleville SIU RSCH / Belleville | 159,426 | 205,351 | 251,276 | 297,200 |
| 5 - Carbondale Southern IL AP / Marion | 162,994 | 209,947 | 256,899 | 303,852 |

7300 Hour Annual Operation Scenario

**Table 6. 7300 Hour Annual Operation Scenario for HDD45**

| Supply Air Fan Runtime = 7300 Hours | $Q_{oa}$ (Annual Btu/cfm) At Supply Air Temperature Of | | | |
|---|---|---|---|---|
| Climate Zone -Weather Station/City | 75°F | 85°F | 95°F | 105°F |
| 1 - Rockford AP / Rockford | 151,914 | 185,369 | 218,823 | 252,278 |
| 2 - Chicago O'Hare AP / Chicago | 137,788 | 168,132 | 198,476 | 228,819 |
| 3 - Springfield #2 / Springfield | 110,328 | 134,624 | 158,921 | 183,217 |
| 4 - Belleville SIU RSCH / Belleville | 72,882 | 88,932 | 104,982 | 121,033 |
| 5 - Carbondale Southern IL AP / Marion | 72,030 | 87,892 | 103,755 | 119,617 |

**Table 7. 7300 Hour Annual Operation Scenario for HDD55**

| Supply Air Fan Runtime = 7300 Hours | $Q_{oa}$ (Annual Btu/cfm) At Supply Air Temperature Of | | | |
|---|---|---|---|---|
| Climate Zone -Weather Station/City | 75°F | 85°F | 95°F | 105°F |
| 1 - Rockford AP / Rockford | 173,511 | 215,950 | 258,389 | 300,828 |
| 2 - Chicago O'Hare AP / Chicago | 163,641 | 203,666 | 243,691 | 283,716 |
| 3 - Springfield #2 / Springfield | 138,338 | 172,174 | 206,010 | 239,846 |
| 4 - Belleville SIU RSCH / Belleville | 102,149 | 127,133 | 152,118 | 177,103 |
| 5 - Carbondale Southern IL AP / Marion | 103,408 | 128,701 | 153,993 | 179,286 |

**Table 8. 7300 Hour Annual Operation Scenario for HDD65**

| Supply Air Fan Runtime = 7300 Hours | $Q_{oa}$ (Annual Btu/cfm) At Supply Air Temperature Of | | | |
|---|---|---|---|---|
| Climate Zone -Weather Station/City | 75°F | 85°F | 95°F | 105°F |
| 1 - Rockford AP / Rockford | 191,803 | 247,046 | 302,288 | 357,531 |
| 2 - Chicago O'Hare AP / Chicago | 185,117 | 238,434 | 291,750 | 345,067 |
| 3 - Springfield #2 / Springfield | 160,444 | 206,655 | 252,866 | 299,076 |
| 4 - Belleville SIU RSCH / Belleville | 127,859 | 164,685 | 201,510 | 238,336 |
| 5 - Carbondale Southern IL AP / Marion | 130,720 | 168,370 | 206,020 | 243,670 |

5266 Hour Annual Operation Scenario

**Table 9. 5266 Hour Annual Operation Scenario for HDD45**

| Supply Air Fan Runtime = 5266 Hours | $Q_{oa}$ (Annual Btu/cfm) At Supply Air Temperature Of | | | |
|---|---|---|---|---|
| Climate Zone -Weather Station/City | 75°F | 85°F | 95°F | 105°F |
| 1 - Rockford AP / Rockford | 104,175 | 127,350 | 150,524 | 173,699 |
| 2 - Chicago O'Hare AP / Chicago | 94,488 | 115,508 | 136,527 | 157,547 |
| 3 - Springfield #2 / Springfield | 75,657 | 92,488 | 109,319 | 126,149 |
| 4 - Belleville SIU RSCH / Belleville | 49,979 | 61,097 | 72,215 | 83,334 |
| 5 - Carbondale Southern IL AP / Marion | 49,394 | 60,383 | 71,371 | 82,359 |

**Table 10. 5266 Hour Annual Operation Scenario for HDD55**

| Supply Air Fan Runtime = 5266 Hours | $Q_{oa}$ (Annual Btu/cfm) At Supply Air Temperature Of | | | |
|---|---|---|---|---|
| Climate Zone -Weather Station/City | 75°F | 85°F | 95°F | 105°F |
| 1 - Rockford AP / Rockford | 118,320 | 147,406 | 176,492 | 205,578 |
| 2 - Chicago O'Hare AP / Chicago | 111,590 | 139,021 | 166,452 | 193,884 |
| 3 - Springfield #2 / Springfield | 94,335 | 117,524 | 140,714 | 163,904 |
| 4 - Belleville SIU RSCH / Belleville | 69,657 | 86,780 | 103,904 | 121,027 |

| Supply Air Fan Runtime = 5266 Hours | $Q_{oa}$ (Annual Btu/cfm) At Supply Air Temperature Of | | | |
|---|---|---|---|---|
| 5 - Carbondale Southern IL AP / Marion | 70,516 | 87,850 | 105,184 | 122,519 |

**Table 11. 5266 Hour Annual Operation Scenario for HDD65**

| Supply Air Fan Runtime = 5266 Hours | $Q_{oa}$ (Annual Btu/cfm) At Supply Air Temperature Of | | | |
|---|---|---|---|---|
| Climate Zone -Weather Station/City | 75°F | 85°F | 95°F | 105°F |
| 1 - Rockford AP / Rockford | 130,903 | 168,718 | 206,532 | 244,347 |
| 2 - Chicago O'Hare AP / Chicago | 126,339 | 162,836 | 199,333 | 235,829 |
| 3 - Springfield #2 / Springfield | 109,501 | 141,133 | 172,765 | 204,398 |
| 4 - Belleville SIU RSCH / Belleville | 87,262 | 112,470 | 137,678 | 162,886 |
| 5 - Carbondale Southern IL AP / Marion | 89,215 | 114,987 | 140,759 | 166,531 |

<u>3911 Hour Annual Operation Scenario</u>

**Table 12. 3911 Hour Annual Operation Scenario for HDD45**

| Supply Air Fan Runtime = 3911 Hours | $Q_{oa}$ (Annual Btu/cfm) At Supply Air Temperature Of | | | |
|---|---|---|---|---|
| Climate Zone -Weather Station/City | 75°F | 85°F | 95°F | 105°F |
| 1 - Rockford AP / Rockford | 75,029 | 91,729 | 108,428 | 125,128 |
| 2 - Chicago O'Hare AP / Chicago | 68,053 | 83,199 | 98,346 | 113,492 |
| 3 - Springfield #2 / Springfield | 54,490 | 66,618 | 78,746 | 90,874 |
| 4 - Belleville SIU RSCH / Belleville | 35,996 | 44,008 | 52,019 | 60,031 |
| 5 - Carbondale Southern IL AP / Marion | 35,575 | 43,493 | 51,411 | 59,329 |

**Table 13. 3911 Hour Annual Operation Scenario for HDD55**

| Supply Air Fan Runtime = 3911 Hours | $Q_{oa}$ (Annual Btu/cfm) At Supply Air Temperature Of | | | |
|---|---|---|---|---|
| Climate Zone -Weather Station/City | 75°F | 85°F | 95°F | 105°F |
| 1 - Rockford AP / Rockford | 85,672 | 106,825 | 127,979 | 149,132 |
| 2 - Chicago O'Hare AP / Chicago | 80,799 | 100,749 | 120,699 | 140,649 |
| 3 - Springfield #2 / Springfield | 68,305 | 85,170 | 102,035 | 118,901 |
| 4 - Belleville SIU RSCH / Belleville | 50,436 | 62,890 | 75,343 | 87,797 |
| 5 - Carbondale Southern IL AP / Marion | 51,058 | 63,665 | 76,272 | 88,879 |

**Table 14. 3911 Hour Annual Operation Scenario for HDD65**

| Supply Air Fan Runtime = 3911 Hours | $Q_{oa}$ (Annual Btu/cfm) At Supply Air Temperature Of | | | |
|---|---|---|---|---|
| Climate Zone -Weather Station/City | 75°F | 85°F | 95°F | 105°F |
| 1 - Rockford AP / Rockford | 95,460 | 123,294 | 151,128 | 178,963 |
| 2 - Chicago O'Hare AP / Chicago | 92,132 | 118,996 | 145,860 | 172,724 |
| 3 - Springfield #2 / Springfield | 79,853 | 103,136 | 126,420 | 149,703 |
| 4 - Belleville SIU RSCH / Belleville | 63,635 | 82,190 | 100,745 | 119,299 |
| 5 - Carbondale Southern IL AP / Marion | 65,059 | 84,029 | 102,999 | 121,969 |

### WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

## Deemed O&M Cost Adjustment Calculation

The actual incremental annual maintenance costs should be used, if available. If not, the incremental cost of $0.05 per 1000 Btu/hr of output capacity should be used for maintaining the combustion condensate disposal system yearly. This incremental cost is from the DOE Technical Support Document for the Notice of Proposed Rulemaking (NOPR) for the Commercial Warm Air Furnace Standard6. Per the DOE documentation, it is based on their representative 250,000 Btu/hr input capacity furnace at a 92% TE.

## Measure Code: CI-HVC-DSFN-V02-190101

## Review Deadline: 1/1/2022

## 4.4.38 Covers and Gap Sealers for Room Air Conditioners

**DESCRIPTION**

Room air conditioners (window ACs, through-the-wall or sleeve ACs, PTACs or PTHPs) constitute a permanent or semi-permanent penetration through the building's envelope. These units are often poorly installed, resulting in gaps that act like air leakage pathways through the building's envelope. The uncontrolled movement of air across the gaps in the envelope (infiltration) increases the building's winter heating requirements and reduces its overall energy performance.

The heat loss and infiltration can be reduced by installing a rigid or flexible insulated cover on the inside of a room AC. These covers should be maintained by building staff and should remain installed through the heating season. Simple uninsulated cloth covers with no sealing at edges do not qualify for this measure.

There are several types of AC covers available that may be eligible for this measure:

1. If the room AC is left in the window or sleeve, a rigid cover that covers the indoor side of the AC unit with foam gaskets to seal the edges may be installed.
2. If the room AC is absent or is removed during the heating months, a rigid cover that fits inside the sleeve with foam gaskets along the edges for proper air sealing may be installed.
3. Flexible covers that are well insulated and perfectly cover the indoor side of the AC unit may also be eligible for this measure.

This measure was developed to be applicable to the following program types: RF, DI. If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

The installed equipment is a rigid cover that fits inside the empty sleeve or completely covers the indoor side of a window AC unit, with foam gaskets sealing the edges. A flexible insulated cover that perfectly covers the indoor side of the unit and seals gaps may also be installed. Covers should remain installed throughout the winter heating season.

**DEFINITION OF BASELINE EQUIPMENT**

The baseline equipment is a room AC (window AC, through-the-wall or sleeve AC, PTAC or PTHP) that is poorly installed with gaps around the edges and does not use AC covers or gap sealers during the winter heating months.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The estimated useful life of typical AC covers is 5 years[587].

**DEEMED MEASURE COST**

The measure cost is the full cost of installing AC covers. Actual installation costs (material and labor) should be used if available. In actual costs are unknown, assume material cost[588] of $24 (flexible covers) up to $119, depending on size of the AC unit. The install time per unit is 15 to 30 minutes at assumed labor rate of $20/hour.

**LOADSHAPE**

Loadshape C04 – Commercial Electric Heating

**COINCIDENCE FACTOR**

N/A

[587] New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs V4, April 2016 (New York TRM).
[588] Cost estimates from customer invoices and vendors. Material costs can be lower for bulk orders.

**Algorithm**

## CALCULATION OF ENERGY SAVINGS

### ELECTRIC ENERGY SAVINGS

If the building is electrically heated, electric energy savings are calculated as follows:

$$\Delta kWh = (Q_{infiltration} * 1.08 * (T_{OA} - T_{SA}) * EFLH_{heat}) / (3,412 * COP)$$

Where:

$Q_{infiltration}$ = Air infiltration (CFM) due to poor installation of window or through-the-wall AC[589]

= $ELA * 0.000645 * (f_s^2 * (T_{OA} - T_{SA}) + f_w^2 * U^2)^{1/2} * 2118.88$

Where:

ELA = Effective Leakage Area (sq. in.)

= Can be collected on site; if unknown, assume 6 sq. in.[590]

0.000645 = Converts square inches to square meters

$f_s$ = Stack Coefficient

= $1/3 * (9.81 * Height * 0.3048) / (T_{OA})^{0.5}$

$f_w$ = Wind Coefficient

= $A * B * (Height * 0.3048) / (10)^C$

Where:

9.81 = Acceleration due to gravity ($m/s^2$)

Height = Height of the location of the leakage area in feet

= Assume 8 ft per floor

$T_{OA}$ = Average Outside Air Temperature during heating period[591]. Use values from table below, based on facility location[592]. This figure must be in Kelvin to determine Stack Coefficient ($f_s$) and infiltration ($Q_{infiltration}$), but in Fahrenheit to determine energy savings (ΔkWh, ΔTherms).

| Zone | $T_{OA}$ (°F) | $T_{OA}$ (K) |
|---|---|---|
| Zone 1 (Rockford) | 31.63 | 272.94 |
| Zone 2 (Chicago) | 33.99 | 274.26 |
| Zone 3 (Springfield) | 34.58 | 274.58 |
| Zone 4 (Belleville) | 36.24 | 275.51 |
| Zone 5 (Marion) | 39.07 | 277.08 |

[589] Infiltration equation and values for stack and wind coefficient equations from "The Use of Blower Door Data." Max Sherman, 1998. The equation is adjusted for wall leakage area (i.e. no ceiling or floor leakage).
[590] Average effective leakage area for multi-family building AC units from "There are Holes in Our Walls." Prepared for Urban Green Council by Steven Winter Associates, April 2011.
[591] "Heating Period" is defined as hours when the TMY3 dry bulb temperature is less than 55°F (balance point)
[592] Based on NREL's Typical Meteorological Year 3 (TMY3) data for different weather stations.

A, B and C = Constants based on the facility site's shielding and terrain parameters. Use values from the tables below[593].

| Shielding Class | Shielding Type | Shielding Description | A |
|---|---|---|---|
| 1 | None | No obstructions or local shielding whatsoever (i.e. isolated building) | 0.324 |
| 2 | Light | Light local shielding with few obstructions (e.g. A few trees or a shed in the vicinity) | 0.285 |
| 3 | Moderate | Moderate local shielding; some obstructions within two house heights (e.g. Thick hedge fence on fence and nearby building) | 0.24 |
| 4 | Heavy | Heavy shielding; obstructions around most of perimeter buildings or trees within five building heights in most directions (e.g. Well developed/dense tract house) | 0.185 |
| 5 | Very Heavy | Very heavy shielding, large obstruction surrounding perimeter within two house heights (e.g. Typical downtown area) | 0.102 |

| Terrain Class | Terrain Type | Terrain Description | B | C |
|---|---|---|---|---|
| 1 | None | Ocean or other body of eater with at least 5 km of unrestricted space | 1.3 | 0.1 |
| 2 | Light | Flat terrain with some isolated obstacles (e.g. Buildings or trees well separated from each other) | 1 | 0.15 |
| 3 | Moderate | Rural areas with low buildings, trees etc. | 0.85 | 0.2 |
| 4 | Heavy | Urban, industrial or forest areas | 0.67 | 0.25 |
| 5 | Very Heavy | Center of large city (e.g. Manhattan) | 0.47 | 0.35 |

0.3048 = Converts feet to meters

$T_{SA}$ = Average Indoor Air Temperature during heating period. This figure will need to be in Kelvin to calculate infiltration ($Q_{infiltration}$) and Fahrenheit to calculate energy savings (ΔkWh, ΔTherms).

= Collected on site. If unknown, assume 72°F (295 K). If known, convert °F to K by using the following equation: K = (°F + 459.67) * (5/9).

U = Average Wind Velocity (m/s) during heating period. Use table below, based on facility location[594].

| Zone | U (m/s) |
|---|---|
| Zone 1 (Rockford) | 4.50 |
| Zone 2 (Chicago) | 4.67 |
| Zone 3 (Springfield) | 4.60 |
| Zone 4 (Belleville) | 3.92 |
| Zone 5 (Marion) | 3.07 |

2118.88 = Converts $m^3/s$ to CFM

[593] Shielding and terrain class descriptions and constants from "The Use of Blower Door Data." Max Sherman, 1998" and "Wind and Infiltration Interaction for Small Buildings." MH Sherman and DT Grimsrud, Lawrence Berkley Laboratory, 1982.
[594] Based on TMY3 data, see "Covers for Room AC_11092016.xls" for more information.

1.08 = Sensible heat transfer constant (Btu/hr.CFM.°F)

$EFLH_{heat}$ = Equivalent Full Load Hours for heating from section 4.4 HVAC End Use[595]

3,412 = Converts Btus to kWh

COP = Coefficient of Performance of the heating unit

= Collected on site. If unknown assume 2.6 for PTHP[596]

Deemed per-unit savings for the Multi-Family Building type for Shielding Class 3 and Terrain Class 3 are as follows:

| Multi-Family - Electric Savings per Unit (kWh/unit) | | | | | | |
|---|---|---|---|---|---|---|
| Floor | Height | Rockford | Chicago | Springfield | Belleville | Marion |
| 1 | 8 | 55.18 | 53.16 | 45.70 | 31.09 | 25.67 |
| 2 | 16 | 68.19 | 65.31 | 56.17 | 38.72 | 32.66 |
| 3 | 24 | 77.92 | 74.34 | 63.96 | 44.45 | 37.97 |
| 4 | 32 | 86.04 | 81.85 | 70.44 | 49.25 | 42.44 |
| 5 | 40 | 93.15 | 88.42 | 76.11 | 53.46 | 46.37 |
| 6 | 48 | 99.56 | 94.34 | 81.22 | 57.26 | 49.93 |
| 7 | 56 | 105.44 | 99.76 | 85.90 | 60.75 | 53.20 |
| 8 | 64 | 110.91 | 104.80 | 90.25 | 63.99 | 56.24 |
| 9 | 72 | 116.04 | 109.53 | 94.33 | 67.04 | 59.11 |
| 10 | 80 | 120.89 | 114.00 | 98.19 | 69.92 | 61.81 |
| 12 | 96 | 129.92 | 122.31 | 105.36 | 75.29 | 66.85 |
| 14 | 112 | 138.21 | 129.94 | 111.95 | 80.22 | 71.49 |
| 16 | 128 | 145.93 | 137.04 | 118.08 | 84.81 | 75.82 |
| 18 | 144 | 153.19 | 143.72 | 123.84 | 89.13 | 79.88 |
| 20 | 160 | 160.05 | 150.03 | 129.29 | 93.21 | 83.72 |
| 22 | 176 | 166.59 | 156.03 | 134.47 | 97.10 | 87.38 |
| 24 | 192 | 172.83 | 161.77 | 139.42 | 100.82 | 90.88 |
| 26 | 208 | 178.82 | 167.28 | 144.18 | 104.38 | 94.23 |
| 28 | 224 | 184.58 | 172.57 | 148.75 | 107.81 | 97.46 |
| 30 | 240 | 190.15 | 177.69 | 153.17 | 111.12 | 100.58 |

[595] Although in theory the hours should be all hours that infiltration is expected (i.e. all hours <55F), the IL TAC has agreed to use the Equivalent Full Load Hours to keep the savings at a more conservative level.
[596] From IECC 2012 Minimum Efficiency Requirements. For a 1 ton PTHP, COP = 2.9 – (0.026 * 12,000/1,000).

**EXAMPLE**

A mid-rise multi-family building located in the moderate terrain class and shielding class of Chicago, has 16 rooms on the 10th floor (80 feet high) with PTHPs that get covered with a cover and foam gasket during the heating months. The indoor temperature during the heating months is maintained at 74°F. The air infiltration and the related energy savings from the AC covers and seals are calculated as follows -

For Shielding Class 3 and Terrain Class 3,

A = 0.24, B = 0.85 and C = 0.2

Therefore,

$f_s = 1/3 * (9.81 \text{ m/s}^2 * 80 \text{ ft} * 0.3048 \text{ m/ft} / 274.26 \text{ K})^{0.5} = 0.3 \text{ m/K}^{½}.\text{s}$

$f_w = 0.24 * 0.85 * (80 \text{ ft} * 0.3048 \text{ m/ft} / 10 \text{ m})^{0.2} = 0.24$

Total effective leakage area (ELA) = 16 units * 6 sq. in. = 96 sq. in.

$Q_{infiltration} = ELA * 0.000645 * (f_s^2 * (T_{OA} – T_{SA}) + f_w^2 * U^2)^{1/2} * 2118.88$

$= 96 * 0.000645 * (0.3^2 * (296.48 \text{ K} – 274.26 \text{ K}) + 0.24^2 * 4.67^2)^{1/2} * 2118.88$

= 237 CFM

ΔkWh = (237 * 1.08 Btu/hr.CFM.°F * (74°F – 33.99°F) * 1,685) / (3,412 Btu/kWh* 2.6)

= 1,945 kWh

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

As the savings occur during the winter season (non-peak), there are no demand savings associated with this measure.

### NATURAL GAS SAVINGS

If the building is heated with gas, the natural gas savings are calculated as follows:

$$\Delta Therms = (Q_{infiltration} * 1.08 \text{ Btu/hr.CFM.°F} * (T_{OA} – T_{SA}) * EFLH_{heat}) / (100{,}000 \text{ Btu/therm} * \eta)$$

Where,

η = Efficiency of heating equipment.

= Collected on site. If unknown, assume 80%[597].

100,000 = Converts Btus to therms

Other factors as defined above

Deemed per-unit savings per unit for the Multi-Family Building type for Shielding Class 3 and Terrain Class 3 are as follows:

| Multi-Family - Gas Savings per Unit (Therms/Unit) | | | | | | |
|---|---|---|---|---|---|---|
| Floor | Height | Rockford | Chicago | Springfield | Belleville | Marion |
| 1 | 8 | 6.12 | 5.90 | 5.07 | 3.45 | 2.85 |
| 2 | 16 | 7.56 | 7.24 | 6.23 | 4.29 | 3.62 |
| 3 | 24 | 8.64 | 8.24 | 7.09 | 4.93 | 4.21 |
| 4 | 32 | 9.54 | 9.08 | 7.81 | 5.46 | 4.71 |
| 5 | 40 | 10.33 | 9.81 | 8.44 | 5.93 | 5.14 |
| 6 | 48 | 11.04 | 10.46 | 9.01 | 6.35 | 5.54 |
| 7 | 56 | 11.69 | 11.06 | 9.53 | 6.74 | 5.90 |
| 8 | 64 | 12.30 | 11.62 | 10.01 | 7.10 | 6.24 |
| 9 | 72 | 12.87 | 12.15 | 10.46 | 7.43 | 6.55 |

[597] Energy Independence and Security Act of 2007 – averaged for hot water and steam boilers.

| Multi-Family - Gas Savings per Unit (Therms/Unit) | | | | | | |
|---|---|---|---|---|---|---|
| Floor | Height | Rockford | Chicago | Springfield | Belleville | Marion |
| 10 | 80 | 13.41 | 12.64 | 10.89 | 7.75 | 6.85 |
| 12 | 96 | 14.41 | 13.56 | 11.68 | 8.35 | 7.41 |
| 14 | 112 | 15.33 | 14.41 | 12.41 | 8.90 | 7.93 |
| 16 | 128 | 16.18 | 15.20 | 13.09 | 9.40 | 8.41 |
| 18 | 144 | 16.99 | 15.94 | 13.73 | 9.88 | 8.86 |
| 20 | 160 | 17.75 | 16.64 | 14.34 | 10.34 | 9.28 |
| 22 | 176 | 18.47 | 17.30 | 14.91 | 10.77 | 9.69 |
| 24 | 192 | 19.16 | 17.94 | 15.46 | 11.18 | 10.08 |
| 26 | 208 | 19.83 | 18.55 | 15.99 | 11.57 | 10.45 |
| 28 | 224 | 20.47 | 19.14 | 16.50 | 11.96 | 10.81 |
| 30 | 240 | 21.09 | 19.70 | 16.98 | 12.32 | 11.15 |

**EXAMPLE**

A gas-heated mid-rise multi-family building located in the moderate terrain class and shielding class of Chicago, has 16 rooms on the 10$^{th}$ floor (80 feet high) with room air conditioners that get covered with an AC cover and foam gasket during the heating months. The indoor temperature during the heating months is maintained at 74°F. The air infiltration and the related therm savings from the AC covers and seals are calculated as follows:

For Shielding Class 3 and Terrain Class 3,

A = 0.24, B = 0.85 and C = 0.2

Therefore,

$f_s = 1/3 * (9.81 \text{ m/s}^2 * 80 \text{ ft} * 0.3048 \text{ m/ft} / 274.26 \text{ K})^{0.5} = 0.3 \text{ m/K}^{½}.\text{s}$

$f_w = 0.24 * 0.85 * (80 \text{ ft} * 0.3048 \text{ m/ft} / 10 \text{ m})^{0.2} = 0.24$

Total effective leakage area (ELA) = 16 units * 6 sq.in = 96 sq. in

$Q_{infiltration} = ELA * 0.000645 * (f_s^2 * (T_{OA} – T_{SA}) + f_w^2 * U^2)^{1/2} * 2118.88$

$= 96 * 0.000645 * (0.3^2 * (296.48 \text{ K} – 274.26 \text{ K}) + 0.24^2 * 4.67^2)^{1/2} * 2118.88$

= 237 CFM

ΔTherms = (237 * 1.08 Btu/hr.CFM.°F * (74°F – 33.99°F) * 1,685) / (100,000 Btu/therm * 80%)

= 216 therms

## Water and Other Non-Energy Impact Descriptions and Calculation

N/A

## Deemed O&M Cost Adjustment Calculation

N/A

## Measure Code: CI-HVC-CRAC-V01-180101

## Review Deadline: 1/1/2023

## 4.4.39 High Temperature Heating and Ventilation (HTHV) Direct Fired Heater

### Description

This measure applies to 100% outside air, high temperature heating and ventilation (HTHV) direct fired gas heaters. These units replace unit heaters (indirect gas fired or steam coil) or rooftop units in warehouses which suffer from extreme temperature stratification, minimal controls and reduced heating efficiencies.

Warehouses have high ceilings (~30 ft high), and suffer from stratification of air. The warm air rises and remains near the roof, which keeps the thermostat from reaching its desired setpoint. This increases the run hours of the heating unit and causes discomfort among the occupants. The HTHV units have high pressure fans that direct high temperature and high velocity air towards the floor and thus help minimize temperature stratification. On average, a 30 ft high warehouse could reduce its linear stratification from 0.53°F/ft to 0.13°F/ft, thus maintaining a more uniform temperature in the room and reducing the operating hours of the heating unit.

Since the HTHV units are direct fired, they also have improved efficiencies of 92% compared to 80% for a typical indirect fired unit heater or rooftop unit. They transfer the latent heat of the flue gases into the space instead of venting it out.

This measure only applies to high ceiling warehouses that do not have any other destratification technologies installed (i.e. destratification fans, air rotation units etc.). New HTHV units must be the warehouse's primary heat source.

This measure was developed to be applicable to the following program types: RF, TOS, NC. If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

The efficient equipment must be a 100% outside air, HTHV direct fired gas heater, with a discharge temperature greater than or equal to 150°F, a temperature rise greater than or equal to 140°F, and an efficiency exceeding 92%.

### Definition of Baseline Equipment

The baseline equipment must be an indirect fired gas or steam unit heater or a rooftop unit used as the primary space heating source. Warehouses with existing destratification technologies (high volume, low speed fans or air turnover units) do not qualify for this measure.

### Deemed Lifetime of Efficient Equipment

The measure life is assumed to be 15 years[598].

### Deemed Measure Cost

The measure cost should be based on a contractor's evaluation of the project scope and may vary significantly on a project to project basis. If unknown, for early replacement or retrofit projects, assume $14.50/MBtu/hr (material cost for an HTHV unit) or $26/MBTUh (sum of material and installation cost)[599].

The incremental measure cost, assuming a baseline of standard efficiency unit heaters, is $7.43/MBtu/hr (material cost)[600].

[598] Based on "Field Demonstation of High Efficiency Gas Heaters", prepared for Better Buildings Alliance, US. DOE, Jim Young, Navigant Consulting, 2014.
[599] Average costs from CLEAResult's evaluation of 9 different projects in the Chicagoland area.
[600] Based on data collected in "Field Demonstation of High Efficiency Gas Heaters", prepared for Better Buildings Alliance, US. DOE, Jim Young, Navigant Consulting, 2014.

**LOADSHAPE**

Loadshape C04: Commercial Electric Heating

**COINCIDENCE FACTOR**

Assumed to be 0.

**Algorithm**

**CALCULATION OF ENERGY SAVINGS**

**ELECTRIC ENERGY SAVINGS**

HTHV units may increase the facility's electric energy consumption due to high pressure motors that supply air at higher velocity.

$$\Delta kWh = - kWh/HDD * HDD$$

Where:

kWh/HDD = increase in electric energy consumption due to HTHV fan motor

= 1.04[601]

HDD = heating degree days

| Zone | City | HDD55[602] | ΔkWh |
|---|---|---|---|
| 1 | Rockford | 4,272 | (4,443) |
| 2 | Chicago | 4,029 | (4,190) |
| 3 | Springfield | 3,406 | (3,542) |
| 4 | Belleville | 2,515 | (2,616) |
| 5 | Marion | 2,546 | (2,648) |

Although HTHV fan motors have a higher power draw, they also result in decreased heating equipment operating time, potentially offsetting some of the increase in electrical energy consumption. Therefore, if replacing heating equipment other than unit heaters, a custom evaluation may be necessary to determine if there is an increase in electrical energy consumption.

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

Since HTHV units operate during the winter (non-peak) season, there are no demand savings associated with this measure.

**NATURAL GAS SAVINGS**

Custom calculation below, otherwise use a deemed savings factor from the table that follows.

$$\Delta Therms = (FLH_{base} * Cap_{base} /(\eta_{base} * 100)) – (FLH_{eff} * Cap_{eff} / (\eta_{eff} * 100))$$

Where:

$FLH_{base}$ = $LF_{base}$ * Hours

$FLH_{eff}$ = $LF_{eff}$ * Hours

[601] Based on data collected in "Field Demonstation of High Efficiency Gas Heaters", prepared for Better Buildings Alliance, US. DOE, Jim Young, Navigant Consulting, 2014. This study replaced four standard unit heaters with HTHV units, and the electrical energy increased from 0.4 kWh/HDD to 1.44 kWh/HDD. Therefore savings are assumed to be 1.04 kWh /HDD.

[602] 30-year normals from the National Climactic Data Center (NCDC), assuming base temperature 55.

Hours = Annual operating hours of the unit, calculated as total number of hours when outside air temperature is less than 55°F. This can be adjusted based on the facility's occupancy schedule.

$LF_{base}$ = load factor of baseline unit heater

= $(Q_{inf,base} + Q_{w,base} + Q_{r,base})/(Cap_{base}*100)$

$LF_{eff}$ = load factor of HTHVheater

= $(Q_{inf,eff} + Q_{w,eff} + Q_{r,eff})/(Cap_{eff}*100)$

$Cap_{base}$ = existing heating unit input capacity (MBtu/hr)

= can be collected on site, or assumed to be the same as HTHV unit capacity, $Cap_{eff}$

$Cap_{eff}$ = HTHV unit input capacity (MBtu/hr)

= can be collected on site or from specification sheets

$\eta_{base}$ = efficiency of existing heating unit

= collected from equipment nameplate or assumed as70% for steam unit heaters, 80% for gas fired unit heaters, and 84% for rooftop units[603]

$\eta_{eff}$ = efficiency of HTHV unit

= collected from equipment nameplate or assumed as 92%

100 = converts MBtu to therms

See table below for savings inputs.

| Parameter | Existing Unit | Proposed (Efficient) Unit |
|---|---|---|
| Temperatures | | |
| Setpoint Temperature (°F) | $T_{setpoint}$ = collected on site, or assumed as 65°F | |
| Ceiling Temperature[604] (°F) | Either collected on site when the existing unit is in operation with an infrared gun, or assumed as: $T_{c,base} = T_{setpoint} + 0.53°F/ft * Height$ | Either collected on site when the proposed unit is in operation with an infrared gun, or assumed as: $T_{c,eff} = T_{setpoint} + 2$ to 4°F |
| Average Room Temperature (°F) | $T_{r,base} = (T_{setpoint} + T_{c,base})/2$ | $T_{r,eff} = (T_{setpoint} + T_{c,eff})/2$ |
| Outside Air Temperature (°F) | $T_{OA}$ , from local weather data[605] | |
| Heat Loads | | |
| Infiltration Load[606]: | $Q_{inf,base}$= 0.04CFM/ft$^2$ * (Wall Surface Area + Roof Surface Area) * 1.08 * ($T_{r,base} - T_{OA}$) | $Q_{inf,eff}$= 0.04CFM/ft$^2$ * (Wall Surface Area + Roof Surface Area) * 1.08 * ($T_{r,eff} - T_{OA}$) |
| Wall Conduction Load[607]: | $Q_{w,base}$ = 1/R-value$_{wall}$ * (Wall Surface Area * 1.08 * ($T_{r,base} - T_{OA}$) Where R-value$_{wall}$ = the insulation value of the wall. It can be collected on site, or assumed as R-15. | $Q_{w,eff}$ = 1/R-value$_{wall}$ * (Wall Surface Area * 1.08 * ($T_{r,eff} - T_{OA}$) Where R-value$_{wall}$ = the insulation value of the wall. It can be collected on site, or assumed as R-15. |

[603] Efficiency of existing systems assumed from ASHRAE 90.1 – 2010 and manufacturer's specification sheets for various equipment. Steam unit heaters have a lower efficiency due to steam distribution losses.

[604] Baseline stratification rate is based on data collected in "Field Demonstation of High Efficiency Gas Heaters", prepared for Better Buildings Alliance, US. DOE, Jim Young, Navigant Consulting, 2014. The study also verifies that the proposed ceiling temperature cen be maintained within 2-4°F of the setpoint.

[605] Use Typical Meteorological Year (TMY3) data from NREL.

[606] Typical infiltration rate assumed from Infiltration Modeling Guidelines for Commercial Building Energy Analysis, prepared for US. DOE by Pacific Northwestern National Laboratory, 2009

[607] Roof and Wall Insulation R-values are based on ASHRAE 90.1- 2010. (Jim Young 2014) (K. Gowri 2009)

| Parameter | Existing Unit | Proposed (Efficient) Unit |
|---|---|---|
| Roof Conduction Load: | $Q_{r,base}$ = 1/R-value$_{roof}$ * (Roof Surface Area * 1.08 * ($T_{r,base}$ - $T_{OA}$)<br>Where R-value$_{roof}$ = the insulation value of the roof. It can be collected on site, or assumed as R-20. | $Q_{r,eff}$ = 1/R-value$_{roof}$ * (Roof Surface Area * 1.08 * ($T_{r,eff}$ - $T_{OA}$)<br>Where R-value$_{roof}$ = the insulation value of the roof. It can be collected on site, or assumed as R-20. |
| Surface Areas | | |
| Roof Surface Area: | Collected on site or assumed as:<br>= facility area in sq.ft.<br>If facility area is unknown, assume facility area[608] = 41.4 sq. ft./MBtu/hr * $Cap_{eff}$ | |
| Wall Surface Area: | Collected on site or assumed as:<br>= (Height * Length + Height * Width) * 2<br>Where:<br>Length, Height and Width (feet) of the facility can be collected on site. If unknown, assume:<br>Length = Width = (Facility Area)$^{1/2}$ and Height = 25 ft<br>If facility area is unknown, assume facility area = 41.4 sq. ft./MBtu/hr * $Cap_{eff}$ | |

The default values from the table above were used to calculate the deemed savings values in the table below. Savings are provided for various rated input capacity ranges and weather stations.

| $Cap_{eff}$ (MBtu/hr) | Average $Cap_{eff}$ (MBtu/hr) | Nearest Weather Station | ΔTherms (Baseline Equipment: Steam Fired Unit Heaters ) | ΔTherms (Baseline Equipment: Gas Fired Unit Heaters) | ΔTherms (Baseline Equipment: Rooftop Units) |
|---|---|---|---|---|---|
| 300 > $Cap_{eff}$ ≥ 500 | 400 | Rockford | 3,120 | 1,996 | 1,620 |
| 500 > $Cap_{eff}$ ≥ 900 | 757 | Rockford | 5,208 | 3,346 | 2,725 |
| 900 > $Cap_{eff}$ ≥ 1,000 | 950 | Rockford | 6,280 | 4,047 | 3,297 |
| 1,000 > $Cap_{eff}$ ≥ 1,400 | 1,200 | Rockford | 7,656 | 4,932 | 4,020 |
| 1,400 > $Cap_{eff}$ ≥ 1,600 | 1,499 | Rockford | 9,249 | 5,966 | 4,872 |
| 1,600 > $Cap_{eff}$ ≥ 2,100 | 1,850 | Rockford | 11,100 | 7,160 | 5,865 |
| 2,100 > $Cap_{eff}$ ≥ 2,400 | 2,200 | Rockford | 12,914 | 8,338 | 6,820 |
| $Cap_{eff}$ ≥ 2,400 | 2,718 | Rockford | 15,547 | 10,084 | 8,236 |
| 300 > $Cap_{eff}$ ≥ 500 | 400 | Chicago | 2,820 | 1,824 | 1,488 |
| 500 > $Cap_{eff}$ ≥ 900 | 757 | Chicago | 4,709 | 3,058 | 2,506 |
| 900 > $Cap_{eff}$ ≥ 1,000 | 950 | Chicago | 5,681 | 3,696 | 3,031 |
| 1,000 > $Cap_{eff}$ ≥ 1,400 | 1,200 | Chicago | 6,924 | 4,512 | 3,696 |
| 1,400 > $Cap_{eff}$ ≥ 1,600 | 1,499 | Chicago | 8,364 | 5,456 | 4,482 |
| 1,600 > $Cap_{eff}$ ≥ 2,100 | 1,850 | Chicago | 10,046 | 6,549 | 5,384 |
| 2,100 > $Cap_{eff}$ ≥ 2,400 | 2,200 | Chicago | 11,682 | 7,634 | 6,292 |
| $Cap_{eff}$ ≥ 2,400 | 2,718 | Chicago | 14,079 | 9,214 | 7,583 |
| 300 > $Cap_{eff}$ ≥ 500 | 400 | Springfield | 2,452 | 1,588 | 1,300 |
| 500 > $Cap_{eff}$ ≥ 900 | 757 | Springfield | 4,095 | 2,665 | 2,188 |
| 900 > $Cap_{eff}$ ≥ 1,000 | 950 | Springfield | 4,950 | 3,221 | 2,651 |
| 1,000 > $Cap_{eff}$ ≥ 1,400 | 1,200 | Springfield | 6,024 | 3,936 | 3,240 |
| 1,400 > $Cap_{eff}$ ≥ 1,600 | 1,499 | Springfield | 7,285 | 4,767 | 3,912 |
| 1,600 > $Cap_{eff}$ ≥ 2,100 | 1,850 | Springfield | 8,732 | 5,717 | 4,718 |
| 2,100 > $Cap_{eff}$ ≥ 2,400 | 2,200 | Springfield | 10,164 | 6,666 | 5,500 |
| $Cap_{eff}$ ≥ 2,400 | 2,718 | Springfield | 12,258 | 8,045 | 6,632 |
| 300 > $Cap_{eff}$ ≥ 500 | 400 | Belleville | 2,456 | 1,604 | 1,320 |
| 500 > $Cap_{eff}$ ≥ 900 | 757 | Belleville | 4,103 | 2,687 | 2,218 |

[608] Based on DOE's Commercial Prototype Modeled Warehouse building (in Chicago), via the Building Energy Codes Program

| $Cap_{eff}$ (MBtu/hr) | Average $Cap_{eff}$ (MBtu/hr) | Nearest Weather Station | ΔTherms (Baseline Equipment: Steam Fired Unit Heaters ) | ΔTherms (Baseline Equipment: Gas Fired Unit Heaters) | ΔTherms (Baseline Equipment: Rooftop Units) |
|---|---|---|---|---|---|
| 900 > $Cap_{eff}$ ≥ 1,000 | 950 | Belleville | 4,950 | 3,249 | 2,689 |
| 1,000 > $Cap_{eff}$ ≥ 1,400 | 1,200 | Belleville | 6,036 | 3,972 | 3,276 |
| 1,400 > $Cap_{eff}$ ≥ 1,600 | 1,499 | Belleville | 7,300 | 4,812 | 3,972 |
| 1,600 > $Cap_{eff}$ ≥ 2,100 | 1,850 | Belleville | 8,751 | 5,772 | 4,773 |
| 2,100 > $Cap_{eff}$ ≥ 2,400 | 2,200 | Belleville | 10,186 | 6,732 | 5,566 |
| $Cap_{eff}$ ≥ 2,400 | 2,718 | Belleville | 12,285 | 8,127 | 6,713 |
| 300 > $Cap_{eff}$ ≥ 500 | 400 | Marion | 2,180 | 1,444 | 1,200 |
| 500 > $Cap_{eff}$ ≥ 900 | 757 | Marion | 3,649 | 2,430 | 2,021 |
| 900 > $Cap_{eff}$ ≥ 1,000 | 950 | Marion | 4,408 | 2,936 | 2,442 |
| 1,000 > $Cap_{eff}$ ≥ 1,400 | 1,200 | Marion | 5,364 | 3,576 | 2,988 |
| 1,400 > $Cap_{eff}$ ≥ 1,600 | 1,499 | Marion | 6,491 | 4,332 | 3,613 |
| 1,600 > $Cap_{eff}$ ≥ 2,100 | 1,850 | Marion | 7,789 | 5,217 | 4,348 |
| 2,100 > $Cap_{eff}$ ≥ 2,400 | 2,200 | Marion | 9,064 | 6,072 | 5,082 |
| $Cap_{eff}$ ≥ 2,400 | 2,718 | Marion | 10,926 | 7,339 | 6,116 |

### Water and Other Non-Energy Impact Descriptions and Calculation

N/A

### Deemed O&M Cost Adjustment Calculation

N/A

### Measure Code: CI-HVC-HTHV-V01-180101

### Review Deadline: 1/1/2023

## 4.4.40 Gas High Efficiency Single Package Vertical Air Conditioner

### Description

This measure covers the installation of a single package vertical air conditional with a high efficiency gas furnace, referred to here as a through the wall (TTW) condensing gas furnace, instead of a standard efficiency gas furnace. The primary market served by TTWs are multifamily housing and hospitality in a new construction application. High efficiency gas furnaces achieve savings through the utilization of a sealed, super insulated combustion chamber, more efficient burners, and multiple heat exchangers that remove a significant portion of the waste heat from the flue gases. Because multiple heat exchangers are used to remove waste heat from the escaping flue gases, most of the flue gases condense and must be drained. Management of the acidic condensate is currently a major limiting factor for retrofit application, making the new construction the best initial market point until the industry develops better strategies for condensate management for retrofit applications. Also, TTWs are normally installed at the exterior wall to access outside air to reject heat in the cooling cycle. Placement of TTWs near the exterior might be prohibitive in retrofit applications. Furnaces equipped with ECM fan motors and with above code EER ratings provide an opportunity for additional electric energy savings.

This measure assumes unit size less than or equal to 65,000 Btu/hr.

This measure was developed to be applicable to the following program types: NC, TOS. If applied to other program types such as RF, the measure savings should be verified via a custom measure.

### Definition of Efficient Equipment

To qualify for this measure the installed equipment must be an TTW condensing system with code minimum 9.0 EER cooling system (minimum code scheduled to increase to 11.0 EER on September 23, 2019) and a high-efficiency gas furnace with an annual fuel utilization efficiency (AFUE) of 90% or greater.[609] Fan electrical efficiency must exceed the program requirements.

### Definition of Baseline Equipment

Baseline equipment for this measure are units with a cooling system that meets the current code minimum 9.0 EER efficiency rating and a heating unit with an AFUE rating of 80% or less.

### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 16.5 years[610].

### Deemed Measure Cost

The incremental capital cost for this measure depends on efficiency as listed below[611]:

| AFUE | Incremental Cost Premium |
|---|---|
| 80% | $400 |
| 90% | $400 |
| 95% | $500 |

### Loadshape

Loadshape R08 – Residential Cooling

[609] Electronic Code of Federal Regulations: 10 CFR 431.97, last modified September 27, 2016. Minimum EER standards are scheduled to increase to 11.0 EER on September 23, 2019.
[610] Average of 15-18 year lifetime estimate made by the Consortium for Energy Efficiency in 2010
[611] Based on discussion with TTW Manufacturers at AHR 2018 Show in Chicago, IL.

### COINCIDENCE FACTOR

The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the average savings over the defined summer peak period, and is presented so that savings can be bid into PJM's Forward Capacity Market.

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Central A/C (during utility peak hour) [4]

= 68%[612]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period)

= 46.6%[613]

## Algorithm

### CALCULATION OF ENERGY SAVINGS

### ELECTRIC ENERGY SAVINGS

Electric savings come from a high efficiency cooling unit[614]. In some instances, the TTW unit provided by the manufacturer may not have higher efficiency cooling and fan blower motor systems integrated in to the TTW design; in these cases, electric energy savings will be zero for those components.

$$\Delta kWh_{EER} = FLH_{cool} * Capacity * (1/EER_{base} - 1/EER_{eff}) / 1000$$

Where:

$FLH_{cool}$ = Full load hours for cooling [615]:

| Climate Zone (City based upon) | $FLH_{cool}$ (multi family) |
|---|---|
| 1 (Rockford) | 467 |
| 2 (Chicago) | 506 |
| 3 (Springfield) | 663 |
| 4 (Belleville) | 940 |
| 5 (Marion) | 820 |
| Weighted Average | 564 |

Capacity = Cooling capacity of the efficient unit in Btu/hr

= Actual installed

$EER_{eff}$ = Energy efficiency ratio of the efficient equipment

= Actual installed rating

[612] Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

[613] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.

[614] If an ECM motor in the packaged system is present, savings should be claimed for this measure by referring to the Residential Furnace Blower Motor measure in the IL TRM.

[615] Full load hours for Chicago, Moline and Rockford are provided in "Final Evaluation Report: Central Air Conditioning Efficiency Services (CACES), 2010, Navigant Consulting", p.33. An average FLH/Cooling Degree Day (from NCDC) ratio was calculated for these locations and applied to the CDD of the other locations in order to estimate FLH. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

$EER_{base}$ = Energy efficiency ratio of the baseline equipment – Presently, the federal minimum efficiency level is 9.0 EER, increasing to 11.0 EER on September 23, 2019[616]

= 9.0

**Example**: for a Rockford non-weatherized multifamily unit conditioned by a SPVAC with a 2-ton (24,000 Btu/hr) cooling capacity, a rated EER of 11.0, and an ECM fan blower motor installed.

ΔkWh = [467 * 24,000 * (1/9.0 – 1/11.0) / 1000] = 958 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$$\Delta kW = CF * Capacity * (1/EER_{base} - 1/EER_{eff}) / 1000$$

Where:

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Central A/C (during utility peak hour)

= 68%[617]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period)

= 46.6%[618]

**NATURAL GAS SAVINGS**

$$\Delta Therms = EFLH_{heat} * Capacity * (AFUE_{eff} – AFUE_{base}) / AFUE_{base} / (100,000\ Btu/Therm)$$

Where

$EFLH_{heat}$ = Equivalent Full Load Hours for heating[619]

| Climate Zone (City based upon) | $EFLH_{heat}$ (general multi family) |
|---|---|
| 1 (Rockford) | 1,742 |
| 2 (Chicago) | 1,704 |
| 3 (Springfield) | 1,498 |
| 4 (Belleville) | 1,208 |
| 5 (Marion) | 1,429 |

Capacity = Nominal heating input capacity furnace size (Btu/hr) for efficient unit

= Actual

$AFUE_{eff}$ = Efficient furnace annual fuel utilization efficiency rating

= Actual installed rating

$AFUE_{base}$ = Baseline furnace annual fuel utilization efficiency rating

= 80%

616 Electronic Code of Federal Regulations: 10 CFR 431.97, last modified September 27, 2016. Minimum EER standards are scheduled to increase to 11.0 EER on September 23, 2019.
617 Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.
618 Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.
619 See section 4.4 for details.

For example for a Chicago non-weatherized multifamily unit heated by an SPVAC with a 40 kBtu/hr capacity and a rated AFUE of 93%.

$\Delta$Therms = 1,704 * 40,000 * [(0.93 – 0.8)/0.8] / (100,000 Btu/Therm) = 111 therms

**WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-HVC -SPVA-V01-190101**

**REVIEW DEADLINE: 1/1/2023**

## 4.4.41 Advanced Rooftop Controls (ARC)

### Description

The Advanced Rooftop Controls (ARC) measure installs demand-controlled ventilation with optional supply-fan speed control via a variable-frequency drive to a single-zone, packaged HVAC unit with a functioning integrated economizer already installed. The demand-controlled ventilation modulates the outside air damper based on CO2 concentration in the conditioned space. The supply-fan speed control options consist of setting the fan speed to 40% in ventilation mode and to 90% in heating and cooling modes, or of setting the fan speed to 40% in ventilation mode, to 75% in 1st stage heating and 1st stage cooling modes, and to 90% in 2nd stage heating and 2nd stage cooling modes. The measure results in fan, cooling, and heating savings compared to a baseline scenario of constant-volume, constant-ventilation operation typical of single-zone, packaged HVAC units. There are a number of off-the-shelf products available for the packaged HVAC unit market that support these control sequences, and the energy savings potential of these strategies has been studied and reported on.[620]

Demand-controlled ventilation modulates the percentage of outside air that is delivered to a space and its occupants by controlling the position of the outside air damper. The outside air damper is set to the minimum position required for the space, and is opened further when CO2 concentration in the conditioned space increases, which indicates an increase in occupancy. The damper also opens to provide 100% outside air cooling (i.e., the unit economizes) when conditions permit. This portion of the measure saves energy by minimizing the energy required to unnecessarily heat and cool outside air. Demand-controlled ventilation can also be combined with the installation of a variable-frequency drive on the supply fan. This drive is used to reduce the speed of the supply fan when the full design airflow is not required. When the unit is only providing ventilation air (i.e., not heating or cooling), the airflow is reduced substantially, but not below the required minimum ventilation rate. The flow for heating and cooling can also be reduced a small amount in most cases. Per the fan affinity laws, the reduction in flow correlates to a near cubic reduction in fan power. In these ways, this measure is able to achieve cooling, heating, and fan energy reduction.

This measure is intended for commercial buildings served by single-zone, packaged HVAC units. This measure was developed to be applicable to the following program types: RF, DI

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

The efficient equipment is a single-zone, packaged HVAC unit (with an existing functional integrated economizer) that has been retrofitted with demand-controlled ventilation controls with optional supply-fan speed control via a variable-frequency drive.

### Definition of Baseline Equipment

The baseline equipment is a single-zone, packaged HVAC unit (with an existing functional integrated economizer) that lacks demand-controlled ventilation controls and lacks supply-fan speed control via a variable-frequency drive.

### Deemed Lifetime of Efficient Equipment

The deemed measure life is 10 years and based on CO2 sensor estimated life.[621]

### Deemed Measure Cost

Actual measure costs should be used if available. If costs are not available, the deemed measure cost below can be used.

---

[620] Katipamula, S., et al, "Advanced Rooftop Control (ARC) Retrofit: Field-Test Results", Pacific Northwest National Laboratory, July 2013

[621] Based on IL TRM v6.0 Vol. 2 – 4.4.19 Demand Controlled Ventilation

**Table 1 – Deemed Measure Cost Details**

| Measure | Material Unit (Each) | Material Cost / Unit | Labor Unit (Hours) | Labor Rate/ Unit | Total Cost |
|---|---|---|---|---|---|
| DCV | 1 | $1,663.90 | 3 | $96.67 | $1,953.91 |
| DCV and VFD with two speed modes (40% ventilating & 90% heating/cooling) | 1 | $3,025.38 | 4 | $96.67 | $3,412.06 |
| DCV and VFD with three speed modes (40% ventilating, 75% 1st stage heating/cooling & 90% 2nd stage heating/cooling) | 1 | $3,487.00 | 4 | $96.67 | $3,873.68 |

### Loadshape

Commercial ventilation C23

### Coincidence Factor

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [622]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [623]

## Algorithm

### Calculation of Energy Savings

To determine the savings associated with the Advanced Rooftop Controls (ARC) measure we utilized the available IL TRM prototype eQuest models which were initially created by the Energy Center of Wisconsin[624] but modified by VEIC in 2014 as part of the IL TRM v4.0 Equivalent Full Load Hours (EFLH) update. For each building type we used the most recent versions of the models for our baseline models (Assembly was not part of EFLH update). These models which were used are the most up-to-date versions and are readily available on the VEIC SharePoint site, under the TRM Reference Documents Section.

Upon examination of the ComEd building prototype models we found several of the baseline models did not have packaged single zone (PSZ) units. This measure is targeting packaged single zone HVAC systems. Therefore, as a basis for savings calculations, we chose only models that: 1) utilized PSZ HVAC systems, and 2) aligned with the small commercial building type applicable to this measure. Once the ComEd baseline models were selected, we determined several modifications were necessary to the prototype models in order to represent the baseline scenario for this measure:

1. Multistage PSZ HVAC System with Constant Volume Supply Fan
2. Optimized Economizer Controls by Climate Zone
    a. Economizer Changeover Type – Set to fixed Dry Bulb
    b. Economizer High-Limit Control Setpoints – Setpoints based on ASHRAE Climate Zones Fixed Dry Bulb Temperature recommendations.

[622] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility's peak hour is divided by the maximum AC load during the year.
[623] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year
[624] Energy Center of Wisconsin, ComEd Portfolio Modeling Report, July 30, 2010

c. Enable Integrated Operation – Allows economizer to operate simultaneously with mechanical cooling

Additionally, a number of the building prototype models were found to have supply fan total static pressure modeled inputs that seem excessive and atypical for packaged single zone rooftop units – these included Convenience Store (5 in. wc), Manufacturing Facility (5 in. wc), Office Low Rise (5 in. wc), Religious Building (5 in. wc), and Restaurant (5 in. wc). The remaining models had supply fan total static pressure inputs more in line with what we would expect to find for packaged single zone rooftop units, ranging from 1.3 to 2 in. wc. For each model having a supply fan total static pressure above 2 in. wc, model inputs were adjusted to set these to 2 in. wc. To implement the modifications shown above, changes were made to eQUEST keywords in the ComEd prototype models as shown in the following table. Hard-coded system capacities and supply airflows can be found in the attached "Advanced Rooftop Controls_End Use Analysis_IL TRM.xlsx" spreadsheet.

**Table 2 – Prototype Modifications to eQuest Keywords**

| Component Adjusted | eQuest Keyword | IL TR Value | Modified Prototype Value |
|---|---|---|---|
| System - System Type | SYSTEM:TYPE | PSZ | PVVT |
| System - Airflow and Temperature Control | SYSTEM:AIR/TEMP-CONTROL | N/A | STAGED-VOLUME |
| System – Supply Fan Total Static Pressure | SYSTEM:SUPPLY-STATIC | Varies | If >2: 2<br>Else: IL TR Value |
| System - Cooling and Heating Capacities | SYSTEM:COOLING-CAPACITY<br>SYSTEM:HEATING-CAPACITY | Auto-sized | Hard-coded (after retrieving auto-sized outputs) |
| System - Supply Fan Control | SYSTEM:FAN-CONTROL | Varies | CONSTANT-VOLUME |
| System - Supply Fan Ratios | SYSTEM:MIN-FLOW-RATIO<br>SYSTEM:CMIN-FLOW-RATIO<br>SYSTEM:HMIN-FLOW-RATIO<br>SYSTEM:-MAX-FAN-RATIO | N/A | 1 |
| System - Supply Airflow | SYSTEM:SUPPLY-FLOW | Auto-sized | Hard-coded (after retrieving auto-sized outputs) |
| Economizer - Changeover Type | SYSTEM:OA-CONTROL | Fixed | Single Dry-Bulb |
| Economizer - Changeover Setpoint | SYSTEM-ECONO-LIMIT-T | Varies | ASHRAE 90.1-2013 – High-Limit Shutoff Control Settings:<br>ASHRAE CLIMATE ZONE – 4A = 65°F<br>ASHRAE CLIMATE ZONE – 5A = 70°F |
| Economizer - Integrated Operation | SYSTEM:ECONO-LOCKOUT | Yes | No |

Further modifications were then made to these baseline models in order to simulate the following measure scenarios:

1. Demand-controlled ventilation (DCV) controls
2. DCV and supply fan variable frequency drive (VFD) with two fan speed modes
    a. 40% fan speed for ventilating
    b. 90% fan speed for heating and cooling
3. DCV and supply fan VFD with three fan speed modes
    a. 40% fan speed for ventilating
    b. 75% fan speed for 1st stage heating and cooling

c. 90% fan speed for 2nd and higher stage heating and cooling

The eQuest modifications from the baseline models to represent these measure scenarios are shown in the following table. Full modeled energy end use and savings summaries can be found in the attached "Advanced Rooftop Controls_End Use Analysis_IL TRM.xlsx" spreadsheet.

**Table 3 – Baseline and Measure Scenario eQuest Keywords**

| Component Adjusted | eQuest Keyword | Baseline Value | Measure Scenario Values | | |
|---|---|---|---|---|---|
| | | | 1 | 2 | 3 |
| System - Minimum Outside Air Control | SYSTEM:MIN-OA-METHOD | Fraction of Design Flow | DCV Return Sensor | DCV Return Sensor | DCV Return Sensor |
| System - Supply Airflow | SYSTEM:SUPPLY-FLOW | Hard-coded | 1.0 × Hard-coded value | 0.9 × Hard-coded value | 0.9 × Hard-coded value |
| System - Supply Fan Control | SYSTEM:FAN-CONTROL | CONSTANT-VOLUME | CONSTANT-VOLUME | FAN-EIR-FPLR | FAN-EIR-FPLR |
| System - Supply Fan Ratios | SYSTEM:MIN-FLOW-RATIO<br>SYSTEM:CMIN-FLOW-RATIO<br>SYSTEM:HMIN-FLOW-RATIO<br>SYSTEM:-MAX-FAN-RATIO | 1<br>1<br>1<br>1 | 1<br>1<br>1<br>1 | 0.44*<br>1<br>1<br>1 | 0.44*<br>0.83**<br>0.83**<br>1 |

*Since the total supply flow is limited by 0.9 of the baseline, a value of 0.44 for the minimum flow ratio results in a 40% fan speed: 0.4/0.9=0.44

** Since the total supply flow is limited by 0.9 of the baseline, a value of 0.83 for the minimum heating/cooling flow ratios results in a 75% fan speed: 0.75/0.9=0.83

With these modifications in place each scenario was simulated in eQuest for each chosen IL TRM prototype building type across the five TRM climate zones. Whole building electric and gas savings were determined from the simulation output and are presented in the following sections. Electric savings have been normalized by cooling tons and heating savings by furnace kBtuh output.

**ELECTRIC ENERGY SAVINGS**

$$\Delta kWh = (tons) \times \text{Normalized Electric Energy Savings}$$

Where:

tons = capacity of the cooling equipment in tons (nominal tonnage may be used).

=Actual

Normalized Electric Energy Savings

= kWh/ton savings value for the appropriate combination of building type, climate zone, and measure scenario per Table 4 – Electric Energy Savings Summary (kWh/ton)

**Table 4 – Electric Energy Savings Summary (kWh/ton)**

| Building Type - IL TRM Prototype Model Name | Rockford - Zone 1 | | | Chicago - Zone 2 | | | Springfield - Zone 3 | | | Mt Vernon/Belleville - Zone 4 | | | Marion - Zone 5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Measure Scenario:<br>1 - DCV<br>2 - DCV and VFD w/ 2-speed fan control<br>3 - DCV and VFD w/ 3-speed fan control | | | | | | | | | | | | | | |
| | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| **Assembly** | 52.0 | 145.8 | 168.7 | 51.4 | 154.6 | 175.5 | 85.2 | 189.0 | 205.8 | 95.7 | 199.7 | 213.7 | 89.7 | 200.8 | 210.4 |
| **Assisted Living** | 8.0 | 574.4 | 604.7 | 8.8 | 580.5 | 605.5 | 14.7 | 578.2 | 598.7 | 15.6 | 589.1 | 609.4 | 16.5 | 600.9 | 615.5 |
| **College** | 49.7 | 410.8 | 448.4 | 54.1 | 410.4 | 442.0 | 106.5 | 464.1 | 490.9 | 139.1 | 514.3 | 537.0 | 158.7 | 511.9 | 526.3 |
| **Conditioned Storage** | 1.9 | 339.8 | 393.6 | 3.5 | 355.1 | 404.5 | 5.9 | 346.3 | 388.6 | 9.5 | 349.5 | 384.5 | 10.3 | 349.5 | 371.7 |
| **Convenience Store** | 46.4 | 918.9 | 984.1 | 49.9 | 921.0 | 977.0 | 82.3 | 955.1 | 1,000.2 | 86.9 | 996.3 | 1,035.0 | 103.7 | 998.3 | 1,022.7 |
| **Garage** | 14.8 | 479.7 | 578.9 | 19.2 | 482.9 | 573.6 | 25.9 | 510.4 | 586.3 | 48.4 | 570.1 | 640.3 | 53.0 | 589.0 | 648.7 |
| **Grocery** | 41.8 | 480.1 | 505.1 | 43.9 | 486.5 | 507.6 | 68.1 | 502.8 | 520.4 | 83.2 | 536.1 | 550.6 | 89.7 | 539.8 | 547.9 |
| **Manufacturing Facility** | 7.7 | 773.4 | 824.8 | 9.0 | 761.4 | 807.1 | 19.6 | 771.8 | 809.3 | 30.8 | 801.2 | 832.8 | 34.2 | 784.9 | 802.5 |
| **Office Low Rise** | 15.2 | 1,071.2 | 1,147.3 | 17.2 | 1,065.8 | 1,131.8 | 23.1 | 1,062.2 | 1,115.7 | 30.5 | 1,091.4 | 1,137.7 | 31.2 | 1,042.2 | 1,071.7 |
| **Religious Building** | 6.5 | 869.4 | 1,016.9 | 6.3 | 894.6 | 1,029.6 | 11.1 | 931.0 | 1,047.1 | 15.5 | 1,005.4 | 1,108.3 | 15.0 | 1,051.1 | 1,134.0 |
| **Restaurant** | 13.8 | 554.0 | 598.2 | 14.9 | 574.2 | 610.8 | 26.4 | 564.5 | 596.6 | 27.7 | 606.3 | 637.2 | 25.8 | 603.5 | 628.3 |
| **Retail Department Store** | 34.0 | 692.6 | 751.0 | 34.4 | 697.7 | 749.0 | 55.4 | 715.0 | 757.7 | 60.8 | 725.4 | 761.1 | 64.3 | 723.2 | 743.8 |
| **Retail Strip Mall** | 30.9 | 739.7 | 782.5 | 32.9 | 734.1 | 770.5 | 50.8 | 748.5 | 776.8 | 55.3 | 761.3 | 784.8 | 60.1 | 755.2 | 768.4 |

For example, a 10-ton rooftop air conditioner on an office low rise building in Chicago installs DCV with 2-speed supply fan control (operating at 40% in ventilating mode and 90% in heating and cooling modes):

$\Delta$Therms = (10 tons) × (1,065.8 kWh/ton)

= 10,658 kWh

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta$kWssp = (tons) × Normalized Electric Peak Demand Savings × CFssp

$\Delta$kWpjm = (tons) × Normalized Electric Peak Demand Savings × CFpjm

Where:

tons = capacity of the cooling equipment in tons (nominal tonnage may be used).

=Actual

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [625]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [626]

Normalized Electric Peak Demand Savings

= kW/ton savings value for the appropriate combination of building type, climate zone, and measure scenario per Table 5 – Electric Peak Demand Savings Summary (kW/ton)

[625] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility's peak hour is divided by the maximum AC load during the year.

[626] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year

**Table 5 – Electric Peak Demand Savings Summary (kW/ton)**

| Building Type - IL TRM Prototype Model Name | Rockford - Zone 1 | | | Chicago - Zone 2 | | | Springfield - Zone 3 | | | Mt Vernon/Belleville - Zone 4 | | | Marion - Zone 5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Measure Scenario:<br>1 - DCV<br>2 - DCV and VFD w/ 2-speed fan control<br>3 - DCV and VFD w/ 3-speed fan control | | | | | | | | | | | | | | |
| | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| **Assembly** | 0.024 | 0.107 | 0.107 | 0.086 | 0.126 | 0.126 | 0.015 | 0.042 | 0.042 | 0.069 | 0.095 | 0.095 | 0.048 | 0.064 | 0.064 |
| **Assisted Living** | 0.021 | 0.116 | 0.116 | 0.021 | 0.075 | 0.075 | 0.018 | 0.086 | 0.086 | 0.021 | 0.092 | 0.092 | 0.024 | 0.081 | 0.081 |
| **College** | 0.007 | 0.207 | 0.207 | 0.007 | 0.090 | 0.090 | 0.006 | 0.179 | 0.179 | 0.005 | 0.132 | 0.132 | 0.009 | 0.074 | 0.074 |
| **Conditioned Storage** | 0.007 | 0.065 | 0.065 | 0.006 | 0.083 | 0.083 | 0.010 | 0.096 | 0.096 | 0.005 | 0.060 | 0.060 | 0.007 | 0.071 | 0.071 |
| **Convenience Store** | 0.047 | 0.369 | 0.369 | 0.053 | 0.394 | 0.394 | 0.042 | 0.395 | 0.395 | 0.017 | 0.356 | 0.356 | 0.067 | 0.390 | 0.390 |
| **Garage** | 0.012 | 0.054 | 0.054 | 0.011 | 0.053 | 0.053 | 0.011 | 0.053 | 0.053 | 0.011 | 0.068 | 0.068 | 0.007 | 0.061 | 0.061 |
| **Grocery** | 0.065 | 0.122 | 0.122 | 0.034 | 0.080 | 0.080 | 0.033 | 0.088 | 0.088 | 0.072 | 0.119 | 0.119 | 0.033 | 0.082 | 0.082 |
| **Manufacturing Facility** | 0.008 | 0.335 | 0.335 | 0.006 | 0.296 | 0.296 | -0.003 | 0.283 | 0.283 | 0.000 | 0.333 | 0.333 | 0.049 | 0.376 | 0.376 |
| **Office Low Rise** | 0.011 | 0.395 | 0.395 | 0.009 | 0.346 | 0.346 | 0.007 | 0.366 | 0.366 | 0.011 | 0.384 | 0.384 | 0.029 | 0.385 | 0.385 |
| **Religious Building** | 0.000 | 0.462 | 0.465 | 0.000 | 0.406 | 0.409 | 0.000 | 0.461 | 0.461 | 0.000 | 0.456 | 0.457 | 0.000 | 0.464 | 0.467 |
| **Restaurant** | 0.030 | 0.231 | 0.231 | 0.034 | 0.162 | 0.162 | 0.023 | 0.113 | 0.113 | 0.033 | 0.134 | 0.134 | 0.006 | 0.069 | 0.069 |
| **Retail Department Store** | 0.057 | 0.152 | 0.152 | 0.042 | 0.120 | 0.120 | 0.029 | 0.099 | 0.099 | 0.029 | 0.113 | 0.113 | 0.066 | 0.149 | 0.149 |
| **Retail Strip Mall** | 0.046 | 0.171 | 0.171 | 0.046 | 0.191 | 0.191 | 0.042 | 0.189 | 0.189 | 0.020 | 0.158 | 0.158 | 0.066 | 0.178 | 0.178 |

For example, a 10-ton rooftop air conditioner on an office low rise building in Chicago installs DCV with 2-speed supply fan control (operating at 40% in ventilating mode and 90% in heating and cooling modes) using the Summer System Peak Coincidence Factor:

$$\Delta kW = (10 \text{ tons}) \times (0.346 \text{ kW/ton}) \times 91.3\%$$

$$= 3.159 \text{ kW}$$

**NATURAL GAS SAVINGS**

$$\Delta Therms = (\text{kBtuh output}) \times \text{Normalized Gas Energy Savings}$$

Where:

kBtuh = heating output of the gas furnace in kBtuh

=Actual

Normalized Gas Energy Savings

= Therms/kBtuh output savings value for the appropriate combination of building type, climate zone, and measure scenario per Table 6 – Gas Energy Savings Summary (Therms/kBtuh output)

**Table 6 – Gas Energy Savings Summary (Therms/kBtuh output)**

| Building Type - IL TRM Prototype Model Name | Rockford - Zone 1 | | | Chicago - Zone 2 | | | Springfield - Zone 3 | | | Mt Vernon/Belleville - Zone 4 | | | Marion - Zone 5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Measure Scenario:<br>1 - DCV<br>2 - DCV and VFD w/ 2-speed fan control<br>3 - DCV and VFD w/ 3-speed fan control | | | | | | | | | | | | | | |
| | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| **Assembly** | 7.1 | 7.3 | 7.3 | 7.1 | 7.3 | 7.3 | 6.1 | 6.5 | 6.4 | 6.0 | 6.4 | 6.3 | 6.0 | 6.6 | 6.5 |
| **Assisted Living** | 1.0 | 0.5 | 0.2 | 0.8 | 0.4 | 0.1 | 0.7 | 0.3 | 0.1 | 0.7 | 0.5 | 0.2 | 0.6 | 0.5 | 0.2 |
| **College** | 7.2 | 6.8 | 6.6 | 6.3 | 6.0 | 5.8 | 5.3 | 5.0 | 4.9 | 4.3 | 4.2 | 4.0 | 2.8 | 2.7 | 2.6 |
| **Conditioned Storage** | 2.5 | 1.4 | 1.2 | 2.2 | 1.1 | 0.9 | 2.0 | 0.9 | 0.7 | 1.9 | 0.8 | 0.6 | 1.5 | 0.4 | 0.3 |
| **Convenience Store** | 4.8 | 3.8 | 3.6 | 4.3 | 3.3 | 3.1 | 3.7 | 2.8 | 2.7 | 3.5 | 2.7 | 2.5 | 2.9 | 2.2 | 2.0 |
| **Garage** | 0.5 | 0.4 | 0.3 | 0.4 | 0.3 | 0.3 | 0.4 | 0.3 | 0.2 | 0.4 | 0.3 | 0.2 | 0.4 | 0.3 | 0.3 |
| **Grocery** | 7.5 | 7.0 | 6.8 | 6.7 | 6.2 | 6.1 | 5.9 | 5.5 | 5.3 | 5.3 | 5.0 | 4.9 | 4.1 | 3.8 | 3.7 |
| **Manufacturing Facility** | 0.5 | 0.4 | 0.3 | 0.4 | 0.3 | 0.3 | 0.4 | 0.3 | 0.2 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| **Office Low Rise** | 2.8 | 1.2 | 1.0 | 2.5 | 0.9 | 0.7 | 2.0 | 0.8 | 0.6 | 1.8 | 0.6 | 0.5 | 1.3 | 0.2 | 0.2 |
| **Religious Building** | 0.9 | 1.1 | 1.3 | 0.8 | 0.9 | 1.1 | 0.7 | 0.8 | 0.9 | 0.6 | 0.8 | 0.9 | 0.6 | 0.6 | 0.7 |
| **Restaurant** | 2.9 | 2.2 | 1.9 | 2.5 | 1.8 | 1.6 | 2.2 | 1.6 | 1.4 | 2.0 | 1.6 | 1.3 | 1.7 | 1.3 | 1.1 |
| **Retail Department Store** | 2.5 | 1.5 | 1.4 | 2.3 | 1.3 | 1.1 | 2.0 | 1.1 | 1.0 | 1.8 | 1.1 | 0.9 | 1.5 | 0.9 | 0.8 |
| **Retail Strip Mall** | 2.4 | 1.9 | 1.7 | 2.1 | 1.6 | 1.5 | 1.8 | 1.4 | 1.3 | 1.7 | 1.4 | 1.3 | 1.5 | 1.2 | 1.1 |

For example, a rooftop unit with a 148 kBtuh output gas furnace on an office low rise building in Chicago installs DCV with 2-speed supply fan control (operating at 40% in ventilating mode and 90% in heating and cooling modes):

$$\Delta kWh = (148\ kBtuh) \times (0.9\ Therms/kBtuh\ output)$$

$$= 133.2\ Therms$$

## WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION

N/A

## DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

## MEASURE CODE: CI-HVC-ARTC-V01-190101

## REVIEW DEADLINE: 1/1/2023

## 4.4.42 Advanced Thermostats for Small Commercial

### DESCRIPTION

This measure characterizes the energy savings from the installation of an "Advanced Thermostat" for reduced heating and cooling consumption in a small commercial building. Advanced thermostats use a configurable schedule of temperature setpoints (like a programmable thermostat) *and* automatic variations to that schedule to better match HVAC system runtimes to meet occupant comfort needs. These schedules may be defaults, established through user interaction, and be changed manually at the device or remotely through a web or mobile app. Automatic variations to that schedule could be driven by local sensors and software algorithms, and/or through connectivity to an internet software service. Data triggers to automatic schedule changes might include, for example: occupancy/activity detection, arrival & departure of conditioned spaces, optimization based on historical or population-specific trends, weather data and forecasts.

The thermostat must be installed to control a single-zone HVAC system. This measure is limited to packaged HVAC units 5 tons or less. Systems larger will likely require more sophisticated controls to meet code requirements.

This class of products and services are relatively new, diverse, and rapidly changing. The savings associated with commercial installations of advanced thermostats have not been evaluated. In the absence of commercial specific assumptions, this TRM provides a deemed estimate based on the average residential savings. This is considered a reasonable starting assumption since the eligibility is limited to residential sized equipment and although on average commercial systems may be larger, it is predicted that reduced savings percentage will result in a similar average savings. It is highly recommended that the application of Advanced Thermostats in commercial settings be evaluated for future revisions.

Note that though these devices and service could potentially be used as part of a demand response program, the costs, delivery, impacts, and other aspects of DR-specific program delivery are not included in this characterization at this time, though they could be added in the future.

This measure was developed to be applicable to the following program types: TOS, NC, RF, DI.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

The criteria for this measure are established by replacement of a manual-only or programmable thermostat, with one that has the default enabled capability—or the capability to automatically—establish a schedule of temperature setpoints according to driving device inputs above and beyond basic time and temperature data of conventional programmable thermostats. As summarized in the description, this category of products and services is broad and rapidly advancing in regards to their capability, usability, and sophistication, but at a minimum must be capable of two-way communication and exceed the typical performance of manual and conventional programmable thermostats through the automatic or default capabilities described above.

### DEFINITION OF BASELINE EQUIPMENT

The baseline is either the actual type (manual or programmable) if it is known, or an assumed mix of these two types based upon information available from evaluations or surveys that represent the population of program participants. This mix may vary by program, but as a default, 44% programmable and 56% manual thermostats may be assumed.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for advanced thermostats is assumed to be 11 years[627].

[627] Based on 2017 Residential Smart Thermostat Workpaper, prepared by SCE and Nest for SCE (Work Paper SCE17HC054, Revision #0). Estimate ability of smart systems to continue providing savings after disconnection and conduct statistical survival analysis which yields 9.2-13.8 year range.

### DEEMED MEASURE COST

For DI and other programs for which installation services are provided, the actual material, labor, and other costs should be used. If unknown then the average incremental cost for the new installation measure is assumed to be $175.

### LOADSHAPE

Loadshape C05 - Commercial Electric Heating and Cooling, or

Loadshape C03 - Commercial Cooling

### COINCIDENCE FACTOR

In the absence of conclusive results from empirical studies on peak savings, the TAC agreed to a temporary assumption of 50% of the cooling coincidence factor, acknowledging that while the savings from the advanced Thermostat will track with the cooling load, the impact during peak periods may be lower. This is an assumption that could use future evaluation to improve these estimates.

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 45.7 [628]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 23.9% [629]

## Algorithm

### CALCULATION OF ENERGY SAVINGS

### ELECTRIC ENERGY SAVINGS

Deemed savings are provided based upon the average savings from the Residential version of this measure. Future evaluation on savings percentages for commercial applications should be used to improve this assumption.

$\Delta kWh$[630] = $\Delta kWh_{heating} + \Delta kWh_{cooling}$

$\Delta kWh_{heating}$ = %ElectricHeat * Elec_Heating_Consumption * Heating_Reduction * HF * Eff_ISR + ($\Delta$Therms * $F_e$ * 29.3)

$\Delta kWh_{cool}$ = %AC * ((FLH * Btu/hr * 1/SEER)/1000) * Cooling_Reduction * Eff_ISR

For basis of values, see Residential measure 5.3.16. Measure assumes commercial building is cooled.

$\Delta kWh_{heating}$ = 0.03 * 15,678 * 0.073 * 1 * 1 + (66.1 * 0.0314 * 29.3)

= 95.1 kWh

$\Delta kWh_{cool}$ = 1.0 * ((629 * 33600 * 1/9.3) / 1000) * 0.06 * 1

= 136.4 kWh

$\Delta kWh$ = 95.1 + 136.4

[628] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility's peak hour is divided by the maximum AC load during the year. Multiplied by 50%.

[629] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year. Multiplied by 50%.

[630] Electrical savings are a function of both heating and cooling energy usage reductions. For heating this is a function of the percent of electric heat (heat pumps) and fan savings in the case of a natural gas furnace.

= 231.5 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = %AC * (Cooling_Reduction * Btu/hr * (1/EER))/1000 * EFF_ISR * CF

For basis of values, see Residential measure 5.3.16. Measure assumes commercial building is cooled.

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 45.7 [631]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 23.9% [632]

$\Delta kW_{SSP}$ = 1.0 * (0.06 * 33600 * (1/7.5))/1000 * 1.0 * 0.457

= 0.1228 kW

$\Delta kW_{PJM}$ = 1.0 * (0.06 * 33600 * (1/7.5))/1000 * 1.0 * 0.239

= 0.0642 kW

**NATURAL GAS SAVINGS**

ΔTherms = %FossilHeat * Gas_Heating_Consumption * Heating_Reduction * HF * Eff_ISR

For basis of values, see Residential measure 5.3.16.

ΔTherms = 0.935 * 955 * 0.073 * 1 * 1

= 65.2 Therms

**WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-HVC-ADTH-V01-190101**

**REVIEW DEADLINE: 1/1/2020**

[631] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility's peak hour is divided by the maximum AC load during the year. Multiplied by 50%.

[632] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year. Multiplied by 50%.

## 4.4.43 Packaged RTU Sealing

### DESCRIPTION

The HVAC Packaged RTU Sealing Measure targets areas of the RTU that are readily accessible and can be easily sealed. By sealing the following areas, the amount of uncontrolled infiltration will be reduced leading to increased occupant comfort and an overall reduction in energy use.

The measure seeks to target the following three areas for sealing.

1. Economizer Hood – Seal the interior and exterior seams that connect the economizer to the RTU using UL listed metal tape and/or silicone caulking.
2. RTU Curb – Seal supply and return duct seams inside of RTU with mastic along with any leaks that are found around the perimeter of the roof to RTU connection using UL listed metal tape and/or silicone caulking.
3. Non-Removable Cabinet Panels – Seal all cabinet seams that are not typically removed during basic service (i.e. control panel) using UL listed metal tape and/or silicone caulking.

Uncontrolled infiltration of non-conditioned outside air (OSA) is a known issue for packaged rooftop units (RTU). This leakage can occur thru the curb, economizer assembly connection and cabinet panels. This leakage not only influences occupant comfort but also increases energy usage by increasing the heating and cooling loads while also reducing the unit's operating energy efficiency.

Prior to a recently released laboratory and field study developed by Robert Mowris & Associates, Inc.[633] the energy effects of uncontrolled infiltration through cabinet leakage were difficult to quantify. However, this study determined that uncontrolled OSA infiltration not only increases the amount of energy to condition the excess air but also reduces the unit's operating efficiency (sensible EER) by 5.4%. By reducing the amount of uncontrolled OSA infiltration through RTU sealing the unit's operating efficiency (EER) can be increased reducing the amount of cooling energy. (Note: The referenced study quantifies improvements only from sealing the economizer hood – sealing the curb and non-access panels are recommended practice here but savings have not been quantified for these actions and may be in a future revision.)

This measure is only appropriate for packaged single zone rooftop units. Custom calculations are required for savings for built up air handling units or packaged multizone systems.

### DEFINITION OF EFFICIENT EQUIPMENT

The efficient equipment condition is assumed to be a packaged HVAC system that has had the economizer hood, curb and non-access cabinet panels sealed.

### DEFINITION OF BASELINE EQUIPMENT

The baseline equipment condition is assumed to be an operational packaged HVAC system that has not been previously sealed. The packaged HVAC systems must be single zone and must have a functioning economizer.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

Because the measure targets existing packaged RTU units, the deemed lifetime of the measure is assumed to be 5 years[634].

### DEEMED MEASURE COST

Actual measure costs should be used if available. If costs are not available the deemed measure cost below listed below can be used. The deemed measure costs are detailed for each individual RTU.

---

[633] Robert Mowris & Associates, Inc., "Laboratory Test Results of Commercial Packaged HVAC Maintenance Faults," California Public Utilities Commission, Feb 15, 2016 page 203

[634] Assumed to be one third of effective useful life of an RTU (15 years)

| Measure | Material Unit | Material Cost / Unit | Labor Unit (Hours) | Labor Rate / Unit | Total Cost |
|---|---|---|---|---|---|
| HVAC Packaged RTU Sealing | 1 | \$48.99 | 1.5 | \$97 | \$194.49 |

**LOADSHAPE**

Loadshape C03 - Commercial Cooling

**COINCIDENCE FACTOR**

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [635]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [636]

## Algorithm

**CALCULATION OF ENERGY SAVINGS**

To determine the savings associated with the Packaged RTU Sealing measure available IL TRM prototype eQuest models, which were initially created by the Energy Center of Wisconsin[637] but modified by VEIC in 2014 as part of the IL TRM v4.0 Equivalent Full Load Hours (EFLH) update, were utilized. For each building type we used the most recent versions of the models for our baseline models (Assembly was not part of EFLH update).

This measure is targeting packaged single zone HVAC systems. Therefore, as a basis for savings calculations, only models that had the following characteristics were chosen: 1) Packaged-Single Zone (PSZ) HVAC systems; and 2) aligned with the small commercial building type applicable to this measure. Several modifications to the models were necessary in order to simulate a functioning airside economizer, which is assumed to be present in the baseline scenario for this measure:

3. Optimized Economizer Controls by Climate Zone
    a. Economizer Changeover Type – Set to fixed Dry Bulb
    b. Economizer High-Limit Control Setpoints – Setpoints based on ASHRAE Climate Zones Fixed Dry Bulb Temperature recommendations.
    c. Enable Integrated Operation – Allows economizer to operate simultaneously with mechanical cooling

To determine the energy use associated with an unsealed RTU the prototype models were modified using the associated reduction in efficiency reported in a Robert Mowris and Associates, Inc. study[638] that was performed for the California Public Utilities Commission in 2016. For further detail on the full modeled energy end use and savings summaries, see: “Packaged RTU Sealing_End Use Analysis_IL TRM 09042018.xlsx” spreadsheet.

After analyzing the modeled cooling annual energy usage for both the baseline (unsealed) and measure (sealed) model scenarios it was determined that the building type and climate zone variables had a minimal impact on the overall energy savings associated with the measure. As a result, the overall average savings factor of 4.67% was deemed applicable for any small commercial building type across all climate zones. This single savings value used in conjunction with the energy and demand savings calculations listed in the following sections will allow the savings

[635] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility’s peak hour is divided by the maximum AC load during the year.
[636] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year
[637] Energy Center of Wisconsin, ComEd Portfolio Modeling Report, July 30, 2010
[638] Robert Mowris & Associates, Inc., “Laboratory Test Results of Commercial Packaged HVAC Maintenance Faults,” California Public Utilities Commission, Feb 15, 2016 Section 5.4

to be calculated based on the unit size and equivalent full load hours listed in the Illinois Technical Resource Manual (TRM).

### ELECTRIC ENERGY SAVINGS

ΔkWh = (kBtu/hr) / EERbefore * EFLH * %Savings

Where:

kBtu/hr = rated capacity of the cooling equipment actually installed in kBtu per hour (1 ton of cooling capacity equals 12 kBtu/hr).

=Actual

EERbefore = Energy Efficiency Ratio (EER) of the baseline equipment

=Actual

%Savings = Deemed savings percentage

= 4.67%[639]

$EFLH_{cooling}$ = IL TRM v6 Equivalent Full Load Hours (EFLH) for cooling are provided in the following table

| Building Type | Cooling EFLH | | | | |
|---|---|---|---|---|---|
| | Zone 1 (Rockford) | Zone 2 (Chicago) | Zone 3 (Springfield) | Zone 4 (Belleville) | Zone 5 (Marion) |
| Assembly | 725 | 796 | 937 | 1,183 | 932 |
| Assisted Living | 1,475 | 1,457 | 1,773 | 2,110 | 1,811 |
| College | 475 | 481 | 662 | 746 | 806 |
| Conditioned Storage (Warehouse) | 357 | 338 | 422 | 647 | 533 |
| Convenience Store | 1,088 | 1,067 | 1,368 | 1,541 | 1,371 |
| Garage | 934 | 974 | 1,226 | 1,582 | 1,383 |
| Grocery | 1,033 | 1,000 | 1,236 | 1,499 | 1,286 |
| Manufacturing Facility | 1,010 | 1,055 | 1,209 | 1,453 | 1,273 |
| Office - Low Rise | 949 | 1,010 | 1,182 | 1,452 | 1,281 |
| Religious Building | 861 | 817 | 967 | 1,159 | 1,067 |
| Restaurant | 1,074 | 1,134 | 1,279 | 1,627 | 1,325 |
| Retail - Department Store | 949 | 889 | 1,124 | 1,367 | 1,157 |
| Retail - Strip Mall | 950 | 919 | 1,149 | 1,351 | 1,215 |

For example, a 12 EER 5-ton rooftop air conditioner on a department store in Rockford receives packaged RTU sealing:

ΔkWh = (5*12) / 12 * 949 * 4.67%

= 221.6 kWh

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkWssp = (kBtu/hr) / EERbefore * %Savings * CFssp

ΔkWpjm = (kBtu/hr) / EERbefore * %Savings * CFpjm

[639] The average cooling energy savings for all building types and climate zones, as determined by modeling 13 small commercial building types across 5 weather zones utilizing the prototype TRM eQuest models. For additional reference on the methodology and approach to the calculation of the deemed savings factor, see "Packaged RTU Sealing_End Use Analysis_IL TRM 09042018.xlsx"

Where:

kBtu/hr = Capacity of the cooling equipment actually installed in kBtu per hour (1 ton of cooling capacity equals 12 kBtu/hr).

=Actual

EERbefore = Energy Efficiency Ratio (EER) of the baseline equipment

=Actual

%Savings = Deemed savings percentage

= 4.67%

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [640]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [641]

For example, a 12 EER 5-ton rooftop air conditioner using the Summer System Peak Coincidence Factor receives RTU sealing:

ΔkW = (5*12) / 12 * 4.67% * 91.3%

= 0.213 kW

**NATURAL GAS SAVINGS**

$$\Delta Therm = (kBtu/hr) / 100 / Efficiency_{before} * EFLH * \%Savings$$

Where:

kBtu/hr = rated capacity of the heating equipment actually installed in kBtu per hour

=Actual

100 = Converts kBtu/hr to Therms/hr

$Efficiency_{before}$ = Efficiency of the baseline equipment (rated)

=Actual

%Savings = Deemed savings percentages by building type and climate zone are provided in the following table

| Building Type | Savings Percentage | | | | |
|---|---|---|---|---|---|
| | Zone 1 (Rockford) | Zone 2 (Chicago) | Zone 3 (Springfield) | Zone 4 (Belleville) | Zone 5 (Marion) |
| Assembly | 2.84% | 2.86% | 2.86% | 2.98% | 2.94% |
| Assisted Living | 4.01% | 4.15% | 4.35% | 4.64% | 5.44% |
| College | 3.86% | 3.88% | 3.97% | 4.09% | 5.10% |
| Conditioned Storage (Warehouse) | 0.92% | 0.90% | 0.87% | 1.00% | 1.23% |
| Convenience Store | 3.07% | 3.20% | 3.43% | 3.70% | 4.63% |

[640] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility's peak hour is divided by the maximum AC load during the year.

[641]Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year

| Building Type | Savings Percentage | | | | |
|---|---|---|---|---|---|
| | Zone 1 (Rockford) | Zone 2 (Chicago) | Zone 3 (Springfield) | Zone 4 (Belleville) | Zone 5 (Marion) |
| Garage | 0.20% | 0.21% | 0.22% | 0.23% | 0.29% |
| Grocery | 3.38% | 3.49% | 3.60% | 3.79% | 4.57% |
| Manufacturing Facility | 0.18% | 0.16% | 0.16% | 0.16% | 0.16% |
| Office - Low Rise | 2.19% | 2.23% | 2.37% | 2.46% | 2.96% |
| Religious Building | 0.28% | 0.28% | 0.30% | 0.31% | 0.37% |
| Restaurant | 2.76% | 2.83% | 2.96% | 3.11% | 3.58% |
| Retail - Department Store | 1.87% | 1.91% | 2.00% | 2.14% | 2.88% |
| Retail - Strip Mall | 2.06% | 2.12% | 2.29% | 2.46% | 3.17% |

$EFLH_{heating}$ = IL TRM v6 Equivalent Full Load Hours (EFLH) for heating are provided in the following table

| Building Type | Heating EFLH | | | | |
|---|---|---|---|---|---|
| | Zone 1 (Rockford) | Zone 2 (Chicago) | Zone 3 (Springfield) | Zone 4 (Belleville) | Zone 5 (Marion) |
| Assembly | 1,787 | 1,831 | 1,635 | 1,089 | 1,669 |
| Assisted Living | 1,683 | 1,646 | 1,446 | 1,063 | 1,277 |
| College | 1,530 | 1,430 | 1,276 | 709 | 849 |
| Conditioned Storage (Warehouse) | 1,338 | 1,098 | 976 | 771 | 810 |
| Convenience Store | 1,481 | 1,368 | 1,214 | 871 | 973 |
| Garage | 985 | 969 | 852 | 680 | 752 |
| Grocery | 1,608 | 1,602 | 1,404 | 876 | 1,047 |
| Manufacturing Facility | 1,048 | 1,013 | 939 | 567 | 634 |
| Office - Low Rise | 1,428 | 1,425 | 1,132 | 692 | 793 |
| Religious Building | 1,603 | 1,504 | 1,440 | 1,054 | 1,205 |
| Restaurant | 1,350 | 1,354 | 1,216 | 920 | 1,091 |
| Retail - Department Store | 1,123 | 979 | 852 | 697 | 689 |
| Retail - Strip Mall | 1,332 | 1,233 | 1,090 | 751 | 810 |

For example, a packaged RTU with an 80% efficient 150-kBtu/hr gas furnace on a department store in Rockford receives packaged RTU sealing:

$$\Delta Therm = (150 / 100) / 80\% * 1,123 * 1.87\%$$

$$= 39.4 \text{ Therms}$$

### WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION

N/A

### DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

### MEASURE CODE: CI-HVC-PRTU-V01-190101

### REVIEW DEADLINE: 1/1/2023

## 4.4.44 Commercial Ground Source and Ground Water Source Heat Pump

### DESCRIPTION

This measure characterizes the installation of a Ground Source Heat Pump under the following scenarios:

A. New Construction:

   i. The installation of a new Ground Source Heat Pump system meeting ENERGY STAR efficiency standards presented below in a new C&I building.
   ii. Note the baseline in this case should be determined via EM&V and the algorithms are provided to allow savings to be calculated from any baseline condition.

B. Time of Sale:

   i. The planned installation of a new Ground Source Heat Pump system meeting ENERGY STAR efficiency standards presented below to replace an existing system(s) that does not meet the criteria for early replacement described in section C below.
   ii. Note the baseline in this case is an equivalent replacement system to that which exists currently in the building. The calculation of savings is dependent on whether an incentive for the installation has been provided by both a gas and electric utility, only an electric utility or only a gas utility.
   iii. DHW savings are calculated based upon the fuel type and efficiency of the existing unit.

C. Early Replacement/Retrofit:

   i. The early removal of functioning electric or gas space heating and/or cooling systems from service, prior to the natural end of life, and replacement with a new high efficiency Ground Source Heat Pump system.
   ii. Note the baseline in this case is the existing equipment being replaced. The calculation of savings is dependent on whether an incentive for the installation has been provided by both a gas and electric utility, only an electric utility or only a gas utility.
   iii. DHW savings are calculated based upon the fuel and efficiency of the existing unit.
   iv. Early Replacement determination will be based on meeting the following conditions:
      - The existing unit is operational when replaced, or
      - The existing unit requires minor repairs to be operational, defined as costing less than[642]:

| Existing System | Maximum repair cost |
|---|---|
| Air Source Heat Pump | $263/ton |
| Chiller | $308/ton |
| Boiler (Steam) | $3.87/ kBtu |
| Boiler (Hot Water) | $4.25/ kBtu |
| Furnace | $2.49/ kBtu |
| Ground Source Heat Pump | $2,185/ton |

      - All other conditions will be considered Time of Sale.

   The Baseline efficiency of the existing unit replaced:
      - Use actual existing efficiency whenever possible.
      - If the efficiency of the existing unit is unknown, use assumptions based on the federal minimum standards provided in tables below.
      - If the operational status or repair cost of the existing unit is unknown use time of sale assumptions.

[642] The Technical Advisory Committee agreed that if the cost of repair is less than 20% of the new baseline replacement cost (defined in the Measure Costs section) it can be considered early replacement.

The installation of the GSHP should meet the following design parameters to ensure a properly sized circulation pump. If the GSHP design does not meet the following parameters, a custom calculation should be performed to account for the motor energy consumed by the circulation pump. Optimal design parameters are:

- Circulation pump is included in the manufacturer assembly of the GSHP system
  Or;
- Circulation pump flow rate less than or equal to 3.0 GPM per system ton
- Variable flow controls on pumps serving systems greater than 10 tons. Variable flow controls include one of the following:
  - A variable speed system pump controlled from differential pressure and 2-way water flow control valves on each heat pump.
  - Individual on/off pumps on each heat pump controlled by heat pump demand. The heat pumps may be decoupled from the ground heat exchanger using a separate variable speed pump controlled by differential temperature across the ground loop.
- On/off or variable flow controls on pumps for systems less than 10 tons. On/off pump controls shall operate only when heat pump(s) are running.
- System pumping head less than 80 feet. For systems 10 tons or smaller system pumping head should not exceed 40 feet.

This measure was developed to be applicable to the following program types: TOS, NC, EREP. If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

In order for this characterization to apply, the efficient equipment must be a Ground Source or Ground Water Source Heat Pump unit meeting the minimum efficiency level standards required by the program.

**DEFINITION OF BASELINE EQUIPMENT**

For these products, the baseline equipment includes Air Conditioning, Space Heating and Domestic Hot Water Heating.

New Construction:

To calculate savings with an electric baseline, the baseline equipment is assumed to be an Air Source Heat Pump meeting the Federal Standard efficiency level as outlined in Table 2; and a Federal Standard electric hot water heater efficiency level as outlined in Table 6.

To calculate savings with a chiller/unitary cooling systems and boiler/furnace baseline, the baseline equipment is assumed to meet the minimum standard efficiencies as outlined in the Table 3 for chillers/unitary cooling systems , and Table 4 for boilers or Table 5 for furnaces. If a desuperheater is installed, the domestic hot water heater minimum standard efficiency is calculated as per Table 6 below.

Note IECC 2018 is scheduled to become effective March 1, 2019 and will become baseline for all New Construction permits from that date.

**Table2: IECC 2015 ASHP Minimum Efficiency Requirements:**

| EQUIPMENT TYPE | SIZE CATEGORY | HEATING SECTION TYPE | SUBCATEGORY OR RATING CONDITION | MINIMUM EFFICIENCY Before 1/1/2016 | MINIMUM EFFICIENCY As of 1/1/2016 | TEST PROCEDURE[a] |
|---|---|---|---|---|---|---|
| Air cooled (cooling mode) | < 65,000 Btu/h[b] | All | Split System | 13.0 SEER[c] | 14.0 SEER[c] | AHRI 210/240 |
| | | | Single Package | 13.0 SEER[c] | 14.0 SEER[c] | |
| Through-the-wall, air cooled | ≤ 30,000 Btu/h[b] | All | Split System | 12.0 SEER | 12.0 SEER | |
| | | | Single Package | 12.0 SEER | 12.0 SEER | |
| Single-duct high-velocity air cooled | < 65,000 Btu/h[b] | All | Split System | 11.0 SEER | 11.0 SEER | |
| Air cooled (cooling mode) | ≥ 65,000 Btu/h and < 135,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 11.0 EER<br>11.2 IEER | 11.0 EER<br>12.0 IEER | AHRI 340/360 |
| | | All other | Split System and Single Package | 10.8 EER<br>11.0 IEER | 10.8 EER<br>11.8 IEER | |
| | ≥ 135,000 Btu/h and < 240,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 10.6 EER<br>10.7 IEER | 10.6 EER<br>11.6 IEER | |
| | | All other | Split System and Single Package | 10.4 EER<br>10.5 IEER | 10.4 EER<br>11.4 IEER | |
| | ≥ 240,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 9.5 EER<br>9.6 IEER | 9.5 EER<br>10.6 IEER | |
| | | All other | Split System and Single Package | 9.3 EER<br>9.4 IEER | 9.3 EER<br>9.4 IEER | |
| Air cooled (heating mode) | < 65,000 Btu/h[b] | — | Split System | 7.7 HSPF[c] | 8.2 HSPF[c] | AHRI 210/240 |
| | | — | Single Package | 7.7 HSPF[c] | 8.0 HSPF[c] | |
| Through-the-wall, (air cooled, heating mode) | ≤ 30,000 Btu/h[b] (cooling capacity) | — | Split System | 7.4 HSPF | 7.4 HSPF | |
| | | — | Single Package | 7.4 HSPF | 7.4 HSPF | |
| Small-duct high velocity (air cooled, heating mode) | < 65,000 Btu/h[b] | — | Split System | 6.8 HSPF | 6.8 HSPF | |
| Air cooled (heating mode) | ≥ 65,000 Btu/h and < 135,000 Btu/h (cooling capacity) | — | 47°F db/43°F wb outdoor air | 3.3 COP | 3.3 COP | AHRI 340/360 |
| | | | 17°Fdb/15°F wb outdoor air | 2.25 COP | 2.25 COP | |
| | ≥ 135,000 Btu/h (cooling capacity) | — | 47°F db/43°F wb outdoor air | 3.2 COP | 3.2 COP | |
| | | | 17°Fdb/15°F wb outdoor air | 2.05 COP | 2.05 COP | |

**Table 3: IECC 2015 Electric Chillers, Air-Cooled and Water-Cooled minimum efficiencies**

| EQUIPMENT TYPE | SIZE CATEGORY | UNITS | BEFORE 1/1/2015 | | AS OF 1/1/2015 | | TEST PROCEDURE[c] |
|---|---|---|---|---|---|---|---|
| | | | Path A | Path B | Path A | Path B | |
| Air-cooled chillers | < 150 Tons | EER (Btu/W) | ≥ 9.562 FL | NA[c] | ≥ 10.100 FL | ≥ 9.700 FL | AHRI 550/590 |
| | | | ≥ 12.500 IPLV | | ≥ 13.700 IPLV | ≥ 15,800 IPLV | |
| | ≥ 150 Tons | | ≥ 9.562 FL | NA[c] | ≥ 10.100 FL | ≥ 9.700 FL | |
| | | | ≥ 12.500 IPLV | | ≥ 14.000 IPLV | ≥ 16.100 IPLV | |
| Air cooled without condenser, electrically operated | All capacities | EER (Btu/W) | Air-cooled chillers without condenser shall be rated with matching condensers and complying with air-cooled chiller efficiency requirements. | | | | |
| Water cooled, electrically operated positive displacement | < 75 Tons | kW/ton | ≤ 0.780 FL | ≤ 0.800 FL | ≤ 0.750 FL | ≤ 0.780 FL | |
| | | | ≤ 0.630 IPLV | ≤ 0.600 IPLV | ≤ 0.600 IPLV | ≤ 0.500 IPLV | |
| | ≥ 75 tons and < 150 tons | | ≤ 0.775 FL | ≤ 0.790 FL | ≤ 0.720 FL | ≤ 0.750 FL | |
| | | | ≤ 0.615 IPLV | ≤ 0.586 IPLV | ≤ 0.560 IPLV | ≤ 0.490 IPLV | |
| | ≥ 150 tons and < 300 tons | | ≥ 0.680 FL | ≥ 0.718 FL | ≥ 0.660 FL | ≥ 0.680 FL | |
| | | | ≥ 0.580 IPLV | ≥ 0.540 IPLV | ≥ 0.540 IPLV | ≥ 0.440 IPLV | |
| | ≥ 300 tons and < 600 tons | | ≤ 0.620 FL | ≤ 0.639 FL | ≤ 0.610 FL | ≤ 0.625 FL | |
| | | | ≤ 0.540 IPLV | ≤ 0.490 IPLV | ≤ 0.520 IPLV | ≤ 0.410 IPLV | |
| | ≥ 600 tons | | ≤ 0.620 FL | ≤ 0.639 FL | ≤ 0.560 FL | ≤ 0.585 FL | |
| | | | ≤ 0.540 IPLV | ≤ 0.490 IPLV | ≤ 0.500 IPLV | ≤ 0.380 IPLV | |
| Water cooled, electrically operated centrifugal | < 150 Tons | kW/ton | ≤ 0.634 FL | ≤ 0.639 FL | ≤ 0.610 FL | ≤ 0.695 FL | |
| | | | ≤ 0.596 IPLV | ≤ 0.450 IPLV | ≤ 0.550 IPLV | ≤ 0.440 IPLV | |
| | ≥ 150 tons and < 300 tons | | ≤ 0.634 FL | ≤ 0.639 FL | ≤ 0.610 FL | ≤ 0.635 FL | |
| | | | ≤ 0.596 IPLV | ≤ 0.450 IPLV | ≤ 0.550 IPLV | ≤ 0.400 IPLV | |
| | ≥ 300 tons and < 400 tons | | ≤ 0.576 FL | ≤ 0.600 FL | ≤ 0.560 FL | ≤ 0.595 FL | |
| | | | ≤ 0.549 IPLV | ≤ 0.400 IPLV | ≤ 0.520 IPLV | ≤ 0.390 IPLV | |
| | ≥ 400 tons and < 600 tons | | ≤ 0.576 FL | ≤ 0.600 FL | ≤ 0.560 FL | ≤ 0.585 FL | |
| | | | ≤ 0.549 IPLV | ≤ 0.400 IPLV | ≤ 0.500 IPLV | ≤ 0.380 IPLV | |
| | ≥ 600 Tons | | ≤ 0.570 FL | ≤ 0.590 FL | ≤ 0.560 FL | ≤ 0.585 FL | |
| | | | ≤ 0.539 IPLV | ≤ 0.400 IPLV | ≤ 0.500 IPLV | ≤ 0.380 IPLV | |
| Air cooled, absorption, single effect | All capacities | COP | ≥ 0.600 FL | NA[c] | ≥ 0.600 FL | NA[c] | AHRI 560 |
| Water cooled absorption, single effect | All capacities | COP | ≥ 0.700 FL | NA[c] | ≥ 0.700 FL | NA[c] | |
| Absorption, double effect, indirect fired | All capacities | COP | ≥ 1.000 FL | NA[c] | ≥ 1.000 FL | NA[c] | |
| | | | ≥ 1.050 IPLV | | ≥ 1.050 IPLV | | |
| Absorption double effect direct fired | All capacities | COP | ≥ 1.000 FL | NA[c] | ≥ 1.000 FL | NA[c] | |
| | | | ≥ 1.000 IPLV | | ≥ 1.050 IPLV | | |

**Table 4: IECC 2015 Boiler minimum efficiency requirements**

| EQUIPMENT TYPE[a] | SUBCATEGORY OR RATING CONDITION | SIZE CATEGORY (INPUT) | MINIMUM EFFICIENCY[d, e] | TEST PROCEDURE |
|---|---|---|---|---|
| Boilers, hot water | Gas-fired | < 300,000 Btu/h | 80% AFUE | 10 CFR Part 430 |
| | | ≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h[b] | 80% $E_t$ | 10 CFR Part 431 |
| | | > 2,500,000 Btu/h[a] | 82% $E_c$ | |
| | Oil-fired[c] | < 300,000 Btu/h | 80% AFUE | 10 CFR Part 430 |
| | | ≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h[b] | 82% $E_t$ | 10 CFR Part 431 |
| | | > 2,500,000 Btu/h[a] | 84% $E_c$ | |
| Boilers, steam | Gas-fired | < 300,000 Btu/h | 75% AFUE | 10 CFR Part 430 |
| | Gas-fired- all, except natural draft | ≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h[b] | 79% $E_t$ | 10 CFR Part 431 |
| | | > 2,500,000 Btu/h[a] | 79% $E_t$ | |
| | Gas-fired-natural draft | ≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h[b] | 77% $E_t$ | |
| | | > 2,500,000 Btu/h[a] | 77% $E_t$ | |
| | Oil-fired[c] | < 300,000 Btu/h | 80% AFUE | 10 CFR Part 430 |
| | | ≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h[b] | 81% $E_t$ | 10 CFR Part 431 |
| | | > 2,500,000 Btu/h[a] | 81% $E_t$ | |

**Table 5: IECC 2015 Warm-air Furnace minimum efficiency standards**

| EQUIPMENT TYPE | SIZE CATEGORY (INPUT) | SUBCATEGORY OR RATING CONDITION | MINIMUM EFFICIENCY[d, e] | TEST PROCEDURE[a] |
|---|---|---|---|---|
| Warm-air furnaces, gas fired | < 225,000 Btu/h | — | 78% AFUE or 80%$E_t$[c] | DOE 10 CFR Part 430 or ANSI Z21.47 |
| | ≥ 225,000 Btu/h | Maximum capacity[c] | 80%$E_t$[f] | ANSI Z21.47 |
| Warm-air furnaces, oil fired | < 225,000 Btu/h | — | 78% AFUE or 80%$E_t$[c] | DOE 10 CFR Part 430 or UL 727 |
| | ≥ 225,000 Btu/h | Maximum capacity[b] | 81%$E_t$[g] | UL 727 |
| Warm-air duct furnaces, gas fired | All capacities | Maximum capacity[b] | 80%$E_c$ | ANSI Z83.8 |
| Warm-air unit heaters, gas fired | All capacities | Maximum capacity[b] | 80%$E_c$ | ANSI Z83.8 |
| Warm-air unit heaters, oil fired | All capacities | Maximum capacity[b] | 80%$E_c$ | UL 731 |

**Table 6: IECC 2015 Water Heaters mininmum performance**

| EQUIPMENT TYPE | SIZE CATEGORY (input) | SUBCATEGORY OR RATING CONDITION | PERFORMANCE REQUIRED[a, b] | TEST PROCEDURE |
|---|---|---|---|---|
| Water heaters, electric | ≤ 12 kW[d] | Resistance | 0.97 - 0.00 132V, EF | DOE 10 CFR Part 430 |
| | > 12 kW | Resistance | $(0.3 + 27/V_m)$, %/h | ANSI Z21.10.3 |
| | ≤ 24 amps and ≤ 250 volts | Heat pump | 0.93 - 0.00 132*V*, EF | DOE 10 CFR Part 430 |
| Storage water heaters, gas | ≤ 75,000 Btu/h | ≥ 20 gal | 0.67 - 0.0019*V*, EF | DOE 10 CFR Part 430 |
| | > 75,000 Btu/h and ≤ 155,000 Btu/h | < 4,000 Btu/h/gal | 80% $E_t$ $(Q/800 + 110\sqrt{V})SL$, Btu/h | ANSI Z21.10.3 |
| | > 155,000 Btu/h | < 4,000 Btu/h/gal | 80% $E_t$ $(Q/800 + 110\sqrt{V})SL$, Btu/h | |
| Instantaneous water heaters, gas | > 50,000 Btu/h and < 200,000 Btu/h[c] | ≥ 4,000 (Btu/h)/gal and < 2 gal | 0.62 - 0.00 19V, EF | DOE 10 CFR Part 430 |
| | ≥ 200,000 Btu/h | ≥ 4,000 Btu/h/gal and < 10 gal | 80% $E_t$ | ANSI Z21.10.3 |
| | ≥ 200,000 Btu/h | ≥ 4,000 Btu/h/gal and ≥ 10 gal | 80% $E_t$ $(Q/800 + 110\sqrt{V})SL$, Btu/h | |

**Table7: IECC 2018 ASHP Minimum Efficiency Requirements:**

TABLE C403.3.2(2)
MINIMUM EFFICIENCY REQUIREMENTS: ELECTRICALLY OPERATED UNITARY AND APPLIED HEAT PUMPS

| EQUIPMENT TYPE | SIZE CATEGORY | HEATING SECTION TYPE | SUBCATEGORY OR RATING CONDITION | MINIMUM EFFICIENCY | TEST PROCEDURE[a] |
|---|---|---|---|---|---|
| Air cooled (cooling mode) | < 65,000 Btu/h[b] | All | Split System | 14.0 SEER | AHRI 210/240 |
| | | | Single Package | 14.0 SEER | |
| Through-the-wall, air cooled | ≤ 30,000 Btu/h[b] | All | Split System | 12.0 SEER | |
| | | | Single Package | 12.0 SEER | |
| Single-duct high-velocity air cooled | < 65,000 Btu/h[b] | All | Split System | 11.0 SEER | |
| Air cooled (cooling mode) | ≥ 65,000 Btu/h and < 135,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 11.0 EER 12.0 IEER | AHRI 340/360 |
| | | All other | Split System and Single Package | 10.8 EER 11.8 IEER | |
| | ≥ 135,000 Btu/h and < 240,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 10.6 EER 11.6 IEER | |
| | | All other | Split System and Single Package | 10.4 EER 11.4 IEER | |
| | ≥ 240,000 Btu/h | Electric Resistance (or None) | Split System and Single Package | 9.5 EER 10.6 IEER | |
| | | All other | Split System and Single Package | 9.3 EER 9.4 IEER | |
| Water to Air: Water Loop (cooling mode) | < 17,000 Btu/h | All | 86°F entering water | 12.2 EER | ISO 13256-1 |
| | ≥ 17,000 Btu/h and < 65,000 Btu/h | All | 86°F entering water | 13.0 EER | |
| | ≥ 65,000 Btu/h and < 135,000 Btu/h | All | 86°F entering water | 13.0 EER | |
| Water to Air: Ground Water (cooling mode) | < 135,000 Btu/h | All | 59°F entering water | 18.0 EER | ISO 13256-1 |
| Brine to Air: Ground Loop (cooling mode) | < 135,000 Btu/h | All | 77°F entering water | 14.1 EER | ISO 13256-1 |
| Water to Water: Water Loop (cooling mode) | < 135,000 Btu/h | All | 86°F entering water | 10.6 EER | ISO 13256-2 |
| Water to Water: Ground Water (cooling mode) | < 135,000 Btu/h | All | 59°F entering water | 16.3 EER | |
| Brine to Water: Ground Loop (cooling mode) | < 135,000 Btu/h | All | 77°F entering fluid | 12.1 EER | |

**Table 7 continued:**

| | | | | | |
|---|---|---|---|---|---|
| Air cooled (heating mode) | < 65,000 Btu/h[b] | — | Split System | 8.2 HSPF | AHRI 210/240 |
| | | — | Single Package | 8.0 HSPF | |
| Through-the-wall, (air cooled, heating mode) | ≤ 30,000 Btu/h[b] (cooling capacity) | — | Split System | 7.4 HSPF | |
| | | — | Single Package | 7.4 HSPF | |
| Small-duct high velocity (air cooled, heating mode) | < 65,000 Btu/h[b] | — | Split System | 6.8 HSPF | |
| Air cooled (heating mode) | ≥ 65,000 Btu/h and < 135,000 Btu/h (cooling capacity) | — | 47°F db/43°F wb outdoor air | 3.3 COP | AHRI 340/360 |
| | | | 17°Fdb/15°F wb outdoor air | 2.25 COP | |
| | ≥ 135,000 Btu/h (cooling capacity) | — | 47°F db/43°F wb outdoor air | 3.2 COP | |
| | | | 17°Fdb/15°F wb outdoor air | 2.05 COP | |
| Water to Air: Water Loop (heating mode) | < 135,000 Btu/h (cooling capacity) | — | 68°F entering water | 4.3 COP | ISO 13256-1 |
| Water to Air: Ground Water (heating mode) | < 135,000 Btu/h (cooling capacity) | — | 50°F entering water | 3.7 COP | |
| Brine to Air: Ground Loop (heating mode) | < 135,000 Btu/h (cooling capacity) | — | 32°F entering fluid | 3.2 COP | |
| Water to Water: Water Loop (heating mode) | < 135,000 Btu/h (cooling capacity) | — | 68°F entering water | 3.7 COP | ISO 13256-2 |
| Water to Water: Ground Water (heating mode) | < 135,000 Btu/h (cooling capacity) | — | 50°F entering water | 3.1 COP | |
| Brine to Water: Ground Loop (heating mode) | < 135,000 Btu/h (cooling capacity) | — | 32°F entering fluid | 2.5 COP | |

For SI: 1 British thermal unit per hour = 0.2931 W, °C = [(°F) - 32]/1.8.

a. Chapter 6 contains a complete specification of the referenced test procedure, including the reference year version of the test procedure.
b. Single-phase, air-cooled heat pumps less than 65,000 Btu/h are regulated by NAECA. SEER and HSPF values are those set by NAECA.

**Table 8: IECC 2018 Electric Chillers, Air-Cooled and Water-Cooled minimum efficiencies**

TABLE C403.3.2(7)
WATER CHILLING PACKAGES — EFFICIENCY REQUIREMENTS[a, b, d]

| EQUIPMENT TYPE | SIZE CATEGORY | UNITS | BEFORE 1/1/2015 | | AS OF 1/1/2015 | | TEST PROCEDURE[c] |
|---|---|---|---|---|---|---|---|
| | | | Path A | Path B | Path A | Path B | |
| Air-cooled chillers | < 150 Tons | EER (Btu/W) | ≥ 9.562 FL | NA[c] | ≥ 10.100 FL | ≥ 9.700 FL | AHRI 550/590 |
| | | | ≥ 12.500 IPLV | | ≥ 13.700 IPLV | ≥ 15,800 IPLV | |
| | ≥ 150 Tons | | ≥ 9.562 FL | NA[c] | ≥ 10.100 FL | ≥ 9.700 FL | |
| | | | ≥ 12.500 IPLV | | ≥ 14.000 IPLV | ≥ 16.100 IPLV | |
| Air cooled without condenser, electrically operated | All capacities | EER (Btu/W) | Air-cooled chillers without condenser shall be rated with matching condensers and complying with air-cooled chiller efficiency requirements. | | | | |
| Water cooled, electrically operated positive displacement | < 75 Tons | kW/ton | ≤ 0.780 FL | ≤ 0.800 FL | ≤ 0.750 FL | ≤ 0.780 FL | |
| | | | ≤ 0.630 IPLV | ≤ 0.600 IPLV | ≤ 0.600 IPLV | ≤ 0.500 IPLV | |
| | ≥ 75 tons and < 150 tons | | ≤ 0.775 FL | ≤ 0.790 FL | ≤ 0.720 FL | ≤ 0.750 FL | |
| | | | ≤ 0.615 IPLV | ≤ 0.586 IPLV | ≤ 0.560 IPLV | ≤ 0.490 IPLV | |
| | ≥ 150 tons and < 300 tons | | ≥ 0.680 FL | ≥ 0.718 FL | ≥ 0.660 FL | ≥ 0.680 FL | |
| | | | ≥ 0.580 IPLV | ≥ 0.540 IPLV | ≥ 0.540 IPLV | ≥ 0.440 IPLV | |
| | ≥ 300 tons and < 600 tons | | ≤ 0.620 FL | ≤ 0.639 FL | ≤ 0.610 FL | ≤ 0.625 FL | |
| | | | ≤ 0.540 IPLV | ≤ 0.490 IPLV | ≤ 0.520 IPLV | ≤ 0.410 IPLV | |
| | ≥ 600 tons | | ≤ 0.620 FL | ≤ 0.639 FL | ≤ 0.560 FL | ≤ 0.585 FL | |
| | | | ≤ 0.540 IPLV | ≤ 0.490 IPLV | ≤ 0.500 IPLV | ≤ 0.380 IPLV | |
| Water cooled, electrically operated centrifugal | < 150 Tons | kW/ton | ≤ 0.634 FL | ≤ 0.639 FL | ≤ 0.610 FL | ≤ 0.695 FL | |
| | | | ≤ 0.596 IPLV | ≤ 0.450 IPLV | ≤ 0.550 IPLV | ≤ 0.440 IPLV | |
| | ≥ 150 tons and < 300 tons | | ≤ 0.634 FL | ≤ 0.639 FL | ≤ 0.610 FL | ≤ 0.635 FL | |
| | | | ≤ 0.596 IPLV | ≤ 0.450 IPLV | ≤ 0.550 IPLV | ≤ 0.400 IPLV | |
| | ≥ 300 tons and < 400 tons | | ≤ 0.576 FL | ≤ 0.600 FL | ≤ 0.560 FL | ≤ 0.595 FL | |
| | | | ≤ 0.549 IPLV | ≤ 0.400 IPLV | ≤ 0.520 IPLV | ≤ 0.390 IPLV | |
| | ≥ 400 tons and < 600 tons | | ≤ 0.576 FL | ≤ 0.600 FL | ≤ 0.560 FL | ≤ 0.585 FL | |
| | | | ≤ 0.549 IPLV | ≤ 0.400 IPLV | ≤ 0.500 IPLV | ≤ 0.380 IPLV | |
| | ≥ 600 Tons | | ≤ 0.570 FL | ≤ 0.590 FL | ≤ 0.560 FL | ≤ 0.585 FL | |
| | | | ≤ 0.539 IPLV | ≤ 0.400 IPLV | ≤ 0.500 IPLV | ≤ 0.380 IPLV | |
| Air cooled, absorption, single effect | All capacities | COP | ≥ 0.600 FL | NA[c] | ≥ 0.600 FL | NA[c] | AHRI 560 |
| Water cooled absorption, single effect | All capacities | COP | ≥ 0.700 FL | NA[c] | ≥ 0.700 FL | NA[c] | |
| Absorption, double effect, indirect fired | All capacities | COP | ≥ 1.000 FL | NA[c] | ≥ 1.000 FL | NA[c] | |
| | | | ≥ 1.050 IPLV | | ≥ 1.050 IPLV | | |
| Absorption double effect direct fired | All capacities | COP | ≥ 1.000 FL | NA[c] | ≥ 1.000 FL | NA[c] | |
| | | | ≥ 1.000 IPLV | | ≥ 1.050 IPLV | | |

**Table 9: IECC 2018 Boiler minimum efficiency requirements**

TABLE C403.3.2(5)
MINIMUM EFFICIENCY REQUIREMENTS: GAS- AND OIL-FIRED BOILERS

| EQUIPMENT TYPE[a] | SUBCATEGORY OR RATING CONDITION | SIZE CATEGORY (INPUT) | MINIMUM EFFICIENCY[d, e] | TEST PROCEDURE |
|---|---|---|---|---|
| Boilers, hot water | Gas-fired | < 300,000 Btu/h[f, g] | 82% AFUE | 10 CFR Part 430 |
| | | ≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h[b] | 80% $E_t$ | 10 CFR Part 431 |
| | | > 2,500,000 Btu/h[a] | 82% $E_c$ | |
| | Oil-fired[c] | < 300,000 Btu/h[g] | 84% AFUE | 10 CFR Part 430 |
| | | ≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h[b] | 82% $E_t$ | 10 CFR Part 431 |
| | | > 2,500,000 Btu/h[a] | 84% $E_c$ | |
| Boilers, steam | Gas-fired | < 300,000 Btu/h[f] | 80% AFUE | 10 CFR Part 430 |
| | Gas-fired- all, except natural draft | ≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h[b] | 79% $E_t$ | 10 CFR Part 431 |
| | | > 2,500,000 Btu/h[a] | 79% $E_t$ | |
| | Gas-fired-natural draft | ≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h[b] | 77% $E_t$ | |
| | | > 2,500,000 Btu/h[a] | 77% $E_t$ | |
| | Oil-fired[c] | < 300,000 Btu/h | 82% AFUE | 10 CFR Part 430 |
| | | ≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h[b] | 81% $E_t$ | 10 CFR Part 431 |
| | | > 2,500,000 Btu/h[a] | 81% $E_t$ | |

**Table 10: IECC 2018 Warm-air Furnace minimum efficiency standards**

TABLE C403.3.2(4)
WARM-AIR FURNACES AND COMBINATION WARM-AIR FURNACES/AIR-CONDITIONING UNITS, WARM-AIR DUCT FURNACES AND UNIT HEATERS, MINIMUM EFFICIENCY REQUIREMENTS

| EQUIPMENT TYPE | SIZE CATEGORY (INPUT) | SUBCATEGORY OR RATING CONDITION | MINIMUM EFFICIENCY[d, e] | TEST PROCEDURE[a] |
|---|---|---|---|---|
| Warm-air furnaces, gas fired | < 225,000 Btu/h | — | 80% AFUE or 80%$E^{c}_{t}$ | DOE 10 CFR Part 430 or ANSI Z21.47 |
| | ≥ 225,000 Btu/h | Maximum capacity[c] | 80%$E_t^{f}$ | ANSI Z21.47 |
| Warm-air furnaces, oil fired | < 225,000 Btu/h | — | 83% AFUE or 80%$E^{c}_{t}$ | DOE 10 CFR Part 430 or UL 727 |
| | ≥ 225,000 Btu/h | Maximum capacity[b] | 81%$E_t^{g}$ | UL 727 |
| Warm-air duct furnaces, gas fired | All capacities | Maximum capacity[b] | 80%$E_c$ | ANSI Z83.8 |
| Warm-air unit heaters, gas fired | All capacities | Maximum capacity[b] | 80%$E_c$ | ANSI Z83.8 |
| Warm-air unit heaters, oil fired | All capacities | Maximum capacity[b] | 80%$E_c$ | UL 731 |

**Table 11: IECC 2018 Water Heaters mininmum performance**

TABLE C404.2
MINIMUM PERFORMANCE OF WATER-HEATING EQUIPMENT

| EQUIPMENT TYPE | SIZE CATEGORY (input) | SUBCATEGORY OR RATING CONDITION | PERFORMANCE REQUIRED[a, b] | TEST PROCEDURE |
|---|---|---|---|---|
| Water heaters, electric | ≤ 12 kW[d] | Tabletop[e], ≥ 20 gallons and ≤ 120 gallons | 0.93 - 0.00132*V*, EF | DOE 10 CFR Part 430 |
| | | Resistance ≥ 20 gallons and ≤ 55 gallons | 0.960 - 0.0003*V*, EF | |
| | | Grid-enabled[f] > 75 gallons and ≤ 120 gallons | 1.061 - 0.00168V, EF | |
| | > 12 kW | Resistance | $(0.3 + 27/V_m)$, %/h | ANSI Z21.10.3 |
| | ≤ 24 amps and ≤ 250 volts | Heat pump > 55 gallons and ≤ 120 gallons | 2.057 - 0.00113V, EF | DOE 10 CFR Part 430 |
| Storage water heaters, gas | ≤ 75,000 Btu/h | ≥ 20 gallons and > 55 gallons | 0.675 - 0.0015V, EF | DOE 10 CFR Part 430 |
| | | > 55 gallons and ≤ 100 gallons | 0.8012 - 0.00078V, EF | |
| | > 75,000 Btu/h and ≤ 155,000 Btu/h | < 4,000 Btu/h/gal | 80% $E_t$ | ANSI Z21.10.3 |
| | > 155,000 Btu/h | < 4,000 Btu/h/gal | 80% $E_t$ | |
| Instantaneous water heaters, gas | > 50,000 Btu/h and < 200,000 Btu/h[c] | ≥ 4,000 (Btu/h)/gal and < 2 gal | 0.82 - 0.00 19V, EF | DOE 10 CFR Part 430 |
| | ≥ 200,000 Btu/h | ≥ 4,000 Btu/h/gal and < 10 gal | 80% $E_t$ | ANSI Z21.10.3 |
| | ≥ 200,000 Btu/h | ≥ 4,000 Btu/h/gal and ≥ 10 gal | 80% $E_t$ | |

Time of Sale: The baseline for this measure is a new replacement unit of the same system type as the existing unit, meeting the minimum standard efficiencies provided above.

Early replacement / Retrofit: The baseline for this measure is the efficiency of the *existing* heating, cooling and hot water equipment for the assumed remaining useful life of the existing unit, and a new baseline heating and cooling system for the remainder of the measure life (as provided in table above).

## DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life of the ground source heat pump is assumed to be 25 years[643].

The expected measure life of the ground loop field is assumed to be 50 years[644].

For early replacement, the remaining life of existing equipment is assumed to be 8 years[645].

## DEEMED MEASURE COST

New Construction and Time of Sale: Incremental costs of the Ground Source Heat Pump should be used. This would be the actual installed cost of the Ground Source Heat Pump, well drilling, building retrofit, and system commissioning costs (default of $10,923 per ton[646]), minus the assumed installation cost of the baseline equipment ($1,316 per ton for ASHP[647] or $12.43 per kBtu capacity for a new baseline 80% efficient furnace or $19.33 per kBtu capacity for a new 80% efficient steam boiler or $21.27 per kBtu capacity for a new 80% efficienct hot water boiler[648] and $1,539 per ton[649] for new baseline chiller replacement).

Early Replacement: The actual installed cost of the Ground Source Heat Pump should be used (default cost for total system retrofit provided above). The assumed deferred cost (after 8 years) of replacing existing equipment with a new baseline unit is assumed to be $1,316 per ton for a new baseline Air Source Heat Pump, or $12.43 per kBtu capacity for a new baseline 80% efficient furnace or $19.33 per kBtu capacity for a new 80% efficient steam boiler or $21.27 per kBtu capacity for a new 80% efficienct hot water boiler and $1,539 per ton for new baseline chiller replacement. This future cost should be discounted to present value using the nominal societal discount rate.

## LOADSHAPE

Loadshape C04 – Commercial Electric Heating (if replacing building with no existing cooling)

Loadshape C05 - Commercial Electric Heating and Cooling.

Note for the purpose of cost effectiveness screening a fuel switch scenario, the heating kWh increase and cooling kWh decrease should be calculated separately such that the appropriate loadshape (i.e. Loadshape C04 - Commercial Electric Heating and Loadshape C03 – Commercial Cooling respectively) can be applied.

## COINCIDENCE FACTOR

The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the *average* savings over the defined summer peak period, and is presented so that savings can be bid into PJM's Forward Capacity Market. Both values provided are based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren.

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

[643] System life of indoor components as per US DOE estimates from the Office of Energy Efficiency & Renewable Energy. The ground loop has a much longer life, but the compressor and other mechanical components are the same as an ASHP.
[644] U.S. DOE Office of Energy Efficiency & Renewable Energy, Energy Saver details and descriptions for Geothermal Heat Pumps
[645] Assumed to be one third of effective useful life per SAG policy
[646] Average calculated based on reviewing cost information received from Chicagoland GSHP installers
[647] Average calculated from Energy Star and RSMeans Mechanical Cost Data 2015
[648] Average calucated based on RSMeans Mechanical Cost Data 2015
[649] Average calucated based on RSMeans Mechanical Cost Data 2015 for Scroll, air cooled condenser chillers

= 91.3% [650]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [651]

**Algorithm**

## CALCULATION OF ENERGY SAVINGS

### ELECTRIC ENERGY SAVINGS

New Construction and Time of Sale (non-fuel switch only):

ΔkWh = [Cooling savings] + [Heating savings] + [DHW savings]

Cooling Savings = $(Capacity_{cool} * EFLH_{Cool} * (1/EER_{base} – 1/EER_{GSHP}))/1000$

Heating Savings = $Elec_{Heat} *((Capacity_{Heat} * EFLH_{Heat} * (1/HSPF_{base} – 1/(COP_{GSHP} * 3.412)))/1000)$

DHW Savings = $Elec_{DHW} * (\%DHW * ((1/EF_{elecbase}) * HotWaterUse_{Gallon} * γWater * (Tout – Tin) * 1/3412))$

New Construction and Time of Sale (fuel switch only):

If measure is supported by gas utility only, ΔkWH = 0

If measure is supported by gas and electric utility or electric utility only, electric utility claim savings calculated below:

ΔkWh = [Cooling savings] + [Heating savings from base ASHP to GSHP] + [DHW savings]

Cooling Savings = $(Capacity_{cool} * EFLH_{Cool} * (1/EER_{base} – 1/EER_{GSHP}))/1000$

Heating Savings from base ASHP to GSHP = $(Capacity_{Heat} * EFLH_{Heat} * (1/HSPF_{ASHP} – 1/(COP_{GSHP} * 3.412)))/1000$

DHW Savings = $Elec_{DHW} * (\%DHW * ((1/EF_{elecbase}) * HotWaterUse_{Gallon} * γWater * (Tout – Tin) * 1/3412))$

Early replacement (non-fuel switch only)[652]:

ΔkWH for remaining life of existing unit (1st 8 years):
= [Cooling savings] + [Heating savings] + [DHW savings]

Cooling Savings = $(Capacity_{cool} * EFLH_{Cool} * (1/EER_{Exist} – 1/EER_{GSHP}))/1000$

Heating Savings = $Elec_{Heat} *((Capacity_{Heat} * EFLH_{Heat} * (1/HSPF_{Exist} – 1/(COP_{GSHP} * 3.412)))/1000)$

DHW Savings = $Elec_{DHW} * (\%DHW * ((1/ EF_{elecbase}) * HotWaterUse_{Gallon} * γWater * (Tout – Tin) * 1/3412))$

ΔkWH for remaining measure life (next 17 years):
= [Cooling savings] + [Heating savings ] + [DHW savings]

[650] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility's peak hour is divided by the maximum AC load during the year.
[651] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year
[652] The two equations are provided to show how savings are determined during the initial phase of the measure (existing to efficient) and the remaining phase (new baseline to efficient). In practice, the screening tools used may either require a First Year savings (using the first equation) and then a "number of years to adjustment" and "savings adjustment" input which would be the (new base to efficient savings)/(existing to efficient savings).

Cooling Savings = $(Capacity_{cool} * EFLH_{Cool} * (1/EER_{base} – 1/EER_{GSHP}))/1000$

Heating Savings = $Elec_{Heat} *((Capacity_{Heat} * EFLH_{Heat} * (1/HSPF_{Base} – 1/(COP_{GSHP} * 3.412)))/1000)$

DHW Savings = $Elec_{DHW} * (\%DHW * ((1/ EF_{elecbase}) * HotWaterUse_{Gallon} * \gamma Water * (Tout – Tin) * 1 /3412))$

Early replacement - fuel switch only (see illustrative examples after Natural Gas section):

If measure is supported by gas utility only, ΔkWH = 0

If measure is supported by gas and electric utility or electric utility only, electric utility claim savings calculated below:

ΔkWh for remaining life of existing unit (1st 8 years):
= [Cooling savings] + [Heating savings from base ASHP to GSHP] + [DHW savings]

Cooling Savings = $(Capacity_{cool} * EFLH_{Cool} * (1/EER_{Exist} – 1/EER_{GSHP}))/1000$

Heating Savings from base ASHP to GSHP = $(Capacity_{Heat} * EFLH_{Heat} * (1/HSPF_{ASHP} – 1/(COP_{GSHP} * 3.412)))/1000$

DHW Savings = $Elec_{DHW} * (\%DHW * ((1/ EF_{elecbase}) * HotWaterUse_{Gallon} * \gamma Water * (Tout – Tin) * 1 /3412))$

ΔkWh for remaining measure life (next 17 years):
= [Cooling savings] + [Heating savings from base ASHP to GSHP] + [DHW savings]

Cooling Savings = $(Capacity_{cool} * EFLH_{Cool} * (1/EER_{base} – 1/EER_{GSHP}))/1000$

Heating Savings from base ASHP to GSHP = $(Capacity_{Heat} * EFLH_{Heat} * (1/HSPF_{ASHP} – 1/(COP_{GSHP} * 3.412)))/1000$

DHW Savings = $Elec_{DHW} * (\%DHW * ((1/ EF_{elecbase}) * HotWaterUse_{Gallon} * \gamma Water * (Tout – Tin) * 1 /3412))$

Where:

$Capacity_{cool}$ = Cooling Capacity of Ground Source Heat Pump (Btu/hr)
= Actual installed

$EFLH_{cool}$ = Cooling Equivalent Full Load Hours
Dependent on building type, provided in section 4.4 HVAC End Use

$EER_{Exist}$ = Energy Efficiency Ratio (EER) of existing cooling unit (kBtu/hr / kW)
= Use actual EER rating where it is possible to measure or reasonably estimate. If EER unknown but SEER available convert using the equation:
$EERexist = (-0.02 * SEERexist^2) + (1.12 * SEERexist)$ [653]

$EER_{base}$ = Energy Efficiency Ratio (EER) of baseline replacement cooling system
= Use minimum standard efficiencies as specified in tables in 'Definition of Baseline Equipment' section

$EER_{GSHP}$ = Part Load Energy Efficiency Ratio efficiency of efficient GSHP unit[654]
= Actual installed

[653] From Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder.

[654] From Res GSHP measure of the IL-TRM: As per conversations with David Buss territory manager for Connor Co, the EER rating of an ASHP equate most appropriately with the full load EER of a GSHP

$Elec_{Heat}$[655] = 1 if existing heating system is electric
= 0 if existing system is non electric

$Capacity_{Heat}$ = Heating Capacity of Ground Source Heat Pump (Btu/hr)
= Actual installed

$EFLH_{Heat}$ = Heating Equivalent Full Load Hours
Dependent on building type, provided in section 4.4 HVAC End Use

$HSPF_{Exist}$ = Heating System Performance Factor of existing electric heating system (kBtu/kWh)
= Actual

$HSPF_{base}$ =Heating System Performance Factor of new replacement baseline heating system (kBtu/kWh)

| Existing Heating System | HSPF_base |
|---|---|
| Ground Source Heat Pump or Air Source Heat Pump | Refer to applicable tables in 'Definition of Baseline Equipment' section |
| Electric Resistance | 3.41[656] |

$HSPF_{ASHP}$ = Heating System Performance Factor of new replacement ASHP (kBtu/kWh) (for fuel switch)

= Refer to applicable tables in 'Definition of Baseline Equipment' section

$COP_{GSHP}$ = Part Load Coefficient of Performance of efficient GSHP[657]

= Actual installed

3.412 = Constant to convert the COP of the unit to the Heating Season Performance Factor (HSPF)

$Elec_{DHW}$ = 1 if building has electric DHW
= 0 if building has non electric DHW
= 0 if one to one replacement of existing Ground Source Heat Pump

%DHW = Percentage of total DHW load that the GSHP will provide
= Actual if known
= If unknown and if desuperheater installed assume 44%[658]
= 0% if no desuperheater installed

$EF_{elecbase}$ = Energy Factor of baseline electric DHW
= Actual. If unknown or for new construction assume federal standard as defined in applicable table in 'Definition of Baseline Equipment' section

$HotWaterUse_{Gallon}$ = Estimated annual hot water consumption (gallons)

= Actual if possible to provide reasonable custom estimate. If not, two methodologies are provided to develop an estimate:

1. Consumption per usable storage tank capacity
   = Capacity * Consumption/cap

655 Applicable only for early Replacement Fuel Switch projects.
656 Electric resistance has a COP of 1.0 which equals 1/0.293 = 3.41 HSPF.
657 As per Res GSHP measure.
658 Assumes that the desuperheater can provide two thirds of hot water needs for eight months of the year (2/3 * 2/3 = 44%). Based on input from Doug Dougherty, Geothermal Exchange Organization.

Where:

Capacity = Usable capacity of hot water storage tank in gallons

= Actual

Consumption/cap = Estimate of consumption per gallon of usable tank capacity, based on building type[659]

| Building Type[660] | Consumption/Cap |
|---|---|
| Convenience | 528 |
| Education | 568 |
| Grocery | 528 |
| Health | 788 |
| Large Office | 511 |
| Large Retail | 528 |
| Lodging | 715 |
| Other Commercial | 341 |
| Restaurant | 622 |
| Small Office | 511 |
| Small Retail | 528 |
| Warehouse | 341 |
| Nursing | 672 |
| Multi-Family | 894 |

2. Consumption per unit area by building type
= (Area/1000) * Consumption/1,000 sq.ft.

Where:

Area = Area in sq.ft that is served by DHW boiler

= Actual

Consumption/1,000 sq.ft. = Estimate of DHW consumption per 1,000 sq.ft. based on building type:[661]

| Building Type[662] | Consumption/1,000 sq.ft. |
|---|---|
| Convenience | 4,594 |
| Education | 7,285 |
| Grocery | 697 |

[659] Methodology based on Cadmus analysis. Annual hot water usage in gallons based on CBECS (2012) and RECS (2009) consumption data of East North Central (removed outliers of 1,000 kBtuh or less) to calculate hot water usage. Annual hot water gallons per tank size gallons based on the tank sizing methodology found in ASHRAE 2011 HVAC Applications. Chapter 50 Service Water Heating. Demand assumptions (gallons per day) for each building type based on ASHRAE Chapter 50 and to LBNL White Paper. LBL-37398 Technology Data Characterizing Water Heating in Commercial Buildings: Application to End Use Forecasting. Assumes hot water heater efficiency of 80%.

[660] According to CBECS 2012 “Lodging” buildings include Dormitories, Hotels, Motel or Inns and other Lodging and “Nursing” buildings include Assisted Living and Nursing Homes.

[661] Methodology based on Cadmus analysis. Annual hot water usage in gallons based on CBECS (2012) and RECS (2009) consumption data of East North Central (removed outliers of 1,000 kBtuh or less) to calculate hot water usage. Annual hot water gallons per tank size gallons based on the tank sizing methodology found in ASHRAE 2011 HVAC Applications. Chapter 50 Service Water Heating. Demand assumptions (gallons per day) for each building type based on ASHRAE Chapter 50 and to LBNL White Paper. LBL-37398 Technology Data Characterizing Water Heating in Commercial Buildings: Application to End Use Forecasting. Assumes hot water heater efficiency of 80%.

[662] According to CBECS 2012 “Lodging” buildings include Dormitories, Hotels, Motel or Inns and other Lodging and “Nursing” buildings include Assisted Living and Nursing Homes.

| Building Type[662] | Consumption/1,000 sq.ft. |
|---|---|
| Health | 24,540 |
| Large Office | 1,818 |
| Large Retail | 1,354 |
| Lodging | 29,548 |
| Other Commercial | 3,941 |
| Restaurant | 44,439 |
| Small Office | 1,540 |
| Small Retail | 6,111 |
| Warehouse | 1,239 |
| Nursing | 30,503 |
| Multi-Family | 15,434 |

γWater = Density of water

= 8.33 pounds per gallon

$T_{out}$ = Tank temperature

= 125°F

$T_{in}$ = Incoming water temperature from well or municiplal system

= 54°F[663]

1 = Heat Capacity of water (1 Btu/lb*°F)

3.412 = Conversion from Btu to kWh

[663] US DOE Building America Program. Building America Analysis Spreadsheet. For Chicago, IL

Illustrative Examples

New Construction using ASHP baseline:

For example, a 10 ton closed loop unit with Part Load EER rating of 20 and Part Load COP of 4.4, with desuperheater installed, and with a 100 gallon electric water heater in an Assisted living building in Chicago:

ΔkWh = [120,000 * 1,457 * (1/11 – 1/20) / 1000] + [1,646* 120,000 * (1/11 – 1/(4.4*3.412)) / 1000] + [1 * 0.44 * ((1/0.9568 * (100*672) * 8.33 * (125-54) * 1)/3412)]

= 7,153 + 4,800 +5,357

= 17,309 kWh

Early Replacement – non-fuel switch (see example after Natural gas section for Fuel switch):

For example, a 10 ton closed loop unit with Part Load EER rating of 20 and Part Load COP of 4.4 and with da esuperheater installed in in an Assisted living building in Chicago with a 100 gallon electric water heater, replacing an existing working Air Source Heat Pump with efficiency ratings of 8.2 EER and 7.7 HSPF:

ΔkWH for remaining life of existing unit (1st 8 years):

= [120,000 * 1,457 * (1/8.2 – 1/20) / 1000] + [1,646* 120,000 * (1/7.7 – 1/(4.4*3.412)) / 1000] + [1 * 0.44 * ((1/0.9568 * (100*672) * 8.33 * (125-54) * 1)/3412)]

= 12,580 + 12,495 +5357

= 30,432 kWh

ΔkWH for remaining measure life (next 17 years):

= [120,000 * 1,457 * (1/11 – 1/20) / 1000] + [1,646* 120,000 * (1/11 – 1/(4.4*3.412)) / 1000] + [1 * 0.44 * ((1/0.9568 * (100*672) * 8.33 * (125-54) * 1)/3412)]

= 7,153 + 4,800 +5,357

= 17,310 kWh

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

New Construction and Time of Sale:

$$\Delta kW = (Capacity_{Cool} * (1/EERbase - 1/EER_{GSHP}))/1000 * CF$$

Early replacement:

ΔkW for remaining life of existing unit (1st 8 years):

$$= (Capacity_{Cool} * (1/EERexist - 1/EER_{GSHP}))/1000 * CF$$

ΔkW for remaining measure life (next 17 years):

$$= (Capacity_{Cool} * (1/EERbase - 1/EER_{GSHP}))/1000 * CF$$

Where:

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)
= 91.3%%[664]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Central A/C (average during peak period)

[664] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility's peak hour is divided by the maximum AC load during the year.

= 47.8%[665]

New Construction or Time of Sale:

For example, a 10 ton closed loop unit with Full Load EER rating of 20:

$\Delta kW_{SSP}$ = (120,000 * (1/11 – 1/20))/1000 * 0.913

= 4.482kW

$\Delta kW_{PJM}$ = (36,000 * (1/11 – 1/20))/1000 * 0.478

= 2.347kW

Early Replacement:

For example, a 10 ton closed loop unit with Full Load 20 EER replaces an existing working Air Source Heat Pump with 8.2 EER:

$\Delta kW_{SSP}$ for remaining life of existing unit (1st 8 years):

= (120,000 * (1/8.2 – 1/20))/1000 * 0.913

= 7.883 kW

$\Delta kW_{SSP}$ for remaining measure life (next 17 years):

= (120,000 * (1/11– 1/20))/1000 * 0.913

= 4.482kW

$\Delta kW_{PJM}$ for remaining life of existing unit (1st 8 years):

= (120,000 * (1/8.2 – 1/20))/1000 * 0.478

= 4.127 kW

$\Delta kW_{PJM}$ for remaining measure life (next 17 years):

= (120,000 * (1/11 – 1/20))/1000 * 0.478

= 2.347kW

**NATURAL GAS SAVINGS**

New Construction and Time of Sale with baseline gas heat and/or hot water:

If measure is supported by gas utility only, gas utility claims savings calculated below:

ΔTherms = [Heating Savings] + [DHW Savings]

Heating Savings = Replaced baseline gas consumption – therm equivalent of GSHP source kWh

= (1 – ElecHeat) * ((Gas_Heating_Load/$Gas_{Effbase}$) – (kWhtoTherm * $EFLH_{heat}$ * $Capacity_{heat}$ * 1/($COP_{GSHP}$ * 3.412))/1000)

DHW Savings = (1 – ElecDHW) * (%DHW * (1/$EF_{GasBase}$ * $HotWaterUse_{Gallon}$ * γWater * (Tout – Tin) * 1 )/100,000

If measure is supported by electric utility only, ΔTherms = 0

If measure is supported by gas and electric utility, gas utility claims savings calculated below, (electric savings is provided in Electric Energy Savings section):

ΔTherms = [Heating Savings] + [DHW Savings]

Heating Savings = Replaced baseline gas consumption – therm equivalent of base ASHP source kWh

[665] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.

$= (1 - ElecHeat) * ((Gas\_Heating\_Load/Gas_{Effbase}) - (kWhtoTherm * EFLH_{heat} * Capacity_{heat} * 1/HSPF_{ASHP})/1000)$

DHW Savings = $(1 - ElecDHW) * (\%DHW * (1/ EF_{GasBase} * HotWaterUse_{Gallon} * \gamma Water * (T_{OUT} - T_{IN}) * 1.0) / 100{,}000)$

Early replacement for buildings with existing gas heat and/or hot water:

If measure is supported by gas utility only, gas utility claims savings calculated below:

ΔTherms for remaining life of existing unit (1st 8 years):

= [Heating Savings] + [DHW Savings]

Heating Savings = Replaced existing gas consumption – therm equivalent of GSHP source kWh

$= [(1 - ElecHeat) * ((Gas\_Heating\_Load/ Gas_{EffExist}) - (kWhtoTherm * EFLH_{heat} * Capacity_{heat} * 1/(COP_{GSHP} * 3.412))/1000)]$

DHW Savings = $(1 - ElecDHW) * (\%DHW * (1/ EF_{GasBase} * HotWaterUse_{Gallon} * \gamma Water * (T_{OUT} - T_{IN}) * 1.0) / 100{,}000)$

ΔTherms for remaining measure life (next 17 years):

= [Heating Savings] + [DHW Savings]

Heating Savings = Replaced baseline gas consumption – therm equivalent of GSHP source kWh

$= [(1 - ElecHeat) * ((Gas\_Heating\_Load/ Gas_{Effbase}) - (kWhtoTherm * EFLH_{heat} * Capacity_{heat} * 1/(COP_{GSHP} * 3.412))/1000)]$

DHW Savings = $(1 - ElecDHW) * (\%DHW * (1/ EF_{GasBase} * HotWaterUse_{Gallon} * \gamma Water * (T_{OUT} - T_{IN}) * 1.0) / 100{,}000)$

If measure is supported by electric utility only, ΔTherms = 0

If measure is supported by gas and electric utility, gas utility claims savings calculated below:

ΔTherms for remaining life of existing unit (1st 8 years):

= [Heating Savings] + [DHW Savings]

Heating Savings = Replaced existing gas consumption – therm equivalent of base ASHP source kWh

$= (1 - ElecHeat) * ((Gas\_Heating\_Load/Gas_{EffExist}) - (kWhtoTherm * EFLH_{heat} * Capacity_{heat} * 1/HSPF_{ASHP})/1000)$

DHW Savings = $(1 - ElecDHW) * (\%DHW * (1/ EF_{GasBase} * HotWaterUse_{Gallon} * \gamma Water * (T_{OUT} - T_{IN}) * 1.0) / 100{,}000)$

ΔTherms for remaining measure life (next 17 years):

= [Heating Savings] + [DHW Savings]

Heating Savings = Replaced baseline gas consumption – therm equivalent of base ASHP source kWh

$= (1 - ElecHeat) * ((Gas\_Heating\_Load/Gas_{EffBase}) - (kWhtoTherm * EFLH_{heat} * Capacity_{heat} * 1/HSPF_{ASHP})/1000)$

DHW Savings = $(1 - ElecDHW) * (\%DHW * (1/ EF_{GasBase} * HotWaterUse_{Gallon} * \gamma Water * (T_{OUT} - T_{IN}) * 1.0) / 100{,}000)$

Where:

Gas_Heating_Load = Estimate of annual heating load

$= Capacity_{heat} * EFLH_{heat} / 100,000$

$Gas_{Effbase}$ = Minimum federal standard baseline efficiency of boiler or furnace

= Refer to applicable table in 'Definition of Baseline Equipment' section

$Gas_{EffExist}$ = Existing efficiency of boiler or furnace

= Actual

kWhtoTherm = Converts source kWh to Therms

$= H_{grid} / 100,000$

$H_{grid}$ = Heat rate of the grid in btu/kWh based on the average fossil heat rate for the EPA eGRID subregion and includes a factor that takes into account T&D losses.

For systems operating less than 6,500 hrs per year:

Use the Non-baseload heat rate provided by EPA eGRID for RFC West region for ComEd territory (including independent providers connected to RFC West), and SERC Midwest region for Ameren territory (including independent providers connected to SERC Midwest) [666]. Also include any line losses.

For systems operating more than 6,500 hrs per year:

Use the All Fossil Average heat rate provided by EPA eGRID for RFC West region for ComEd territory, and SERC Midwest region for Ameren territory. Also include any line losses

$Capacity_{heat}$ = Heating Capacity of Ground Source Heat Pump (Btu/hr)

= Actual installed

$EFLH_{heat}$ = Heating Equivalent Full Load Hours

Dependent on building type, provided in section 4.4 HVAC End Use

$EF_{GasBase}$ = Energy factor of Baseline natural gas DHW heater

= Actual. If unknown or New Construction assume federal standard as defined in applicable table in 'Definition of Baseline Equipment' section

All other variabes provided above.

[666] These values are subject to regular updates so should be reviewed regularly to ensure the current assumptions are correct. Refer to the latest EPA eGRID data. Current values, based on eGrid 2016 are:

- Non-Baseload RFC West: 10,539 Btu/kWh * (1 + Line Losses)
- Non-Baseload SERC Midwest: 9,968 Btu/kWh * (1 + Line Losses)
- All Fossil Average RFC West: 9,962 Btu/kWh * (1 + Line Losses)
- All Fossil Average SERC Midwest: 9,996 Btu/kWh * (1 + Line Losses)

Illustrative Examples *[for illustrative purposes a Hgrid value of 10,000 Btu/kWh is used]*

New construction using gas boiler and air-cooled chiller, *supported by Gas utility only*:

For example, a 10 ton closed loop unit with Part Load EER rating of 20 and Part Load COP of 4.4 in an Assisted Living building in Chicago with a 100 gallon gas water heater is installed in place of a natural gas boiler and air-cooled chiller:

ΔkWH = 0

ΔTherms = [Replaced baseline gas consumption – therm equivalent of GSHP source kWh] + [DHW Savings]

= [(1-0)* ((1,975/80%)-(10,000/100,000 *1,646 *120,000 *1/(4.4 *3.412))/1,000)] + [(1 - 0) * 0.44 * (1/80% * (100*672) * 8.33 * (125- 54) * 1 )/100,000]

= 1,153 +219

= 1,372 therms

Early Replacement fuel switch, *supported by gas and electric utility*:

For example, a 10 ton closed loop unit with Part Load EER rating of 20 and Part Load COP of 4.4 in an Assisted Living building in Chicago with a 100 gallon gas water heater replaces an existing working natural gas boiler with 75% efficiency and air-cooled chiller of 9.5 EER, and desuperheater installed with natural gas existing DHW heater:

ΔkWh for remaining life of existing unit (1st 8 years):

= [Cooling savings] + [Heating savings from base ASHP to GSHP] + [DHW savings]

= $[(Capacity_{cool} * EFLH_{Cool} * (1/EER_{Exist} – 1/EER_{GSHP}))/1000] + [(Capacity_{Heat} * EFLH_{Heat} * (1/HSPF_{ASHP} – 1/(COP_{GSHP} * 3.412)))/1000] + [Elec_{DHW} * (\%DHW * ((1/EF_{elecbase}) * HotWaterUse_{Gallon} * γWater * (Tout – Tin) * 1 /3412))]$

= [(120,000 * 1,457 * (1/9.5 - 1/20))/1,000] + [(120,000 * 1,646 * (1/11 - 1/(4.4 * 3.412)))/1,000] + [0 * (0.44 * ((1/0.9568) * (100*672) * 8.33 * (125 - 54) * 1 /3412))]

= 9,662 + 4,800 + 0

= 14,462 kWh

Continued on next page.

Illustrative Example continued

ΔkWh for remaining measure life (next 17 years):

= [Cooling savings] + [Heating savings from base ASHP to GSHP] + [DHW savings]

= $[(Capacity_{cool} * EFLH_{Cool} * (1/EER_{base} – 1/EER_{GSHP}))/1000] + [(Capacity_{Heat} * EFLH_{Heat} * (1/HSPF_{ASHP} – 1/(COP_{GSHP} * 3.412)))/1000] + [Elec_{DHW} * (\%DHW * ((1/EF_{elecbase}) * HotWaterUse_{Gallon} * γWater * (Tout – Tin) * 1 /3412))]$

= [120,000 * 1,457 * (1/11 – 1/20) / 1000] + [1,646* 120,000 * (1/11 – 1/(4.4*3.412)) / 1000] + [0 * 0.44 * ((1/0.9568 * (100*672) * 8.33 * (125-54) * 1)/3412)]

= 7,153 + 4,800 +0

= 11,953 kWh

ΔTherms for remaining life of existing unit (1st 8 years):

= [Heating Savings] + [DHW Savings]

= [Replaced existing gas consumption – therm equivalent of base ASHP source kWh] + [DHW Savings]

= $[(1 – ElecHeat) * ((Gas\_Heating\_Load/Gas_{EffExist}) – (kWhtoTherm * EFLH_{heat} * Capacity_{heat} * 1/HSPF_{ASHP})/1000)] + [(1 – ElecDHW) * (\%DHW * (1/ EF_{GasBase} * HotWaterUse_{Gallon} * γWater * (T_{OUT} – T_{IN}) * 1.0) / 100,000)]$

= [(1 - 0)*((1975/75%) - (10000/100000 * 1646 * 120,000 * 1/11)/1000)]+ [(1 - 0) *( 0.44 * (1/ 80% *(100*672) * 8.33 * (125- 54) * 1) / 100000)]

= 838 + 219

= 1,057 therms

ΔTherms for remaining measure life (next 17 years):

= [Replaced baseline gas consumption – therm equivalent of base ASHP source kWh] + [DHW Savings]

= $[(1 – ElecHeat) * ((Gas\_Heating\_Load/Gas_{EffBase}) – (kWhtoTherm * EFLH_{heat} * Capacity_{heat} * 1/HSPF_{ASHP})/1000)] + [(1 – ElecDHW) * (\%DHW * (1/ EF_{GasBase} * HotWaterUse_{Gallon} * γWater * (T_{OUT} – T_{IN}) * 1.0) / 100,000)]$

= [(1-0)* ((1,975/80%)-(10,000/100,000 *1,646 *120,000 *1/11)/1,000)] + [(1 - 0) * 0.44 * (1/80% * (100*672) * 8.33 * (125- 54) * 1 )/100,000]

= 673 + 219

= 892 therms

## Water and Other Non-Energy Impact Descriptions and Calculation

N/A

## Deemed O&M Cost Adjustment Calculation

N/A

## Cost Effectiveness Screening and Load Reduction Forecasting when Fuel Switching

This measure can involve fuel switching from gas to electric.

For the purposes of forecasting load reductions due to fuel switch GSHP projects; changes in site energy use at the customer's meter (using ΔkWh algorithm below) adjusted for utility line losses (at-the-busbar savings), customer switching estimates, NTG, and any other adjustment factors deemed appropriate, should be used.

The inputs to cost effectiveness screening should reflect the actual impacts on the electric and fuel consumption at the customer meter and, for fuel switching measures, this will not match the output of the calculation/allocation methodology presented in the "Electric Energy Savings" and "Natural Gas Savings" sections above. Therefore in addition to the calculation of savings claimed, the following values should be used to assess the cost effectiveness of the measure.

ΔTherms = [Heating Consumption Replaced[667]] + [DHW Savings if existing natural gas DHW]

$= [(1 - ElecHeat) * ((Gas\_Heating\_Load / Gas_{Effbase})] + [(1 - ElecDHW) * \%DHW * (1/EF_{GasBase} * HotWaterUse_{Gallon} * \gamma Water * (T_{OUT} - T_{IN}) * 1.0) / 100{,}000)]$

ΔkWh = - [GSHP heating consumption] + [Cooling savings[668]] + [DHW savings if existing electric DHW]

$= - [(EFLH_{heat} * Capacity_{Heat} * (1/ COP_{GSHP} * 3.412))/1000] + [(EFLH_{cool} * Capacity_{Cool} * (1/EER_{base} - 1/EER_{GSHP}))/1000] + [ElecDHW * \%DHW * ((1/EF_{ELEC} * HotWaterUse_{Gallon} * \gamma Water * (T_{OUT} - T_{IN}) * 1.0) / 3412)]$

Illustrative Example of Cost Effectiveness Inputs for Fuel Switching

For example, a 10 ton unit with Part Load EER rating of 20 and Part Load COP of 4.4 in an Assisted living building in Chicago with a 100 gallon gas water heater replaces an existing working natural gas boiler with 75% efficiency and air-cooled chiller of 9.5 EER. [Note the calculation provides the annual savings for the first 8 years of the measure life, an additional calculation (not shown) would be required to calculated the annual savings for the remaining life (years 9-25)]:

ΔTherms $= [(1 - ElecHeat) * ((Gas\_Heating\_Load / Gas_{Effbase})] + [(1 - ElecDHW) * \%DHW * (1/EF_{GasBase} * HotWaterUse_{Gallon} * \gamma Water * (T_{OUT} - T_{IN}) * 1.0) / 100{,}000)]$

$= [(1-0) * (1975/0.8)] + [((1 - 0) * 0.44 * (1/0.8 * (100*672) * 8.33 * (125- 54) * 1 )/100000)]$

= 2,469 + 219

= 2,688 therms

ΔkWh $= - [(EFLH_{heat} * Capacity_{Heat} * (1/ COP_{GSHP} * 3.412))/1000] + [(EFLH_{cool} * Capacity_{Cool} * (1/EER_{base} - 1/EER_{GSHP}))/1000] + [ElecDHW * \%DHW * ((1/EF_{ELEC} * HotWaterUse_{Gallon} * \gamma Water * (T_{OUT} - T_{IN}) * 1.0) / 3412)]$

$= - [(1646 * 120000 * (1/ 4.4 * 3.412))/1000] + [( 1457* 120000 * (1/11 - 1/20))/1000] + [0 * (0.44 * ((1/0.9568) * (100*672) * 8.33 * (125 - 54) * 1 /3412))]$

= -153,168 + 7153 + 0

= -146,015 kWh

**MEASURE CODE: CI-HVC-GSHP-V01-190101**

**REVIEW DEADLINE: 1/1/2021**

[667] Note $Gas_{Effbase}$ in the algorithm should be replaced with $Gas_{EffExist}$ for early replacement measures.

[668] Note $EER_{base}$ in the algorithm should be replaced with $EER_{exist}$ for early replacement measures.

## 4.4.45 Adsorbent Air Cleaning

### Description

The Adsorbent Air Cleaning (AAC) measure installs modular adsorbent air cleaning devices ("AAC modules") into commercial forced air HVAC systems. These devices pass return air through adsorbent media which remove the gas-phase contaminants carbon dioxide and species of volatile organic compounds (VOCs) from the return air, allowing it to be recirculated rather than removed from the building as exhaust and replaced with ventilation air. This allows HVAC system operators to substantially reduce the amount of outside air brought in for ventilation while still maintaining acceptable indoor air quality, resulting in heating and cooling energy savings. An energy penalty is incurred due to the operation of fans integrated within the AAC modules, as well as from integrated electric heaters used in a regeneration cycle which purges the adsorbent media of contaminants to allow them to be used again.

This measure serves the market for medium to large commercial and institutional buildings.

This measure was developed to be applicable to the following program types: NC, RF, DI. If applied to other program types, the measure savings should be verified.

### Definition Of Efficient Equipment

Efficient equipment is defined as a commercial HVAC system which has AAC modules installed in the return airstream, with the number of modules determined by appropriate sizing calculations. The modules allow for a substantial reduction in the volume of outside air introduced to the building compared to systems without AAC modules.

### Definition Of Baseline Equipment

Two baselines are defined here. The first is a variable air volume HVAC system equipped with an integrated economizer and which recirculates a portion of its return air. The other baseline is a dedicated outside air system; that is, a system which obtains 100% of its supply air from outside air.

### Deemed Lifetime Of Efficient Equipment

The expected measure life for HVAC applications is 20 years.[669]

### Deemed Measure Cost

Actual measure costs should be used if available. If costs are not available, the deemed measure cost below can be used[670].

Table 1 – Deemed Measure Cost Details

| Unit | Material Cost / Unit | Labor Cost / Unit | Total Cost / Unit ($/cfm) |
|---|---|---|---|
| cfm | $1.12 | $0.50 | $1.62 |

For example, the default deemed measure cost of installing the AAC measure in an HVAC system with a design supply air flow rate of 75,000 cfm is:

Deemed Measure Cost ($) = 75,000 cfm * $1.62/cfm = $121,500

### Loadshape

For buildings with gas heat:

[669] ASHRAE Owning and Operating Cost Database, Equipment Life/Maintenance Cost Survey; HVAC Service Life Database. Accessed 8/29/2018.
[670] Default measure cost is based on sales information and labor cost estimates provided by a major Original Equipment Manufacturer (OEM) of AAC units. The OEM's estimates are based on prior installation experiences and case studies.

Loadshape C03 – Commercial Cooling

For buildings with electric heat:

Loadshape C05 – Commercial Electric Heating and Cooling

### COINCIDENCE FACTOR

The concidence factor is assumed to be 1.0 – that is, building ventilation will always be provided during peak periods.

## Algorithm

### CALCULATION OF ENERGY SAVINGS

To determine the savings associated with the Adsorbent Air Cleaning measure, the IL TRM prototype eQuest models were utilized. These models were developed by Seventhwave (formerly the Energy Center of Wisconsin)[671] and modified by VEIC in 2014 as part of the IL TRM v4.0 Equivalent Full Load Hours Update. The prototype models were modified in order to simulate the following measure scenarios:

1. Commercial variable air volume HVAC system with integrated economizer and recirculated return air
    a. Natural gas heating
    b. Electric heating
2. Dedicated outside air system (100% OA), with and without energy recovery ventilation
    a. Natural gas heating
    b. Electric heating
    c. Heat pump

Three major modifications to the prototype energy models were introduced in order to simulate the AAC measure. The first was a reduction in outside air consistent with reductions previously demonstrated in field studies. The second was a reduction in supply fan static pressure to simulate the pressure contribution of the AAC modules' internal fans. The third was the introduction of an electrical load and schedule to account for the energy consumed by the AAC modules' internal fans and regeneration heater. Simulation results were normalized to the amount of outside air reduced by the AAC measure.

### ELECTRIC ENERGY SAVINGS

$\Delta kWh = \Delta V_{OA}$ * Normalized Electric Energy Savings

Where:

$\Delta V_{OA}$ = reduction in minimum outside air flow in scfm due to incorporating an AAC module

= if the rate is unknown, calculate using the following equation:

$\Delta V_{OA} = V\_supply * F_{OA} * F_R$, where:

V_supply = design or operational peak supply air flow rate of air handler in scfm

$F_{OA}$ = operational minimum fraction of outside air in supply airflow before installing AAC modules

For DOAS systems, which have a baseline condition of 100% outside air, $F_{OA} = 1$. For systems which recirculate a portion of their return air, $F_{OA}$ will vary between 0 and 1. In these cases, $F_{OA}$ can be determined by using the design minimum outside air flow or measured by correlating the minimum outside air

[671] Energy Center of Wisconsin, ComEd Portfolio Modeling Report, July 30, 2010

damper position to outside air flow, or by using an airflow measurement station.

$F_R$ = percentage reduction of outside air due to AAC modules

= custom; if unknown, use 0.7 as a default[672]

Normalized Electric Energy Savings

= ΔkWh/Δscfm savings value for the appropriate combination of HVAC system type, climate zone, and measure scenario per Table 2 – Electric Energy Savings Summary (kWh/scfm)

**Table 2 – Electric Energy Savings Summary**

| HVAC System Type | Normalized Electricity Savings (kWh/scfm) | | | | |
|---|---|---|---|---|---|
| | Rockford - Zone 1 | Chicago - Zone 2 | Springfield - Zone 3 | Mt Vernon/Belleville - Zone 4 | Marion - Zone 5 |
| **Variable Air Volume** | | | | | |
| **VAV with Gas Heat** | **4.68** | **4.53** | **5.73** | **6.44** | **5.77** |
| **VAV with Electric Heat** | **31.87** | **24.84** | **21.60** | **15.66** | **13.91** |
| **Dedicated Outside Air System - no energy recovery** | | | | | |
| *No humidity control* | | | | | |
| **DOAS With Gas Heat** | **1.99** | **1.56** | **2.28** | **2.38** | **1.65** |
| **DOAS With Electric Heat** | **17.60** | **14.90** | **13.71** | **11.84** | **8.12** |
| **DOAS - Heat Pump** | **1.98** | **1.63** | **1.76** | **2.38** | **2.33** |
| *With humidity control* | | | | | |
| **DOAS With Gas Heat** | **2.33** | **2.11** | **2.95** | **3.41** | **2.52** |
| **DOAS With Electric Heat** | **11.31** | **15.96** | **14.82** | **13.80** | **9.71** |
| **DOAS - Heat Pump** | **2.44** | **2.22** | **2.22** | **3.01** | **3.14** |
| **Dedicated Outside Air System - sensible and latent energy recovery** | | | | | |
| *No humidity control* | | | | | |
| **DOAS With Gas Heat** | **1.67** | **1.38** | **2.28** | **1.47** | **0.76** |
| **DOAS With Electric Heat** | **3.12** | **2.43** | **2.36** | **1.82** | **1.82** |
| **DOAS - Heat Pump** | **0.40** | **0.34** | **0.21** | **0.37** | **0.32** |
| *With humidity control* | | | | | |
| **DOAS With Gas Heat** | **1.83** | **1.61** | **1.75** | **2.12** | **1.27** |
| **DOAS With Electric Heat** | **3.44** | **3.07** | **2.86** | **3.24** | **3.07** |
| **DOAS - Heat Pump** | **0.66** | **0.50** | **0.50** | **0.81** | **0.79** |
| **Dedicated Outside Air System - sensible energy recovery** | | | | | |
| *No humidity control* | | | | | |
| **DOAS With Gas Heat** | **2.15** | **1.78** | **2.44** | **2.60** | **1.89** |
| **DOAS With Electric Heat** | **8.08** | **6.67** | **6.37** | **5.39** | **5.26** |
| **DOAS - Heat Pump** | **1.15** | **0.83** | **0.92** | **1.17** | **1.13** |
| *With humidity control* | | | | | |
| **DOAS With Gas Heat** | **2.48** | **2.27** | **3.13** | **3.62** | **2.76** |
| **DOAS With Electric Heat** | **8.70** | **7.62** | **7.43** | **7.25** | **7.08** |
| **DOAS - Heat Pump** | **1.50** | **1.30** | **1.30** | **1.69** | **1.80** |

[672] The default value of 0.7 for $F_R$ is based on a survey of previous case studies which documented the field installation of AAC modules in existing HVAC systems. See references for more information.

**EXAMPLE:**

An office building in Climate Zone 3 is equipped with a VAV system with hot water heat, and has a design supply air flow rate of 50,000 scfm and an outdoor air ventilation rate of 5,000 scfm. Installing AAC modules will allow reduction of the outdoor air ventilation rate by 70%. In this case:

V_supply = 50,000 scfm

$F_{OA}$ = 5,000 scfm / 50,000 scfm = 0.1

$F_R$ = 0.7

$\Delta V_{OA}$ = V_supply * $F_{OA}$ * $F_R$ = 50,000 scfm * 0.1 * 0.7 = 3,500 scfm

Normalized Electric Energy Savings = 5.73 kWh/scfm

ΔkWh = $\Delta V_{OA}$ * Normalized Electric Energy Savings

= 3,500 scfm * 5.73 kWh/scfm = 20,055 kWh

= 21,665 kWh

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = $\Delta V_{OA}$ * Normalized Electric Peak Demand Savings * CF

Where:

$\Delta V_{OA}$ = reduction in minimum outside air flow in scfm due to incorporating an AAC module

= if the rate is unknown, calculate using the following equation:

$\Delta V_{OA}$ = V_supply * $F_{OA}$ * $F_R$, where:

V_supply = design or operational peak supply air flow rate of air handler in scfm

$F_{OA}$ = operational minimum fraction of outside air in supply airflow before installing AAC modules

For DOAS systems, which have a baseline condition of 100% outside air, $F_{OA}$ = 1. For systems which recirculate a portion of their return air, $F_{OA}$ will vary between 0 and 1. In these cases, $F_{OA}$ can be determined by using the design minimum outside air flow or measured by correlating the minimum outside air damper position to outside air flow, or by using an airflow measurement station.

$F_R$ = percentage reduction of outside air due to AAC modules

= custom; if unknown, use 0.7 as a default

CF = 1.0

Normalized Electric Peak Demand Savings

= ΔkW/Δscfm savings value for the appropriate combination of building type, climate zone, and measure scenario per Table 3 – Electric Peak Demand Savings Summary (kW/cfm)

**Table 3 – Electric Demand Savings Summary**

| HVAC System Type | Normalized Electric Demand Savings (kW/scfm) | | | | |
|---|---|---|---|---|---|
| | Rockford - Zone 1 | Chicago - Zone 2 | Springfield - Zone 3 | Mt Vernon/Belleville - Zone 4 | Marion - Zone 5 |
| **Variable Air Volume** | | | | | |
| **VAV with Gas Heat** | 0.006 | 0.007 | 0.007 | 0.000 | 0.000 |
| **VAV with Electric Heat** | 0.005 | 0.007 | 0.007 | 0.000 | 0.000 |
| **Dedicated Outside Air System - no energy recovery** | | | | | |
| *No humidity control* | | | | | |
| **DOAS With Gas Heat** | 0.004 | 0.003 | 0.004 | 0.005 | 0.004 |
| **DOAS With Electric Heat** | 0.004 | 0.004 | 0.004 | 0.005 | 0.004 |
| **DOAS - Heat Pump** | 0.003 | 0.003 | 0.004 | 0.003 | 0.004 |
| *With humidity control* | | | | | |
| **DOAS With Gas Heat** | 0.005 | 0.004 | 0.005 | 0.006 | 0.004 |
| **DOAS With Electric Heat** | 0.005 | 0.005 | 0.005 | 0.007 | 0.005 |
| **DOAS - Heat Pump** | 0.005 | 0.005 | 0.005 | 0.004 | 0.005 |
| **Dedicated Outside Air System - sensible and latent energy recovery** | | | | | |
| *No humidity control* | | | | | |
| **DOAS With Gas Heat** | 0.002 | 0.001 | 0.002 | 0.002 | 0.002 |
| **DOAS With Electric Heat** | 0.001 | 0.000 | 0.002 | 0.002 | 0.002 |
| **DOAS - Heat Pump** | 0.001 | 0.000 | 0.001 | 0.001 | 0.001 |
| *With humidity control* | | | | | |
| **DOAS With Gas Heat** | 0.002 | 0.002 | 0.002 | 0.001 | 0.001 |
| **DOAS With Electric Heat** | 0.002 | 0.003 | 0.002 | 0.003 | 0.002 |
| **DOAS - Heat Pump** | 0.003 | 0.001 | 0.001 | 0.001 | 0.001 |
| **Dedicated Outside Air System - sensible energy recovery** | | | | | |
| *No humidity control* | | | | | |
| **DOAS With Gas Heat** | 0.004 | 0.002 | 0.005 | 0.005 | 0.004 |
| **DOAS With Electric Heat** | 0.003 | 0.003 | 0.003 | 0.004 | 0.003 |
| **DOAS - Heat Pump** | 0.001 | 0.002 | 0.002 | 0.002 | 0.002 |
| *With humidity control* | | | | | |
| **DOAS With Gas Heat** | 0.005 | 0.004 | 0.005 | 0.006 | 0.004 |
| **DOAS With Electric Heat** | 0.006 | 0.006 | 0.006 | 0.007 | 0.006 |
| **DOAS - Heat Pump** | 0.003 | 0.003 | 0.003 | 0.002 | 0.003 |

**EXAMPLE:**

Under the same conditions as the previous example,

Normalized Electric Demand Savings = 0.007 kW/scfm

$\Delta kWh = \Delta V_{OA}$ * Normalized Demand Energy Savings * CF

= 3,500 scfm * 0.007 kW/scfm * 1

= 24.5 kW

**NATURAL GAS SAVINGS**

$$\Delta therms = \Delta V_{OA} * \text{Normalized Gas Energy Savings}$$

Where:

$\Delta V_{OA}$ = reduction in minimum outside air flow in scfm due to incorporating an AAC module

= custom; if unknown, calculate using the following equation:

$\Delta V_{OA} = V\_supply * F_{OA} * F_R$, where:

V_supply = design or operational peak supply air flow rate of air handler in scfm

$F_{OA}$ = operational minimum fraction of outside air in supply airflow before installing AAC modules

For DOAS systems, which have a baseline condition of 100% outside air, $F_{OA}$ = 1. For systems which recirculate a portion of their return air, $F_{OA}$ will vary between 0 and 1. In these cases, $F_{OA}$ can be determined by using the design minimum outside air flow or measured by correlating the minimum outside air damper position to outside air flow, or by using an airflow measurement station.

$F_R$ = percentage reduction of outside air due to AAC modules

= custom; if unknown, use 0.7 as a default

Normalized Gas Energy Savings

= Δtherms/Δscfm savings value for the appropriate combination of building type, climate zone, and measure scenario per Table 4 – Gas Energy Savings Summary (therms/scfm)

**Table 4 – Natural Gas Energy Savings Summary (therms/cfm)**

| HVAC System Type | Normalized Natural Gas Savings (therms/scfm) | | | | |
|---|---|---|---|---|---|
| | Rockford - Zone 1 | Chicago - Zone 2 | Springfield - Zone 3 | Mt Vernon/Belleville - Zone 4 | Marion - Zone 5 |
| **Variable Air Volume** | | | | | |
| VAV with Gas Heat | 1.01 | 0.77 | 0.59 | 0.39 | 0.39 |
| VAV with Electric Heat | n/a | n/a | n/a | n/a | n/a |
| **Dedicated Outside Air System - no energy recovery** | | | | | |
| *No humidity control* | | | | | |
| DOAS With Gas Heat | 0.79 | 0.70 | 0.58 | 0.50 | 0.33 |
| DOAS With Electric Heat | n/a | n/a | n/a | n/a | n/a |
| DOAS - Heat Pump | 0.69 | 0.59 | 0.59 | 0.35 | 0.34 |
| *With humidity control* | | | | | |
| DOAS With Gas Heat | 0.80 | 0.73 | 0.60 | 0.55 | 0.38 |
| DOAS With Electric Heat | n/a | n/a | n/a | n/a | n/a |
| DOAS - Heat Pump | 0.69 | 0.59 | 0.59 | 0.35 | 0.34 |
| **Dedicated Outside Air System - sensible and latent energy recovery** | | | | | |
| *No humidity control* | | | | | |
| DOAS With Gas Heat | 0.16 | 0.17 | 0.10 | 0.07 | 0.07 |
| DOAS With Electric Heat | n/a | n/a | n/a | n/a | n/a |
| DOAS - Heat Pump | 0.11 | 0.09 | 0.08 | 0.04 | 0.04 |
| *With humidity control* | | | | | |
| DOAS With Gas Heat | 0.16 | 0.16 | 0.11 | 0.12 | 0.11 |
| DOAS With Electric Heat | n/a | n/a | n/a | n/a | n/a |
| DOAS - Heat Pump | 0.11 | 0.08 | 0.08 | 0.04 | 0.04 |
| **Dedicated Outside Air System - sensible energy recovery** | | | | | |
| *No humidity control* | | | | | |
| DOAS With Gas Heat | 0.38 | 0.33 | 0.27 | 0.23 | 0.21 |
| DOAS With Electric Heat | n/a | n/a | n/a | n/a | n/a |
| DOAS - Heat Pump | 0.30 | 0.25 | 0.25 | 0.14 | 0.13 |
| *With humidity control* | | | | | |
| DOAS With Gas Heat | 0.39 | 0.37 | 0.29 | 0.29 | 0.27 |
| DOAS With Electric Heat | n/a | n/a | n/a | n/a | n/a |
| DOAS - Heat Pump | 0.30 | 0.25 | 0.25 | 0.14 | 0.13 |

**EXAMPLE:**

Under the same conditions as the previous example,

Normalized Gas Energy Savings = 0.59 therms/scfm

Δtherms = $\Delta V_{OA}$* Normalized Gas Energy Savings

= 3,500 scfm * 0.59 therms/scfm

= 2,065 therms

**MEASURE CODE: CI-HVC-ADAC-V01-190101**

**REVIEW DEADLINE: 1/1/2021**

## 4.5 Lighting End Use

The commercial lighting measures use a standard set of variables for hours or use, waste heat factors, coincident factors and HVAC interaction effects. This table has been developed based on information provided by the various stakeholders. For ease of review, the table is included here and referenced in each measure.

The building characteristics can be found in the reference table named "EFLH Building Descriptions Updated 2014-11-21.xlsx". Note a modeling subcommittee is in the process of transferring and calibrating models from eQuest to OpenStudio. The model source is provided in the table.

Note where a measure installation is within a building or application that does not fit with any of the defined building types below, the user should apply custom assumptions where it is reasonable to estimate them, else the building of best fit should be utilized.

| Building/Space Type | Fixture Annual Operating Hours[673] | Screw based bulb Annual Operating hours[674] | Waste Heat Cooling Energy WHFe [675] | Waste Heat Cooling Demand WHFd | Coinci-dence Factor CF[676] | Waste Heat Gas Heating IFTherms[677] | Waste Heat Electric Resistance Heating IFkWh[678] | Waste Heat Electric Heat Pump Heating IFkWh | Model Source |
|---|---|---|---|---|---|---|---|---|---|
| Assisted Living | 7,862 | 5,950 | 1.14 | 1.30 | 0.66 | 0.035 | 0.823 | 0.358 | eQuest |
| Childcare/Pre-School | 2,860 | 2,860 | 1.17 | 1.29 | 0.72 | 0.018 | 0.420 | 0.183 | eQuest |
| College | 3,395 | 2,588 | 1.06 | 1.39 | 0.63 | 0.020 | 0.462 | 0.201 | eQuest |
| Convenience Store | 4,672 | 3,650 | 1.09 | 1.26 | 0.76 | 0.035 | 0.828 | 0.360 | eQuest |
| Elementary School | 3,038 | 2,118 | 1.17 | 1.29 | 0.72 | 0.018 | 0.420 | 0.183 | eQuest |
| Garage | 3,401 | 3,540 | 1.00 | 1.00 | 0.92 | 0.000 | 0.000 | 0.000 | eQuest |
| Garage, 24/7 lighting | 8,766 | 8,766 | 1.00 | 1.00 | 1.00 | 0.000 | 0.000 | 0.000 | eQuest |
| Grocery | 4,650 | 3,650 | 1.05 | 1.22 | 0.73 | 0.022 | 0.511 | 0.222 | eQuest |
| Healthcare Clinic | 3,890 | 4,207 | 1.40 | 1.85 | 0.65 | 0.006 | 0.144 | 0.063 | eQuest |
| High School | 3,038 | 2,327 | 1.18 | 1.39 | 0.72 | 0.028 | 0.656 | 0.285 | eQuest |
| Hospital - CAV no econ | 7,616 | 4,207 | 1.11 | 1.29 | 0.76 | 0.022 | 0.527 | 0.229 | eQuest |
| Hospital - CAV econ | 7,616 | 4,207 | 1.06 | 1.27 | 0.75 | 0.023 | 0.533 | 0.232 | eQuest |
| Hospital - VAV econ | 7,616 | 4,207 | 1.37 | 1.79 | 0.70 | 0.010 | 0.241 | 0.105 | eQuest |

[673] Fixtures hours of use are based upon schedule assumptions used in the eQuest models, except for those building types where Illinois based metering results provide a statistically valid estimate (currently: College, Elementary School, High School, Manufacturing, Low and Mid rise Office, Retail Department Store and Warehouse). Miscellaneous is a weighted average of indoor spaces using the relative area of each building type in the region (CBECS).

[674] Hours of use for screw based bulbs are derived from DEER 2008 by building type for cfls. Garage, exterior and multi-family common area values are from the Hours of Use Table in this document. Miscellaneous is an average of interior space values. Some building types are averaged when DEER has two values: these include office, restaurant and retail. Healthcare clinic uses the hospital value.

[675] The Waste Heat Factor for Energy and is developed using EQuest models for various building types base on Chicago Illinois (closest to statewide average HDD and CDD). Exterior and garage values are 1, unknown is a weighted average of the other building types.

[676] Coincident diversity factors are based on either combined IL evaluation results (College, Elementary School, High School, Manufacturing, Low and Mid rise Office, Retail Department Store and Warehouse), case lighting projects performed over several years by Michaels Energy in Illinois and other jurisdictions (Refrigerated and Freezer Cases), or based upon schedules defined in the eQuest models described (all others).

[677] IF Therms value is developed using EQuest models consistent with methodology for Waste Heat Factor for Energy.

[678] Electric heat penalty assumptions are based on converting the IFTherm multiplier value in to kWh and then applying relative heating system efficiencies. The gas efficiency was assumed to be 78% AFUE based upon standard TRM assumption for existing unit average efficiency, and the electric resistance is assumed to be 100%, for Heat Pump is assumed to be 2.3COP: IFElectricHeat = IFTherms * 29.3 kWh/therm * 78% (Gas Heating Equipment Efficiency) / 100% (Electric Resistance Efficiency)

| Building/Space Type | Fixture Annual Operating Hours[673] | Screw based bulb Annual Operating hours[674] | Waste Heat Cooling Energy WHFe [675] | Waste Heat Cooling Demand WHFd | Coinci-dence Factor CF[676] | Waste Heat Gas Heating IFTherms[677] | Waste Heat Electric Resistance Heating IFkWh[678] | Waste Heat Electric Heat Pump Heating IFkWh | Model Source |
|---|---|---|---|---|---|---|---|---|---|
| Hospital - FCU | 7,616 | 4,207 | 1.38 | 1.29 | 0.73 | 0.001 | 0.033 | 0.015 | eQuest |
| Manufacturing Facility | 4,618 | 2,629 | 1.02 | 1.04 | 0.81 | 0.012 | 0.270 | 0.117 | eQuest |
| MF - High Rise - Common | 6,138 | 5,950 | 1.14 | 1.32 | 0.64 | 0.025 | 0.596 | 0.259 | eQuest |
| MF - Mid Rise - Common | 5,216 | 5,950 | 1.24 | 1.55 | 0.82 | 0.032 | 0.741 | 0.322 | OpenStudio |
| Hotel/Motel - Guest | 2,390 | 777 | 1.18 | 1.36 | 0.28 | 0.020 | 0.463 | 0.201 | eQuest |
| Hotel/Motel - Common | 6,138 | 4,542 | 1.20 | 1.24 | 0.73 | 0.032 | 0.748 | 0.325 | eQuest |
| Movie Theater | 3,506 | 5,475 | 1.11 | 1.38 | 0.53 | 0.029 | 0.673 | 0.293 | eQuest |
| Office - High Rise - CAV no econ | 2,886 | 3,088 | 1.00 | 1.07 | 0.57 | 0.037 | 0.874 | 0.380 | eQuest |
| Office - High Rise - CAV econ | 2,886 | 3,088 | 1.00 | 1.07 | 0.57 | 0.039 | 0.905 | 0.394 | eQuest |
| Office - High Rise - VAV econ | 2,886 | 3,088 | 1.27 | 1.65 | 0.53 | 0.022 | 0.510 | 0.222 | eQuest |
| Office - High Rise - FCU | 2,886 | 3,088 | 1.35 | 1.56 | 0.59 | 0.015 | 0.346 | 0.150 | eQuest |
| Office - Low Rise | 2,698 | 3,088 | 1.11 | 1.31 | 0.52 | 0.016 | 0.371 | 0.161 | eQuest |
| Office - Mid Rise | 3,266 | 3,088 | 1.06 | 1.34 | 0.60 | 0.006 | 0.139 | 0.060 | OpenStudio |
| Religious Building | 2,085 | 1,664 | 1.12 | 1.37 | 0.48 | 0.015 | 0.356 | 0.155 | eQuest |
| Restaurant | 5,571 | 4,784 | 1.17 | 1.31 | 0.68 | 0.021 | 0.491 | 0.213 | eQuest |
| Retail - Department Store | 4,099 | 2,935 | 1.06 | 1.06 | 0.94 | 0.015 | 0.346 | 0.150 | OpenStudio |
| Retail - Strip Mall | 4,093 | 2,935 | 1.12 | 1.29 | 0.71 | 0.019 | 0.450 | 0.196 | eQuest |
| Warehouse | 3,135 | 4,293 | 1.02 | 1.17 | 0.85 | 0.016 | 0.378 | 0.164 | OpenStudio |
| Unknown | 3,379 | 3,612 | 1.09 | 1.36 | 0.58 | 0.022 | 0.522 | 0.227 | n/a |
| Exterior – dusk to dawn[679] | 4,303 | 4,303 | 1.00 | 1.00 | 0.00 | 0.000 | 0.000 | 0.000 | n/a |
| Exterior – dusk to business close | See calculation below | | 1.00 | 1.00 | 0.00 | 0.000 | 0.000 | 0.000 | n/a |
| Low-Use Small Business | 2,954 | 2,954 | 1.31 | 1.53 | 0.66 | 0.023 | 0.524 | 0.262 | n/a |
| Uncooled Building | Varies | varies | 1.00 | 1.00 | 0.66 | 0.014 | 0.320 | 0.160 | n/a |
| Refrigerated Cases | 5,802 | n/a | 1.29 | 1.29 | 1.00 | 0.000 | 0.000 | 0.000 | n/a |
| Freezer Cases | 5,802 | n/a | 1.50 | 1.5 | 1.00 | 0.000 | 0.000 | 0.000 | n/a |

[679] Based on Navigant verified value using 2014 Astronomical Applications Department, U.S. Naval Observatory data for ComEd's service territory. See Navigant Memorandum 'RE: LED Street Lighting Program Hours of Use for the ComEd and DCEO Programs. June 21, 2017'.

**Exterior Lighting Hours – dusk to business close**

Hours = (6.19 * Days) + (%Adj * Days)

Where:

6.19 = Average hours per day between dusk and midnight[680]

Days = Days of business operation

= Actual

%Adj = Percent adjustment dependent on hour closing[681]

| Business closes at | 4pm | 5pm | 6pm | 7pm | 8pm | 9pm | 10pm | 11pm | 12pm | 1am | 2am | 3am |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| %Adj | -619% | -604% | -564% | -500% | -400% | -300% | -200% | -100% | 0% | 100% | 200% | 300% |

For example a business open until 8pm, 260 days per year, would assume:

Hours = (6.19 * 260) + (-400% * 260) = 569.4 hours

[680] Calculated using the eQuest model by finding the total number of hours of exterior lighting consumption between dusk and midnight and dividing by 365 (2261 / 365 = 6.19 hours per day).
[681] See "IL TRM Ext Lighting.xlsx" for calculation.

### 4.5.1 Commercial ENERGY STAR Compact Fluorescent Lamp (CFL)

**NOTE: THIS MEASURE IS EFFECTIVE UNTIL 12/31/2018. IT IS LEFT IN THE MANUAL FOR REFERENCE PURPOSES AND FOR CALCULATION OF CARRY OVER SAVINGS.**

**DESCRIPTION**

A low wattage qualified compact fluorescent screw-in bulb (CFL) is installed in place of a baseline screw-in bulb. Note a new ENERGY STAR specification v2.0 becomes effective on 1/2/2017 (https://www.energystar.gov/products/spec/lamps_specification_version_2_0_pd). The efficacy requirements can not currently be met by Compact Fluorescent Lamps, and therefore this specification has been removed. ENERGY STAR will maintain a list on their website with the final qualifying list of products prior to this change and it is strongly recommended that programs continue to use this list as qualifying criteria for products in the programs.

This characterization assumes that the CFL is installed in a commercial location. If the implementation strategy does not allow for the installation location to be known a deemed split should be used. For Residential targeted programs (e.g. an upstream retail program), a deemed split of 95% Residential and 5% Commercial assumptions should be used[682], and for Commercial targeted programs a deemed split of 4% Residential and 96% Commercial should be used[683].

Federal legislation stemming from the Energy Independence and Security Act of 2007 (EISA) required all general-purpose light bulbs between 40W and 100W to be approximately 30% more energy efficient than current incandescent bulbs. Production of 100W, standard efficacy incandescent lamps ended in 2012 followed by restrictions on 75W in 2013 and 60W and 40W in 2014. The baseline for this measure has therefore become bulbs (improved incandescent or halogen) that meet the new standard.

Finally, a provision in the EISA regulations requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the baseline equivalent to a current day CFL. Therefore the measure life (number of years that savings should be claimed) should be reduced once the assumed lifetime of the bulb exceeds 2020. Due to expected delay in clearing retail inventory and to account for the operating life of a halogen incandescent potentially spanning over 2020, this shift is assumed not to occur until 2021.

This measure was developed to be applicable to the following program types: TOS, NC, RF. If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

In order for this characterization to apply, the high-efficiency equipment must be a standard qualified compact fluorescent lamp.

**DEFINITION OF BASELINE EQUIPMENT**

The baseline equipment is assumed to be an EISA qualified incandescent or halogen as provided in the table provided in the Electric Energy Savings section.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected measure life (number of years that savings should be claimed) should be calculated by dividing the rated life of the bulb (10,000 hours[684]) by the run hours. For example using Miscellaneous at 3,612 hours would give 2.8 years. When the number of years exceeds 2021, the number of years to that date should be used.

---

[682] RES v C&I split is based on a weighted (by sales volume) average of ComEd PY6, PY7 and PY8 and Ameren PY5, PY6 and PY8 in store intercept survey results. See 'RESvCI Split_112016.xls'.

[683] Based upon final weighted (by sales volume) average of the BILD program (ComEd's commercial lighting program) for PY 4 and PY5 and PY6.

[684] Energy Star bulbs have a rated life of at least 8000 hours. In commercial settings you expect significantly less on/off switching than residential and so a rated life assumption of 10,000 hours is used.

### Deemed Measure Cost

The incremental capital cost assumption for all bulbs under 2600 lumens is \$1.20[685].

For bulbs over 2600 lumens the assumed incremental capital cost is \$5.

### Loadshape

Loadshape C06 - Commercial Indoor Lighting
Loadshape C07 - Grocery/Conv. Store Indoor Lighting
Loadshape C08 - Hospital Indoor Lighting
Loadshape C09 - Office Indoor Lighting
Loadshape C10 - Restaurant Indoor Lighting
Loadshape C11 - Retail Indoor Lighting
Loadshape C12 - Warehouse Indoor Lighting
Loadshape C13 - K-12 School Indoor Lighting
Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights)
Loadshape C15 - Indust. 2-shift (16/5) (e.g., comp. air, lights)
Loadshape C16 - Indust. 3-shift (24/5) (e.g., comp. air, lights)
Loadshape C17 - Indust. 4-shift (24/7) (e.g., comp. air, lights)
Loadshape C18 - Industrial Indoor Lighting
Loadshape C19 - Industrial Outdoor Lighting
Loadshape C20 - Commercial Outdoor Lighting

### Coincidence Factor

The summer peak coincidence factor for this measure is dependent on the location type. Values are provided for each building type in section 4.5.

## Algorithm

### Calculation of Savings

### Electric Energy Savings

ΔkWh =((WattsBase-WattsEE)/1000) * ISR * Hours * WHFe

Where:

WattsBase = Actual (if retrofit measure) or based on lumens of CFL bulb and program year installed:

| Minimum Lumens | Maximum Lumens | Incandescent Equivalent Post-EISA 2007 (WattsBase) |
|---|---|---|
| 5280 | 6209 | 300 |
| 3000 | 5279 | 200 |
| 2601 | 2999 | 150 |
| 1490 | 2600 | 72 |

685 Based upon field data collected by CLEAResult and provided by ComEd. See ComEd Pricing Projections 06302016.xlsx for analysis.

| Minimum Lumens | Maximum Lumens | Incandescent Equivalent Post-EISA 2007 (WattsBase) |
|---|---|---|
| 1050 | 1489 | 53 |
| 750 | 1049 | 43 |
| 310 | 749 | 29 |
| 250 | 309 | 25 |

WattsEE = Actual wattage of CFL purchased or installed

ISR = In Service Rate or the percentage of units rebated that get installed.

=100%[686] if application form completed with sign off that equipment is not placed into storage

If sign off form not completed assume the following 3 year ISR assumptions:

| Weighted Average 1st year In Service Rate (ISR) | 2nd year Installations | 3rd year Installations | Final Lifetime In Service Rate |
|---|---|---|---|
| 71.2%[687] | 14.5% | 12.3% | 98.0%[688] |

Hours = Average hours of use per year are provided in Reference Table in Section 4.5, Screw based bulb annual operating hours, for each building type[689]. If unknown use the Miscellaneous value.

WHFe = Waste heat factor for energy to account for cooling energy savings from efficient lighting are provided below for each building type in Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

For example, a 14W standard CFL is installed in an office and sign off form provided:

ΔkWh = (((43 - 14)/1000)* 1.0 * 3088 * 1.25

= 111.9 kWh

686 Illinois evaluation of PY1 through PY3 has not found that fixtures or lamps placed into storage to be a significant enough issue to warrant including an "In-Service Rate" when commercial customers complete an application form.

687 1st year in service rate is based upon review of PY4-6 evaluations from ComEd's commercial lighting program (BILD) (see 'IL Commercial Lighting ISR_2014.xls' for more information. The average first year ISR was calculated weighted by the number of bulbs sold.

688The 98% Lifetime ISR assumption is based upon review of two evaluations:
'Nexus Market Research, RLW Analytics and GDS Associates study; "New England Residential Lighting Markdown Impact Evaluation, January 20, 2009' and 'KEMA Inc, Feb 2010, Final Evaluation Report:, Upstream Lighting Program, Volume 1.' This implies that only 2% of bulbs purchased are never installed. The second and third year installations are based upon Ameren analysis of the Californian KEMA study showing that 54% of future installs occur in year 2 and 46% in year 3. The 2nd and 3rd year installations should be counted as part of those future program year savings. Note that this Final Install Rate does NOT account for leakage of purchased bulbs being installed outside of the utility territory. EM&V should assess how and if data from evaluation should adjust this final installation rate to account for this impact

689 Based on ComEd analysis taking DEER 2008 values and averaging with PY1 and PY2 evaluation results.

### HEATING PENALTY

If electrically heated building:

$$\Delta kWh_{heatpenalty}{}^{690} = (((WattsBase-WattsEE)/1000) * ISR * Hours * -IFkWh$$

Where:

IFkWh = Lighting-HVAC Interation Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficent lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

For example, a 14W standard CFL is installed in a heat pump heated office and sign off form provided:

$$\Delta kWh_{heatpenalty} = (((43 - 14)/1000)* 1.0*3088*-0.183$$
$$= - 16.4 \text{ kWh}$$

### DEFERRED INSTALLS

As presented above, if a sign off form is not completed the characterization assumes that a percentage of bulbs purchased are not installed until Year 2 and Year 3 (see ISR assumption above). The Illinois Technical Advisory Committee has determined the following methodology for calculating the savings of these future installs.

Year 1 (Purchase Year) installs: Characterized using assumptions provided above or evaluated assumptions if available.

Year 2 and 3 installs: Characterized using delta watts assumption and hours of use from the Install Year i.e. the actual deemed (or evaluated if available) assumptions active in Year 2 and 3 should be applied.

The NTG factor for the Purchase Year should be applied.

For example, for a 14W CFL (60W standard incandescent and 43W EISA qualified incandescent/halogen) purchased and using miscellaneous hours assumption.

$$\Delta kWH_{1st\ year\ installs} = ((43 - 14) / 1000) * 0.755 * 3612 * 1.06$$
$$= 83.8 \text{ kWh}$$

$$\Delta kWH_{2nd\ year\ installs} = ((43 - 14) / 1000) * 0.121 * 3612 * 1.06$$
$$= 13.4 \text{ kWh}$$

Note: Here we assume no change in hours assumption. NTG value from Purchase year applied.

$$\Delta kWH_{3rd\ year\ installs} = ((43 - 14) / 1000) * 0.103 * 3612 * 1.06$$
$$= 11.4 \text{ kWh}$$

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = ((WattsBase-WattsEE)/1000) * ISR * WHFd * CF$$

Where:

WHFd = Waste heat factor for demand to account for cooling savings from efficient lighting in cooled buildings is provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value..

[690] Negative value because this is an increase in heating consumption due to the efficient lighting.

CF = Summer Peak Coincidence Factor for measure is provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value..

Other factors as defined above

> For example, a 14W standard CFLis installed in an office and sign off form provided:
>
> ΔkW = ((43 - 14)/1000)*1.0*1.3*0.66
>
> = 0.025kW

**NATURAL GAS ENERGY SAVINGS**

Heating Penalty if fossil fuel heated building (or if heating fuel is unknown):

ΔTherms[691] = (((WattsBase-WattsEE)/1000) * ISR * Hours *- IFTherms

Where:

IFTherms = Lighting-HVAC Interation Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficent lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

Other factors as defined above

> For example, a 14W standard CFL is installed in an office and sign off form provided:
>
> ΔTherms = (((43 - 14)/1000)* 1.0*3088*-0.016
>
> = - 1.4 Therms

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

The O&M assumptions that should be used in cost effectiveness calculations are provided below:

| Replacement Period (years)[692] | Replacement Cost[693] |
|---|---|
| = 1000 / Hours | $1.25 |

It is important to note that for cost-effectiveness screening purposes, the O&M cost adjustments should only be applied in cases where the light bulbs area actually in service and so should be multiplied by the appropriate ISR.

---

691 Negative value because this is an increase in heating consumption due to the efficient lighting.

692 Calculated by dividing assumed rated life of baseline bulb by hours of use. Assumed lifetime of EISA qualified Halogen/ Incandescents is 1000 hours. The manufacturers are simply using a regular incandescent lamp with halogen fill gas rather than Halogen Infrared to meet the standard (as provided by G. Arnold, NEEP and confirmed by N. Horowitz at NRDC).

693 Based upon field data collected by CLEAResult and provided by ComEd. See ComEd Pricing Projections 06302016.xlsx for analysis.

**MEASURE CODE: CI-LTG-CCFL-V08-190101**

**REVIEW DEADLINE: 1/1/2020**

## 4.5.2 Fluorescent Delamping

### DESCRIPTION

This measure addresses the permanent removal of existing 8', 4', 3' and 2' fluorescent lamps. Unused lamps, lamp holders, and ballasts must be permanently removed from the fixture. This measure is applicable when retrofitting from T12 lamps to T8 lamps or simply removing lamps from a T8 fixture. Removing lamps from a T12 fixture that is not being retrofitted with T8 lamps are not eligible for this incentive.

Customers are responsible for determining whether or not to use reflectors in combination with lamp removal in order to maintain adequate lighting levels. Lighting levels are expected to meet the Illuminating Engineering Society of North America (IESNA) recommended light levels. Unused lamps, lamp holders, and ballasts must be permanently removed from the fixture and disposed of in accordance with local regulations. A pre-approval application is required for lamp removal projects.

This measure was developed to be applicable to the following program types: RF. If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

Savings are defined on a per removed lamp basis. The retrofit wattage (efficient conditioned) is therefore assumed to be zero. The savings numbers provided below are for the straight lamp removal measures, as well as the lamp removal and install reflector measures. The lamp installed/retrofit is captured in another measure.

### DEFINITION OF BASELINE EQUIPMENT

The baseline condition is either a T12 or a T8 lamp with default wattages provided below. Note, if the program does not allow for the lamp type to be known, then a T12:T8 weighting of 80%:20% can be applied[694].

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 11 years per DEER 2005.

### DEEMED MEASURE COST

The incremental capital cost is provided in the table below:

| Measure Category | Value | Source |
|---|---|---|
| 8-Foot Lamp Removal | $16.00 | ComEd/KEMA regression[695] |
| 4-Foot Lamp Removal | $12.00 | ICF Portfolio Plan |
| 8-Foot Lamp Removal with reflector | $30.00 | KEMA Assumption |
| 4-Foot Lamp Removal with reflector | $25.00 | KEMA Assumption |
| 2-Foot or 3-Foot Removal | $12.35 | KEMA Assumption |
| 2-Foot or 3-Foot Removal with reflector | $25.70 | KEMA Assumption |

### LOADSHAPE

Loadshape C06 - Commercial Indoor Lighting

Loadshape C07 - Grocery/Conv. Store Indoor Lighting

Loadshape C08 - Hospital Indoor Lighting

---

[694] Based on ComEd's estimate of lamp type saturation.

[695] Based on the assessment of active projects in the 2008-09 ComEd Smart Ideas Program. See files "ltg costs 12-10-10.xl." and "Lighting Unit Costs 102605.doc"

Loadshape C09 - Office Indoor Lighting
Loadshape C10 - Restaurant Indoor Lighting
Loadshape C11 - Retail Indoor Lighting
Loadshape C12 - Warehouse Indoor Lighting
Loadshape C13 - K-12 School Indoor Lighting
Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights)
Loadshape C15 - Indust. 2-shift (16/5) (e.g., comp. air, lights)
Loadshape C16 - Indust. 3-shift (24/5) (e.g., comp. air, lights)
Loadshape C17 - Indust. 4-shift (24/7) (e.g., comp. air, lights)
Loadshape C18 - Industrial Indoor Lighting
Loadshape C19 - Industrial Outdoor Lighting
Loadshape C20 - Commercial Outdoor Lighting

### COINCIDENCE FACTOR

The summer peak coincidence factor for this measure is dependent on the location type. Values are provided for each building type in the reference section below.

## Algorithm

### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

ΔkWh =((WattsBase-WattsEE)/1000) * ISR * Hours * WHFe

Where:

WattsBase = Assume wattage reduction of lamp removed

| | Wattage of lamp removed[696] | | Weighted average |
|---|---|---|---|
| | T8 | T12 | 80% T12, 20% T8 |
| 8-ft T8 | 38.6 | 60.3 | 56.0 |
| 4-ft T8 | 19.4 | 33.7 | 30.8 |
| 3-ft T8 | 14.6 | 40.0 | 34.9 |
| 2-ft T8 | 9.8 | 28.0 | 24.4 |

WattsEE = 0

ISR = In Service Rate or the percentage of units rebated that get installed.

=100% if application form completed with sign off that equipment permanently removed and disposed of.

Hours = Average hours of use per year are provided in Reference Table in Section 4.5. If unknown use the Miscellaneous value.

[696] Default wattage reducetion is based on averaging the savings from moving from a 2 to 1, 3 to 2 and 4 to 3 lamp fixture, as provided in the Standard Performance Contract Procedures Manual: Appendix B: Table of Standard Fixture Wattages, Version 3.0, SCE, March 2004. An adjustment is made to the T8 delamped fixture to account for the significant increase in ballast factor. See 'Delamping calculation.xls' for details.

WHFe = Waste heat factor for energy to account for cooling energy savings from efficient lighting are provided below for each building type in Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

For example, delamping a 4 ft T8 fixture in an office building:

$\Delta$kWh =((19.4 - 0)/1000) * 1.0 * 4439 * 1.25

= 107.6 kWh

**HEATING PENALTY**

If electrically heated building:

$\Delta kWh_{heatpenalty}$[697] = (((WattsBase-WattsEE)/1000) * ISR * Hours * -IFkWh

Where:

IFkWh = Lighting-HVAC Interation Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficent lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

For example, delamping a 4 ft T8 fixture in a heat pump heated office building:

$\Delta kWh_{heatpenalty}$ =((19.4 - 0)/1000) * 1.0 * 4439 * -0.151

=-13.0 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$\Delta$kW = ((WattsBase-WattsEE)/1000) * ISR * WHFd * CF

Where:

WHFd = Waste heat factor for demand to account for cooling savings from efficient lighting in cooled buildings is provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value..

CF = Summer Peak Coincidence Factor for measure is provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value..

Other factors as defined above

For example, delamping a 4 ft T8 fixture in an office building:

$\Delta$kW =((19.4 - 0)/1000) * 1.0 * 1.3 * 0.66

= 0.017 kW

**NATURAL GAS ENERGY SAVINGS**

Heating Penalty if fossil fuel heated building (or if heating fuel is unknown):

$\Delta$Therms[698] = (((WattsBase-WattsEE)/1000) * ISR * Hours *- IFTherms

Where:

IFTherms = Lighting-HVAC Interation Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by

[697]Negative value because this is an increase in heating consumption due to the efficient lighting.

[698] Negative value because this is an increase in heating consumption due to the efficient lighting.

the efficent lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

Other factors as defined above

For example, delamping a 4 ft T8 fixture in an office building:

ΔTherms =((19.4 - 0)/1000) * 1.0 * 4439 * -0.016

=-1.4 therms

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-LTG-DLMP-V02-140601**

**REVIEW DEADLINE: 1/1/2021**

## 4.5.3 High Performance and Reduced Wattage T8 Fixtures and Lamps

### DESCRIPTION

This measure applies to “High Performance T8” (HPT8) lamp/ballast systems that have higher lumens per watt than standard T8 systems. This measure applies to the installation of new equipment with efficiencies that exceed that of the equipment that would have been installed following standard market practices and is applicable to time of sale as well as retrofit measures. Retrofit measures may include new fixtures or relamp/reballast measures. In addition, options have been provided to allow for the “Reduced Wattage T8 lamps” or RWT8 lamps that result in re-lamping opportunities that produce equal or greater light levels than standard T8 lamps while using fewer watts.

If the implementation strategy does not allow for the installation location to be known, a deemed split of 100% Commercial and 0% Residential should be used[699].

This measure was developed to be applicable to the following program types: TOS, RF, DI.

If applied to other program types, the measure savings should be verified.

The measure applies to all commercial HPT8 installations excluding new construction and major renovation or change of use measures (see lighting power density measure). Lookup tables have been provided to account for the different types of installations. Whenever possible, actual costs and hours of use should be utilized for savings calculations. Default new and baseline assumptions have been provided in the reference tables. Default component costs and lifetimes have been provided for Operating and Maintenance Calculations. Please see the Definition Table to determine applicability for each program. HPT8 configurations not included in the TRM may be included in custom program design using the provided algorithms as long as energy savings is achieved. The following table defines the applicability for different programs

| Time of Sale (TOS) | Retrofit (RF) and Direct Install (DI) |
|---|---|
| This measure relates to the installation of new equipment with efficiency that exceeds that of equipment that would have been installed following standard market practices. In general, the measure will include qualifying high efficiency low ballast factor ballasts paired with high efficiency long life lamps as detailed in the attached tables. High-bay applications use this system paired with qualifying high ballast factor ballasts and high performance 32 w lamps. Custom lighting designs can use qualifying low, normal or high ballast factor ballasts and qualifying lamps in lumen equivalent applications where total system wattage is reduced when calculated using the Calculation of Savings Algorithms. | This measure relates to the replacement of existing equipment with new equipment with efficiency that exceeds that of the existing equipment. In general, the retrofit will include qualifying high efficiency low ballast factor ballasts paired with high efficiency long life lamps as detailed in the attached tables. Custom lighting designs can use qualifying low, normal or high ballast factor ballasts and qualifying lamps in lumen equivalent applications where total system wattage is reduced when calculated using the Calculation of Savings Algorithms.<br><br>High efficiency troffers (new/or retrofit) utilizing HPT8 technology can provide even greater savings. When used in a high-bay application, high-performance T8 fixtures can provide equal light to HID high-bay fixtures, while using fewer watts; these systems typically utilize high ballast factor ballasts, but qualifying low and normal ballast factor ballasts may be used when appropriate light levels are provided and overall wattage is reduced. |

[699] Based on weighted average of Final ComEd’s Instant Discounts program data from PY7 and PY9. For Residential installations, hours of use assumptions from ‘5.5 Interior Hardwired Compact Fluorescent Lamp (CFL) Fixture’ measure should be used.

### Definition of Efficient Equipment

The efficient conditions for all applications are a qualifying HP or RWT8 fixture and lamp/ballast combinations listed on the CEE website under qualifying HP T8 products[700] and qualifying RWT8 products[701].

The definition of efficient equipment varies based on the program and is defined below:

| Time of Sale (TOS) | Retrofit (RF) and Direct Install (DI) |
|---|---|
| High efficiency troffers combined with high efficiency lamps and ballasts allow for fewer lamps to be used to provide a given lumen output. High efficiency troffers must have a fixture efficiency of 80% or greater to qualify. Default values are given for a 2 lamp HPT8 fixture replacing a 3 lamp standard efficiency T8 fixture, but other configurations may qualify and the Calculation of savings algorithm used to account for base watts being replaced with EE watts.<br>High bay fixtures must have fixture efficiencies of 85% or greater.<br>RWT8 lamps: 2', 3' and 8' lamps must meet the wattage requirements specified in the RWT8 new and baseline assumptions table. This measure assumes a lamp only purchase. | High efficiency troffers (new or retrofit kits) combined with high efficiency lamps and ballasts allow for fewer lamps to be used to provide a given lumen output. High efficiency troffers must have a fixture efficiency of 80% or greater to qualify. Default values are given for a 2 lamp HPT8 fixture replacing a 3 lamp standard efficiency T8 fixture, but other configurations may qualify and the Calculation of savings algorithm used to account for base watts being replaced with EE watts.<br>High bay fixtures will have fixture efficiencies of 85% or greater.<br>RWT8: 2', 3' and 8' lamps must meet the wattage requirements specified in the RWT8 new and baseline assumptions table. |

### Definition of Baseline Equipment

The definition of baseline equipment varies based on the program and is defined below:

| Time of Sale (TOS) | Retrofit (RF) and Direct Install (DI) |
|---|---|
| The baseline is standard efficiency T8 systems that would have been installed. The baseline for high-bay fixtures is pulse start metal halide fixtures, the baseline for a 2 lamp high efficiency troffer is a 3 lamp standard efficency troffer. | The baseline is the existing system.<br>In July 14, 2012, Federal Standards were enacted that were expected to eliminate T-12s as an option for linear fluorescent fixtures. Through v3.0 of the TRM, it was assumed that the T-12 would no longer be baseline for retrofits from 1/1/2016. However, due to significant loopholes in the legislation, T-12 compliant product is still freely available and in Illinois T-12s continue to hold a significant share of the existing and replacement lamp market. Therefore the timing of the sunsetting of T-12s as a viable baseline has been pushed back in v7.0 until 1/1/2020 and will be revisited in future update sessions.<br>There will be a baseline shift applied to all measures installed before 2020. See table C-1. |

### Deemed Lifetime of Efficient Equipment

The deemed lifetime of efficient equipment varies based on the program and is defined below:

[700] Consortium for Energy Efficiency (CEE) Energy Efficiency Program Library, High-Performance T8 Specification, June 30, 2009
[701] Consortium for Energy Efficiency (CEE) Energy Efficiency Program Library, Reduced Wattage T8 Specification, July 29, 2013

| Time of Sale (TOS) | Retrofit (RF) and Direct Install (DI) |
|---|---|
| Fixture lifetime is rated lifetime of fixture/hours of use. If unknown default is 12 years[702].<br>Fixture retrofits which utilize RWT8 lamps have a lifetime equivalent to the life of the lamp, capped at 15 years. There is no guarantee that a reduced wattage lamp will be installed at time of burnout, but if one is, savings will be captured in the RWT8 measure below.<br>RWT8 lifetime is the life of the product, at the reported operating hours (lamp life in hours divided by operating hours per year – see reference table "RWT8 Component Costs and Lifetime"), capped at 12 years.[703] | Fixture lifetime is rated lifetime of fixture/hours of use. If unknown default is 15 years.<br>As per explanation above, for existing T12 fixtures, a mid life baseline shift should be applied in 2019 as described in table C-1.<br>Note, since the fixture lifetime is deemed at 12 years, the replacement cost of both the lamp and ballast should be incorporated in to the O&M calculation. |

**DEEMED MEASURE COST**

The deemed measure cost is found in the reference table at the end of this characterization.

**LOADSHAPE**

Loadshape C06 - Commercial Indoor Lighting
Loadshape C07 - Grocery/Conv. Store Indoor Lighting
Loadshape C08 - Hospital Indoor Lighting
Loadshape C09 - Office Indoor Lighting
Loadshape C10 - Restaurant Indoor Lighting
Loadshape C11 - Retail Indoor Lighting
Loadshape C12 - Warehouse Indoor Lighting
Loadshape C13 - K-12 School Indoor Lighting
Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights)
Loadshape C15 - Indust. 2-shift (16/5) (e.g., comp. air, lights)
Loadshape C16 - Indust. 3-shift (24/5) (e.g., comp. air, lights)
Loadshape C17 - Indust. 4-shift (24/7) (e.g., comp. air, lights)
Loadshape C18 - Industrial Indoor Lighting
Loadshape C19 - Industrial Outdoor Lighting
Loadshape C20 - Commercial Outdoor Lighting

[702] 12 years is based on average of mostly CEE lamp products (9 years), T5 lamps (10.7 years) and GDS Measure Life Report, June 2007, (15 years), as recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.
[703] ibid

**Algorithm**

## CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

$$\Delta kWh = ((Watts_{base}-Watts_{EE})/1000) * Hours * WHF_e * ISR$$

Where:

$Watts_{base}$ = Input wattage of the existing system which depends on the baseline fixture configuration (number and type of lamp) and number of fixtures. Value can be selected from the appropriate reference table as shown below, or a custom value can be entered if the configurations in the tables is not representative of the exisitng system.

| Program | Reference Table |
|---|---|
| Time of Sale | A-1: HPT8 New and Baseline Assumptions |
| Retrofit | A-2: HPT8 New and Baseline Assumptions |
| Reduced Wattage T8, time of sale or retrofit | A-3: RWT8 New and Baseline Assumptions |

$Watts_{EE}$ = New Input wattage of EE fixture which depends on new fixture configuration (number of lamps) and ballast factor and number of fixtures. Value can be selected from the appropriate reference table as shown below, of a custom value can be entered if the configurations in the tables is not representative of the exisitng system.

| Program | Reference Table |
|---|---|
| Time of Sale | A-1: HPT8 New and Baseline Assumptions |
| Retrofit | A-2: HPT8 New and Baseline Assumptions |
| Reduced Wattage T8, time of sale or retrofit | A-3: RWT8 New and Baseline Assumptions |

Hours = Average hours of use per year as provided by the customer or selected from the Reference Table in Section 4.5, Fixture annual operating hours. If hours or building type are unknown, use the Miscellaneous value.

$WHF_e$ = Waste heat factor for energy to account for cooling energy savings from efficient lighting is selected from the Reference Table in Section 4.5 for each building type. If building is un-cooled, the value is 1.0.

ISR = In Service Rate or the percentage of units rebated that get installed.

=100%[704] if application form completed with sign off that equipment is not placed into storage

If sign off form not completed assume the following 3 year ISR assumptions:

[704] Illinois evaluation of PY1 through PY3 has not found that fixtures or lamps placed into storage to be a significant enough issue to warrant including an "In-Service Rate" when commercial customers complete an application form.

| Weighted Average 1st year In Service Rate (ISR) | 2nd year Installations | 3rd year Installations | Final Lifetime In Service Rate |
|---|---|---|---|
| 93.4%[705] | 2.5% | 2.1% | 98.0%[706] |

### HEATING PENALTY

If electrically heated building:

$$\Delta kWh_{heatpenalty}{}^{707} = (((WattsBase-WattsEE)/1000) * ISR * Hours * -IFkWh$$

Where:

IFkWh = Lighting-HVAC Interation Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficent lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

### SUMMER COINCIDENT DEMAND SAVINGS

$$\Delta kW = ( (Watts_{base}-Watts_{EE})/1000) * WHF_d*CF*ISR$$

Where:

$WHF_d$ = Waste Heat Factor for Demand to account for cooling savings from efficient lighting in cooled buildings is selected from the Reference Table in Section 4.5 for each building type. If the building is not cooled WHFd is 1.

CF = Summer Peak Coincidence Factor for measure is selected from the Reference Table in Section 4.5 for each building type. If the building type is unknown, use the Miscellaneous value of 0.66.

Other factors as defined above

### NATURAL GAS SAVINGS

$$\Delta Therms^{708} = (((WattsBase-WattsEE)/1000) * ISR * Hours *- IFTherms$$

Where:

IFTherms = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Please select from the Reference Table in Section 4.5 for each building type.

[705] Based on ComEd's Instant Incentives program data from PY7 and PY9, see "IL Commercial Lighting ISR_2018.xlsx".

[706] The 98% Lifetime ISR assumption is based upon review of two evaluations:
'Nexus Market Research, RLW Analytics and GDS Associates study; "New England Residential Lighting Markdown Impact Evaluation, January 20, 2009' and 'KEMA Inc, Feb 2010, Final Evaluation Report:, Upstream Lighting Program, Volume 1.' This implies that only 2% of bulbs purchased are never installed. The second and third year installations are based upon Ameren analysis of the Californian KEMA study showing that 54% of future installs occur in year 2 and 46% in year 3. The 2nd and 3rd year installations should be counted as part of those future program year savings. Note that this Final Install Rate does NOT account for leakage of purchased bulbs being installed outside of the utility territory. EM&V should assess how and if data from evaluation should adjust this final installation rate to account for this impact

[707] Negative value because this is an increase in heating consumption due to the efficient lighting.

[708] Negative value because this is an increase in heating consumption due to the efficient lighting.

### Water Impact Descriptions and Calculation

N/A

### Deemed O&M Cost Adjustment Calculation

Actual operation and maintenance costs will vary by specific equipment installed/replaced. See Reference tables for Operating and Maintenance Values;

| Program | Reference Table |
|---|---|
| Time of Sale | B-1: HPT8 Component Costs and Lifetime |
| Retrofit | B-2: HPT8 Component Costs and Lifetime |
| Reduced Wattage T8, time of sale or retrofit | B-3: HPT8 Component Costs and Lifetime |

### Reference Tables

See following page

A-1: Time of Sale: HPT8 New and Baseline Assumptions[709]

| EE Measure Description | Nominal Watts | $Watts_{EE}$ | Baseline Description | Nominal Watt | $Watts_{BASE}$ | Incremental Cost | $Watts_{SAVE}$ |
|---|---|---|---|---|---|---|---|
| 4-Lamp HPT8 w/ High-BF Ballast High-Bay | 128 | 147.2 | 200 Watt Pulse Start Metal-Halide | 200 | 232 | $75 | 84.80 |
| 4-Lamp HPT8 w/ High-BF Ballast High-Bay | 128 | 147.2 | 250 Watt Metal Halide | 250 | 295 | $75 | 147.80 |
| 6-Lamp HPT8 w/ High-BF Ballast High-Bay | 192 | 220.8 | 320 Watt Pulse Start Metal-Halide | 320 | 348.8 | $75 | 128.00 |
| 6-Lamp HPT8 w/ High-BF Ballast High-Bay | 192 | 220.8 | 400 Watt Pulse Start Metal Halide | 400 | 455 | $75 | 234.20 |
| 8-Lamp HPT8 w/ High-BF Ballast High-Bay | 256 | 294.4 | Proportionally Adjusted according to 6-Lamp HPT8 Equivalent to 320 PSMH | 320 | 476 | $75 | 181.60 |
| 8-Lamp HPT8 w/ High-BF Ballast High-Bay | 256 | 292.4 | Proportionally Adjusted according to 6-Lamp HPT8 Equivalent to 400 W Metal Halide | 400 | 618 | 75 | 323.60 |
| 1-Lamp HPT8-high performance 32 w lamp | 32 | 24.64 | 1-Lamp Standard F32T8 w/ Elec. Ballast | 32 | 28.16 | $15 | 3.52 |
| 1-Lamp HPT8-high performance 28 w lamp | 28 | 21.56 | 1-Lamp Standard F32T8 w/ Elec. Ballast | 32 | 28.16 | $15 | 6.60 |
| 1-Lamp HPT8-high performance 25 w lamp | 25 | 19.25 | 1-Lamp Standard F32T8 w/ Elec. Ballast | 32 | 28.16 | $15 | 8.91 |
| 2-Lamp HPT8 -high performance 32 w lamp | 64 | 49.28 | 2-Lamp Standard F32T8 w/ Elec. Ballast | 64 | 56.32 | $18 | 7.04 |
| 2-Lamp HPT8-high performance 28 w lamp | 56 | 43.12 | 2-Lamp Standard F32T8 w/ Elec. Ballast | 64 | 56.32 | $18 | 13.20 |
| 2-Lamp HPT8-high performance 25 w lamp | 50 | 38.5 | 2-Lamp Standard F32T8 w/ Elec. Ballast | 64 | 56.32 | $18 | 17.82 |
| 3-Lamp HPT8-high performance 32 w lamp | 96 | 73.92 | 3-Lamp Standard F32T8 w/ Elec. Ballast | 96 | 84.48 | $20 | 10.56 |
| 3-Lamp HPT8-high performance 28 w lamp | 84 | 64.68 | 3-Lamp Standard F32T8 w/ Elec. Ballast | 96 | 84.48 | $20 | 19.80 |
| 3-Lamp HPT8-high performance 25 w lamp | 75 | 57.75 | 3-Lamp Standard F32T8 w/ Elec. Ballast | 96 | 84.48 | $20 | 26.73 |
| 4-Lamp HPT8 -high performance 32 w lamp | 128 | 98.56 | 4-Lamp Standard F32T8 w/ Elec. Ballast | 128 | 112.64 | $23 | 14.08 |
| 4-Lamp HPT8-high performance 28 w lamp | 112 | 86.24 | 4-Lamp Standard F32T8 w/ Elec. Ballast | 128 | 112.64 | $23 | 26.40 |
| 4-Lamp HPT8-high performance 25 w lamp | 100 | 77 | 4-Lamp Standard F32T8 w/ Elec. Ballast | 128 | 112.64 | $23 | 35.64 |
| | | | | | | | |
| 2-lamp High-Performance HPT8 Troffer | 64 | 49.28 | 3-Lamp F32T8 w/ Elec. Ballast | 96 | 84.48 | $100 | 35.20 |

Table developed using a constant ballast factor of .77 for troffers/linear HPT8 and 1.15 for HPT8 highbay, 1.0 for all MH/MHPS, and 0.95 for T12 and 0.88 for standard T8. Input wattages are an average of manufacturer inputs that account for ballast efficacy

[709] Watt, lumen, lamp life, and ballast factor assumptions for efficient measures are based upon Consortium for Energy Efficiency (CEE) Commercial Lighting Qualifying Product Lists. Watt, lumen, lamp life, and ballast factor assumptions for baseline fixtures are based upon manufacturer specification sheets. Baseline and efficient measure cost data comes from lighting suppliers, past Efficiency Vermont projects, and professional judgment.

A-2: Retrofit HPT8 New and Baseline Assumptions[710]

| EE Measure Description | Nominal Watts | Ballast Factor | $Watts_{EE}$ | Baseline Description | Nominal Watts | $Watts_{BASE}$ | $Watts_{SAVE}$ | Full Measure Cost |
|---|---|---|---|---|---|---|---|---|
| 4-Lamp HPT8 w/ High-BF Ballast High-Bay | 128 | 1.15 | 147.2 | 200 Watt Pulse Start Metal-Halide | 200 | 232 | 84.80 | $200 |
| 4-Lamp HPT8 w/ High-BF Ballast High-Bay | 128 | 1.15 | 147.2 | 250 Watt Metal Halide | 250 | 295 | 147.80 | $200 |
| 6-Lamp HPT8 w/ High-BF Ballast High-Bay | 192 | 1.15 | 220.8 | 320 Watt Pulse Start Metal-Halide | 320 | 348.8 | 128.00 | $225 |
| 6-Lamp HPT8 w/ High-BF Ballast High-Bay | 192 | 1.15 | 220.8 | 400 Watt Pulse Start Metal Halide | 400 | 455 | 234.20 | $225 |
| 8-Lamp HPT8 w/ High-BF Ballast High-Bay | 256 | 1.15 | 294.4 | Proportionally Adjusted according to 6-Lamp HPT8 Equivalent to 320 PSMH | 320 | 476 | 181.60 | $250 |
| 8-Lamp HPT8 w/ High-BF Ballast High-Bay | 256 | 1.15 | 294.4 | Proportionally Adjusted according to 6-Lamp HPT8 Equivalent to 400 W Metal Halide | 400 | 618 | 323.60 | $250 |
| 1-Lamp Relamp/Reballast T12 to HPT8 | 32 | 0.77 | 24.64 | 1-Lamp F34T12 w/ EEMag Ballast | 34 | 42 | 17.36 | $50 |
| 2-Lamp Relamp/Reballast T12 to HPT8 | 64 | 0.77 | 49.28 | 2-Lamp F34T12 w/ EEMag Ballast | 68 | 67 | 17.72 | $55 |
| 3-Lamp Relamp/Reballast T12 to HPT8 | 96 | 0.77 | 73.92 | 3-Lamp F34T12 w/ EEMag Ballast | 102 | 104 | 30.08 | $60 |
| 4-Lamp Relamp/Reballast T12 to HPT8 | 128 | 0.77 | 98.56 | 4-Lamp F34T12 w/ EEMag Ballast | 136 | 144 | 45.44 | $65 |
| | | | | | | | | |
| 1-Lamp Relamp/Reballast T12 to HPT8 | 32 | 0.77 | 24.64 | 1-Lamp F40T12 w/ EEMag Ballast | 40 | 41 | 16.36 | $50 |
| 2-Lamp Relamp/Reballast T12 to HPT8 | 64 | 0.77 | 49.28 | 2-Lamp F40T12 w/ EEMag Ballast | 80 | 87 | 37.72 | $55 |
| 3-Lamp Relamp/Reballast T12 to HPT8 | 96 | 0.77 | 73.92 | 3-Lamp F40T12 w/ EEMag Ballast | 120 | 141 | 67.08 | $60 |
| 4-Lamp Relamp/Reballast T12 to HPT8 | 128 | 0.77 | 98.56 | 4-Lamp F40T12 w/ EEMag Ballast | 160 | 172 | 73.44 | $65 |
| | | | | | | | | |
| 1-Lamp Relamp/Reballast T12 to HPT8 | 32 | 0.77 | 24.64 | 1-Lamp F40T12 w/ Mag Ballast | 40 | 51 | 26.36 | $50 |
| 2-Lamp Relamp/Reballast T12 to HPT8 | 64 | 0.77 | 49.28 | 2-Lamp F40T12 w/ Mag Ballast | 80 | 97 | 47.72 | $55 |
| 3-Lamp Relamp/Reballast T12 to HPT8 | 96 | 0.77 | 73.92 | 3-Lamp F40T12 w/ Mag Ballast | 120 | 135 | 61.08 | $60 |
| 4-Lamp Relamp/Reballast T12 to HPT8 | 128 | 0.77 | 98.56 | 4-Lamp F40T12 w/ Mag Ballast | 160 | 175 | 76.44 | $65 |
| | | | | | | | | |
| 1-Lamp Relamp/Reballast T8 to HPT8 | 32 | 0.77 | 24.64 | 1-Lamp F32T8 w/ Elec. Ballast | 32 | 28.16 | 3.52 | $50 |
| 2-Lamp Relamp/Reballast T8 to HPT8 | 64 | 0.77 | 49.28 | 2-Lamp F32T8 w/ Elec. Ballast | 64 | 56.32 | 7.04 | $55 |
| 3-Lamp Relamp/Reballast T8 to HPT8 | 96 | 0.77 | 73.92 | 3-Lamp F32T8 w/ Elec. Ballast | 96 | 84.48 | 10.56 | $60 |
| 4-Lamp Relamp/Reballast T8 to HPT8 | 128 | 0.77 | 98.56 | 4-Lamp F32T8 w/ Elec. Ballast | 128 | 112.64 | 14.08 | $65 |

[710] Watt, lumen, lamp life, and ballast factor assumptions for efficient measures are based upon Consortium for Energy Efficiency (CEE) Commercial Lighting Qualifying Product Lists. Watt, lumen, lamp life, and ballast factor assumptions for baseline fixtures are based upon manufacturer specification sheets. Baseline and efficient measure cost data comes from lighting suppliers, past Efficiency Vermont projects, Xcel Energy Lighting Efficiency Input Wattage Guide and professional judgment.

| EE Measure Description | Nominal Watts | Ballast Factor | $Watts_{EE}$ | Baseline Description | Nominal Watts | $Watts_{BASE}$ | $Watts_{SAVE}$ | Full Measure Cost |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| 2-lamp High-Performance HPT8 Troffer or high efficiency retrofit troffer | 64 | 0.77 | 49.28 | 3-Lamp F32T8 w/ Elec. Ballast | 96 | 84.48 | 35.20 | $100 |

Table developed using a constant ballast factor of 0.77 for troffers/linear HPT8 and 1.15 for HPT8 highbay, 1.0 for all MH/MHPS, and 0.95 for T12 and 0.88 for standard T8. Input wattages are an average of manufacturer inputs that account for ballast efficacy.

| EE Measure Description | Nominal Watts | $Watts_{EE}$ | EE Lamp Cost | Baseline Description | Base Lamp Cost | Nominal Watts | $Watts_{BASE}$ | $Watts_{SAVE}$ | Measure Cost |
|---|---|---|---|---|---|---|---|---|---|
| RW T8 - F28T8 Lamp | 28 | 24.64 | $4.50 | F32 T8 Standard Lamp | $2.50 | 32 | 28.16 | 3.52 | $2.00 |
| RWT8 F2T8 Extra Life Lamp | 28 | 24.64 | $4.50 | F32 T8 Standard Lamp | $2.50 | 32 | 28.16 | 3.52 | $2.00 |
| RWT8 - F32/25W T8 Lamp | 25 | 22.00 | $4.50 | F32 T8 Standard Lamp | $2.50 | 32 | 28.16 | 6.16 | $2.00 |
| RWT8 - F32/25W T8 Lamp Extra Life | 25 | 22.00 | $4.50 | F32 T8 Standard Lamp | $2.50 | 32 | 28.16 | 6.16 | $2.00 |
| RWT8 F17T8 Lamp - 2 ft | 16 | 14.08 | $4.80 | F17 T8 Standard Lamp - 2ft | $2.80 | 17 | 14.96 | 0.88 | $2.00 |
| RWT8 F25T8 Lamp - 3 ft | 23 | 20.24 | $5.10 | F25 T8 Standard Lamp - 3ft | $3.10 | 25 | 22.00 | 1.76 | $2.00 |
| RWT8 F30T8 Lamp - 6' Utube | 30 | 26.40 | $11.31 | F32 T8 Standard Utube | $9.31 | 32 | 28.16 | 1.76 | $2.00 |
| RWT8 F29T8 Lamp - Utube | 29 | 25.52 | $11.31 | F32 T8 Standard Utube | $9.31 | 32 | 28.16 | 2.64 | $2.00 |
| RWT8 F96T8 Lamp - 8 ft | 65 | 57.20 | $9.00 | F96 T8 Standard Lamp - 8 ft | $7.00 | 70 | 61.60 | 4.40 | $2.00 |

A– 3: RWT8 New and Baseline Assumptions

Table developed using a constant ballast factor of 0.88 for RWT8 and Standard T8.

B-1: Time of Sale T8 Component Costs and Lifetime[711]

[711] Watt, lumen, lamp life, and ballast factor assumptions for efficient measures are based upon Consortium for Energy Efficiency (CEE) Commercial Lighting Qualifying Product Lists. Watt, lumen, lamp life, and ballast factor assumptions for baseline fixtures are based upon manufacturer specification sheets. Baseline and efficient measure cost data comes from lighting suppliers, past Efficiency Vermont projects, and professional judgment

| EE Measure Description | EE Lamp Cost | EE Lamp Life (hrs) | EE Lamp Rep. Labor Cost per lamp | EE Ballast Cost | EE Ballast Life (hrs) | EE Ballast Rep. Labor Cost | Baseline Description | Base Lamp Cost | Base Lamp Life (hrs) | Base Lamp Rep. Labor Cost | Base Ballast Cost | Base Ballast Life (hrs) | Base Ballast Rep. Labor Cost |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4-Lamp HPT8 w/ High-BF Ballast High-Bay | $5.00 | 24000 | $6.67 | $32.50 | 70000 | $15.00 | 200 Watt Pulse Start Metal-Halide | $21.00 | 10000 | $6.67 | $87.75 | 40000 | $22.50 |
| 6-Lamp HPT8 w/ High-BF Ballast High-Bay | $5.00 | 24000 | $6.67 | $32.50 | 70000 | $15.00 | 320 Watt Pulse Start Metal-Halide | $21.00 | 20000 | $6.67 | $109.35 | 40000 | $22.50 |
| 8-Lamp HPT8 w/ High-BF Ballast High-Bay | $5.00 | 24000 | $6.67 | $32.50 | 70000 | $15.00 | Lamp HPT8 Equivalent to 320 PSMH | $21.00 | 20000 | $6.67 | $109.35 | 40000 | $22.50 |
| | | | | | | | | | | | | | |
| 1-Lamp HPT8 – all qualifying lamps | $5.00 | 24000 | $2.67 | $32.50 | 70000 | $15.00 | 1-Lamp Standard F32T12 w/ Elec Ballast | $2.50 | 20000 | $2.67 | $15.00 | 70000 | $15.00 |
| 2-Lamp HPT8 – all qualifying lamps | $5.00 | 24000 | $2.67 | $32.50 | 70000 | $15.00 | 2-Lamp Standard F32T12 w/ Elec Ballast | $2.50 | 20000 | $2.67 | $15.00 | 70000 | $15.00 |
| 3-Lamp HPT8 – all qualifying lamps | $5.00 | 24000 | $2.67 | $32.50 | 70000 | $15.00 | 3-Lamp Standard F32T8 w/ Elec. Ballast | $2.50 | 20000 | $2.67 | $15.00 | 70000 | $15.00 |
| 4-Lamp HPT8 – all qualifying lamps | $5.00 | 24000 | $2.67 | $32.50 | 70000 | $15.00 | 4-Lamp Standard F32T8 w/ Elec. Ballast | $2.50 | 20000 | $2.67 | $15.00 | 70000 | $15.00 |
| | | | | $32.50 | | | | | | | | | |
| 2-lamp High-Performance HPT8 Troffer | $5.00 | 24000 | $2.67 | $32.50 | 70000 | $15.00 | 3-Lamp F32T8 w/ Elec. Ballast | $2.50 | 20000 | $2.67 | $15.00 | 70000 | $15.00 |

B-2: T8 Retrofit Component Costs and Lifetime[712]

[712] Cost assumptions for baseline fixtures are based upon manufacturer specification sheets. Baseline and efficient measure cost data comes from lighting suppliers, past Efficiency Vermont projects, and professional judgment

| EE Measure Description | EE Lamp Cost | EE Lamp Life (hrs) | EE Lamp Rep. Labor Cost per lamp | EE Ballast Cost | EE Ballast Life (hrs) | EE Ballast Rep. Labor Cost | Baseline Description | Base Lamp Cost | Base Lamp Life (hrs) | Base Lamp Rep. Labor Cost | Base Ballast Cost | Base Ballast Life (hrs) | Base Ballast Rep. Labor Cost |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4-Lamp HPT8 w/ High-BF Ballast High-Bay | $5.00 | 24000 | $6.67 | $32.50 | 70000 | $15.00 | 200 Watt Pulse Start Metal-Halide | $29.00 | 12000 | $6.67 | $87.75 | 40000 | $22.50 |
| 6-Lamp HPT8 w/ High-BF Ballast High-Bay | $5.00 | 24000 | $6.67 | $32.50 | 70000 | $15.00 | 320 Watt Pulse Start Metal-Halide | $72.00 | 20000 | $6.67 | $109.35 | 40000 | $22.50 |
| 8-Lamp HPT8 w/ High-BF Ballast High-Bay | $5.00 | 24000 | $6.67 | $32.50 | 70000 | $15.00 | Proportionally Adjusted according to 6-Lamp HPT8 Equivalent to 320 PSMH | $17.00 | 20000 | $6.67 | $109.35 | 40000 | $22.50 |
| 1-Lamp Relamp/Reballast T12 to HPT8 | $5.00 | 24000 | $2.67 | $32.50 | 70000 | $15.00 | 1-Lamp F34T12 w/ EEMag Ballast | $2.70 | 20000 | $2.67 | $20.00 | 40000 | $15.00 |
| 2-Lamp Relamp/Reballast T12 to HPT8 | $5.00 | 24000 | $2.67 | $32.50 | 70000 | $15.00 | 2-Lamp F34T12 w/ EEMag Ballast | $2.70 | 20000 | $2.67 | $20.00 | 40000 | $15.00 |
| 3-Lamp Relamp/Reballast T12 to HPT8 | $5.00 | 24000 | $2.67 | $32.50 | 70000 | $15.00 | 3-Lamp F34T12 w/ EEMag Ballast | $2.70 | 20000 | $2.67 | $20.00 | 40000 | $15.00 |
| 4-Lamp Relamp/Reballast T12 to HPT8 | $5.00 | 24000 | $2.67 | $32.50 | 70000 | $15.00 | 4-Lamp F34T12 w/ EEMag Ballast | $2.70 | 20000 | $2.67 | $20.00 | 40000 | $15.00 |
| 1-Lamp Relamp/Reballast T8 to HPT8 | $5.00 | 24000 | $2.67 | $32.50 | 70000 | $15.00 | 1-Lamp F32T8 w/ Elec. Ballast | $2.70 | 20000 | $2.67 | $20.00 | 70000 | $15.00 |
| 2-Lamp Relamp/Reballast T8 to HPT8 | $5.00 | 24000 | $2.67 | $32.50 | 70000 | $15.00 | 2-Lamp F32T8 w/ Elec. Ballast | $2.70 | 20000 | $2.67 | $20.00 | 70000 | $15.00 |
| 3-Lamp Relamp/Reballast T8 to HPT8 | $5.00 | 24000 | $2.67 | $32.50 | 70000 | $15.00 | 3-Lamp F32T8 w/ Elec. Ballast | $2.70 | 20000 | $2.67 | $20.00 | 70000 | $15.00 |
| 4-Lamp Relamp/Reballast T8 to HPT8 | $5.00 | 24000 | $2.67 | $32.50 | 70000 | $15.00 | 4-Lamp F32T8 w/ Elec. Ballast | $2.70 | 20000 | $2.67 | $20.00 | 70000 | $15.00 |
| 2-lamp High-Performance HPT8 Troffer | $5.00 | 24000 | $2.67 | $32.50 | 70000 | $15.00 | 3-Lamp F32T8 w/ Elec. Ballast | $2.50 | 20000 | $2.67 | $15.00 | 70000 | $15.00 |

B-3: Reduced Wattage T8 Component Costs and Lifetime[713]

| EE measure description | EE Lamp Cost | EE Lamp Life (hrs) | Baseline Description | Base Lamp Cost | Base Lamp Life (hrs) | Base Lamp Rep. Labor Cost |
|---|---|---|---|---|---|---|
| RW T8 - F28T8 Lamp | $4.50 | 30000 | F32 T8 Standard Lamp | $2.50 | 15000 | $2.67 |
| RWT8 F2T8 Extra Life Lamp | $4.50 | 36000 | F32 T8 Standard Lamp | $2.50 | 15000 | $2.67 |
| RWT8 - F32/25W T8 Lamp | $4.50 | 30000 | F32 T8 Standard Lamp | $2.50 | 15000 | $2.67 |
| RWT8 - F32/25W T8 Lamp Extra Life | $4.50 | 36000 | F32 T8 Standard Lamp | $2.50 | 15000 | $2.67 |
| RWT8 F17T8 Lamp - 2 ft | $4.80 | 18000 | F17 T8 Standard Lamp - 2ft | $2.80 | 15000 | $2.67 |
| RWT8 F25T8 Lamp - 3 ft | $5.10 | 18000 | F25 T8 Standard Lamp - 3ft | $3.10 | 15000 | $2.67 |
| RWT8 F30T8 Lamp - 6' Utube | $11.31 | 24000 | F32 T8 Standard Utube | $9.31 | 15000 | $2.67 |
| RWT8 F29T8 Lamp - Utube | $11.31 | 24000 | F32 T8 Standard Utube | $9.31 | 15000 | $2.67 |
| RWT8 F96T8 Lamp - 8 ft | $9.00 | 24000 | F96 T8 Standard Lamp - 8 ft | $7.00 | 15000 | $2.67 |

713 Cost assumptions for baseline fixtures are based upon manufacturer specification sheets. Baseline and efficient measure cost data comes from lighting suppliers, past Efficiency Vermont projects, and professional judgment.

C-1: T12 Baseline Adjustment:

For measures installed up to 1/1/2020, the full savings (as calculated above in the Algorithm section) will be claimed up to 1/1/2020. A savings adjustment will be applied to the annual savings for the remainder of the measure life. The adjustment to be applied for each measure is listed in the reference table below.

Savings Adjustment Factors

| EE Measure Description | Savings Adjustment T12 EEmag ballast and 34 w lamps to HPT8 | Savings Adjustment T12 EEmag ballast and 40 w lamps to HPT8 | Savings Adjustment T12 mag ballast and 40 w lamps to HPT8 |
|---|---|---|---|
| 1-Lamp Relamp/Reballast T12 to HPT8 | 47% | 30% | 20% |
| 2-Lamp Relamp/Reballast T12 to HPT8 | 53% | 30% | 22% |
| 3-Lamp Relamp/Reballast T12 to HPT8 | 42% | 38% | 21% |
| 4-Lamp Relamp/Reballast T12 to HPT8 | 44% | 29% | 23% |

Measures installed in 2019 will claim full savings for one year. Savings adjustment factors will be applied to the full savings for savings starting in 1/1/2020 and for the remainder of the measure life. The savings adjustment is equal to the ratio between wattage reduction from T8 baseline to HPT8 and wattage reduction from T12 EE ballast with 40 w lamp baseline from the table 'T8 New and Baseline Assumptions'.[714]

Example: 2 lamp T8 to 2 lamp HPT8 retrofit saves 10 watts, while the T12 EE with 40 w lamp to HPT8 saves 33 watts. Thus the ratio of wattage reduced is 30%.

**MEASURE CODE: CI-LTG-T8FX-V07-190101**

**REVIEW DEADLINE: 1/1/2020**

[715] RES v C&I split is based on a weighted (by sales volume) average of ComEd PY7, PY8 and PY9 and Ameren PY8 in store intercept survey results. See 'RESvCI Split_2018.xlsx.

## 4.5.4 LED Bulbs and Fixtures

### Description

This characterization provides savings assumptions for a variety of LED lamps including Omnidirectional (e.g. A-Type lamps), Decorative (e.g. Globes and Torpedoes) and Directional (PAR Lamps, Reflectors, MR16), and fixtures including refrigerated case, recessed and outdoor/garage fixtures.

If the implementation strategy does not allow for the installation location to be known, for Residential targeted programs (e.g. an upstream retail program), a deemed split of 97% Residential and 3% Commercial assumptions should be used[715], and for Commercial targeted programs a deemed split of 98% Commercial and 2% Residential should be used[716].

This measure was developed to be applicable to the following program types: TOS, NC, RF.

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

In order for this characterization to apply, new lamps must be ENERGY STAR labeled. Note a new ENERGY STAR specification v2.1 becomes effective on 1/2/2017.[717]

Lamps and fixtures should be found in the reference tables below. Fixtures must be ENERGY STAR labeled or on the Design Lights Consortium qualifying fixture list.

### Definition of Baseline Equipment

Refer to the baseline tables.

In 2012, Federal legislation stemming from the Energy Independence and Security Act of 2007 (EIAS) required all general-purpose light bulbs (defined as omni-directional or standard A-lamps) between 40 watts and 100 watts to have ~30% increased efficiency, essentially phasing out standard incandescent technology. In 2012, the 100 w lamp standards went in to effect followed by the 75 w lamp standards in 2013 and 60 w and 40 w lamps in 2014.

Additionally, an EISA backstop provision requires replacement baseline lamps to meet an efficacy requirement of 45 lumens/watt or higher beginning on 1/1/2020. Since baseline lamps have significantly lower rated lifetimes, this requires that a baseline shift reducing the annual savings is incorporated during the lifetime of the measure. Due to expected delay in clearing retail inventory and to account for the operating life of a halogen or incandescent lamp potentially spanning past 1/1/2020, this shift under the EISA backstop provision is assumed to not to occur until 1/1/2021 for omnidirectional lamps.

Specialty and Directional lamps were not included in the original definition of General Service Lamps in the Energy Independence and Security Act of 2007 (EISA). Therefore, the initial baseline is an incandescent / halogen lamp described in the tables below.

However, a DOE Final Rule released on 1/19/2017 updated the EISA regulations to remove the exemption for these lamp types such that they become subject to the backstop provision defined within the original legislation.

There is however, uncertainty around the final application of the EISA backstop provision, particularly whether the expanded definition will hold, as well as uncertainty regarding how the market for these products would change absent the backstop. Therefore the 2019 version of this measure delays application of the midlife adjustment associated with the backstop provision for specialty and directional lamps to 1/1/2024. However, TAC members

[715] RES v C&I split is based on a weighted (by sales volume) average of ComEd PY7, PY8 and PY9 and Ameren PY8 in store intercept survey results. See 'RESvCI Split_2018.xlsx.

[716] Based on final ComEd's Instant Incentives program data from PY7 and PY9. For Residential installations, hours of use assumptions from '5.5.6 LED Downlights' should be used for LED fixtures and '5.5.8 LED Screw Based Omnidirectional Bulbs' should be used for LED bulbs.

[717] ENERGY STAR Program Requirements Product Specifications for Lamps (Light Bulbs), version 2.1, effective January 2, 2017

commit to making appropriate mid-year adjustments to the measure characterization in the event that new information adds sufficient clarity and concludes any legal challenges to support making a change to this agreement. This means that if within PY2019, it becomes clear that the EISA backstop *will* apply to the specialty and directional lamps, the timing of the midlife adjustment will be changed to be applied in 2021, consistent with the omnidirectional measure. Likewise, if it becomes clear that these specialty and directional lamp types will revert to being exempt, the midlife adjustment will be removed. In addition, the TAC and IL TRM Administrator must consider NTG and lifetime assumptions and if consensus is reached apply coordinated adjustments to the TRM at that time (if consensus is not reached the most recent NTG evaluation results for these measures will be applied). Any mid-year adjustments to the TRM and NTG would be applied for all installs beginning 30 days after agreement is reached, rather than waiting for the next TRM update.

### Deemed Lifetime of Efficient Equipment

Lifetime is the life of the product, at the reported operating hours (lamp life in hours divided by operating hours per year – see reference table "LED component Costs and Lifetime."  The analysis period is the same as the lifetime, capped at 15 years.  (15 years from GDS Measure Life Report, June 2007).

### Deemed Measure Cost

Wherever possible, actual incremental costs should be used. Refer to reference table "LED component Cost & Lifetime" for defaults.

### Loadshape

Loadshape C06 - Commercial Indoor Lighting

Loadshape C07 - Grocery/Conv. Store Indoor Lighting

Loadshape C08 - Hospital Indoor Lighting

Loadshape C09 - Office Indoor Lighting

Loadshape C10 - Restaurant Indoor Lighting

Loadshape C11 - Retail Indoor Lighting

Loadshape C12 - Warehouse Indoor Lighting

Loadshape C13 - K-12 School Indoor Lighting

Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights)

Loadshape C15 - Indust. 2-shift (16/5) (e.g., comp. air, lights)

Loadshape C16 - Indust. 3-shift (24/5) (e.g., comp. air, lights)

Loadshape C17 - Indust. 4-shift (24/7) (e.g., comp. air, lights)

Loadshape C18 - Industrial Indoor Lighting

Loadshape C19 - Industrial Outdoor Lighting

Loadshape C20 - Commercial Outdoor Lighting

### Coincidence Factor

The summer peak coincidence factor for this measure is dependent on the location type. Values are provided for each building type in the reference section below.

## Algorithm

### Calculation of Savings

### Electric Energy Savings

$$\Delta kWh = ((Watts_{base} - Watts_{EE})/1000) * Hours * WHF_e * ISR$$

Where:

$Watts_{base}$ = Input wattage of the existing or baseline system. Reference the "LED New and Baseline Assumptions" table for default values.

$Watts_{EE}$ = Actual wattage of LED purchased / installed. If unknown, use default provided below:

For ENERGY STAR rated lamps the following lumen equivalence tables should be used:[718]

**Omnidirectional Lamps - ENERGY STAR Minimum Luminous Efficacy = 80Lm/W for <90 CRI lamps and 70Lm/W for >=90 CRI lamps.**

| Minimum Lumens | Maximum Lumens | Lumens used to calculate LED Wattage (midpoint) | LED Wattage[719] (WattsEE) | Baseline 2014-2020 (WattsBase) | Delta Watts 2014-2020 (WattsEE) | Baseline From 1/1/2021[720] (WattsBase) | Delta Watts From 1/1/2021 (WattsEE) |
|---|---|---|---|---|---|---|---|
| 5280 | 6209 | 5745 | 72.9 | 300.0 | 227.1 | 300.0 | 227.1 |
| 3301 | 5279 | 4290 | 54.5 | 200.0 | 145.5 | 200.0 | 145.5 |
| 2601 | 3300 | 2951 | 37.5 | 150.0 | 112.5 | 65.6 | 28.1 |
| 1490 | 2600 | 2045 | 26.0 | 72.0 | 46.0 | 45.4 | 19.5 |
| 1050 | 1489 | 1270 | 16.1 | 53.0 | 36.9 | 28.2 | 12.1 |
| 750 | 1049 | 900 | 11.4 | 43.0 | 31.6 | 20.0 | 8.6 |
| 310 | 749 | 530 | 6.7 | 29.0 | 22.3 | 11.8 | 5.0 |
| 250 | 309 | 280 | 3.5 | 25.0 | 21.5 | 25.0 | 21.5 |

**Decorative Lamps - ENERGY STAR Minimum Luminous Efficacy = 65Lm/W for all lamps**

| Bulb Type | Minimum Lumens | Maximum Lumens | Lumens used to calculate LED Wattage (midpoint) | LED Wattage ($Watts_{EE}$) | Baseline 2014-2023 ($Watts_{Base}$) | Delta Watts 2014-2023 (WattsEE) | Baseline From 1/1/2024 ($Watts_{Base}$)[721] | Delta Watts From 1/1/2024 (WattsEE) |
|---|---|---|---|---|---|---|---|---|
| 3-Way[722] | 250 | 449 | 350 | 4.4 | 25 | 20.6 | 7.8 | 3.3 |
| | 450 | 799 | 625 | 7.9 | 40 | 32.1 | 13.9 | 6.0 |
| | 800 | 1,099 | 950 | 12.1 | 60 | 47.9 | 21.1 | 9.0 |
| | 1,100 | 1,599 | 1350 | 17.1 | 75 | 57.9 | 30.0 | 12.9 |
| | 1,600 | 1,999 | 1800 | 22.8 | 100 | 77.2 | 40.0 | 17.1 |
| | 2,000 | 2,549 | 2275 | 28.9 | 125 | 96.1 | 50.5 | 21.7 |
| | 2,550 | 2,999 | 2775 | 35.2 | 150 | 114.8 | 61.7 | 26.4 |
| Globe (medium and | 90 | 179 | 135 | 2.1 | 10 | 7.9 | 3.0 | 0.9 |
| | 180 | 249 | 215 | 3.3 | 15 | 11.7 | 4.8 | 1.5 |

[718] See file "LED baseline and EE wattage table_2018.xlsx" for details on lamp wattage calculations.
[719] Based on ENERGY STAR V2.0 specs – for omnidirectional <90CRI: 80 lm/W and for omnidirectional >=90 CRI: 70 lm/W. To weight these two criteria, the ENERGY STAR qualified list was reviewed and found to contain 87.8% lamps <90CRI and 12.2% >=90CRI.
[720] Calculated as 45lm/W for all EISA non-exempt bulbs.
[721] Calculated as 45lm/W for all EISA non-exempt bulbs
[722] For 3-way bulbs or fixtures, the product's median lumens value will be used to determine both LED and baseline wattages.

| Bulb Type | Minimum Lumens | Maximum Lumens | Lumens used to calculate LED Wattage (midpoint) | LED Wattage ($Watts_{EE}$) | Baseline 2014-2023 ($Watts_{Base}$) | Delta Watts 2014-2023 (WattsEE) | Baseline From 1/1/2024 ($Watts_{Base}$)[721] | Delta Watts From 1/1/2024 (WattsEE) |
|---|---|---|---|---|---|---|---|---|
| intermediate bases less than 750 lumens) | 250 | 349 | 300 | 4.6 | 25 | 20.4 | 6.7 | 2.0 |
| | 350 | 749 | 550 | 8.5 | 40 | 31.5 | 12.2 | 3.8 |
| Decorative (Shapes B, BA, C, CA, DC, F, G, medium and intermediate bases less than 750 lumens) | 70 | 89 | 80 | 1.2 | 10 | 8.8 | 1.8 | 0.5 |
| | 90 | 149 | 120 | 1.8 | 15 | 13.2 | 2.7 | 0.8 |
| | 150 | 299 | 225 | 3.5 | 25 | 21.5 | 5.0 | 1.5 |
| | 300 | 749 | 525 | 8.1 | 40 | 31.9 | 11.7 | 3.6 |
| Globe (candelabra bases less than 1050 lumens) | 90 | 179 | 135 | 2.1 | 10 | 7.9 | 3.0 | 0.9 |
| | 180 | 249 | 215 | 3.3 | 15 | 11.7 | 4.8 | 1.5 |
| | 250 | 349 | 300 | 4.6 | 25 | 20.4 | 6.7 | 2.0 |
| | 350 | 499 | 425 | 6.5 | 40 | 33.5 | 9.4 | 2.9 |
| | 500 | 1,049 | 775 | 11.9 | 60 | 48.1 | 17.2 | 5.3 |
| Decorative (Shapes B, BA, C, CA, DC, F, G, candelabra bases less than 1050 lumens) | 70 | 89 | 80 | 1.2 | 10 | 8.8 | 1.8 | 0.5 |
| | 90 | 149 | 120 | 1.8 | 15 | 13.2 | 2.7 | 0.8 |
| | 150 | 299 | 225 | 3.5 | 25 | 21.5 | 5.0 | 1.5 |
| | 300 | 499 | 400 | 6.1 | 40 | 33.9 | 8.9 | 2.7 |
| | 500 | 1,049 | 775 | 11.9 | 60 | 48.1 | 17.2 | 5.3 |

**Directional Lamps -** ENERGY STAR Minimum Luminous Efficacy = 70Lm/W for <90 CRI lamps and 61 Lm/W for >=90CRI lamps.

For Directional R, BR, and ER lamp types:

| Bulb Type | Minimum Lumens | Maximum Lumens | Lumens used to calculate LED Wattage (midpoint) | LED Wattage ($Watts_{EE}$) | Baseline 2014-2023 ($Watts_{Base}$) | Delta Watts 2014-2023 (WattsEE) | Baseline From 1/1/2024 ($Watts_{Base}$)[723] | Delta Watts From 1/1/2024 (WattsEE) |
|---|---|---|---|---|---|---|---|---|
| R, ER, BR with medium screw bases w/ diameter >2.25" (*see exceptions below) | 420 | 472 | 446 | 6.6 | 40 | 33.4 | 9.9 | 3.4 |
| | 473 | 524 | 499 | 7.3 | 45 | 37.7 | 11.1 | 3.8 |
| | 525 | 714 | 620 | 9.1 | 50 | 40.9 | 13.8 | 4.7 |
| | 715 | 937 | 826 | 12.1 | 65 | 52.9 | 18.4 | 6.2 |
| | 938 | 1259 | 1099 | 16.2 | 75 | 58.8 | 24.4 | 8.3 |
| | 1260 | 1399 | 1330 | 19.6 | 90 | 70.4 | 29.6 | 10.0 |
| | 1400 | 1739 | 1570 | 23.1 | 100 | 76.9 | 34.9 | 11.8 |
| | 1740 | 2174 | 1957 | 28.8 | 120 | 91.2 | 43.5 | 14.7 |
| | 2175 | 2624 | 2400 | 35.3 | 150 | 114.7 | 53.3 | 18.0 |
| | 2625 | 2999 | 2812 | 41.3 | 175 | 133.7 | 62.5 | 21.1 |
| | 3000 | 4500 | 3750 | 55.1 | 200 | 144.9 | 83.3 | 28.2 |

[723] Calculated as 45lm/W for all EISA non-exempt bulbs

| Bulb Type | Minimum Lumens | Maximum Lumens | Lumens used to calculate LED Wattage (midpoint) | LED Wattage ($Watts_{EE}$) | Baseline 2014-2023 ($Watts_{Base}$) | Delta Watts 2014-2023 (WattsEE) | Baseline From 1/1/2024 ($Watts_{Base}$)[723] | Delta Watts From 1/1/2024 (WattsEE) |
|---|---|---|---|---|---|---|---|---|
| *R, BR, and ER with medium screw bases w/ diameter <=2.25" | 400 | 449 | 425 | 6.2 | 40 | 33.8 | 9.4 | 3.2 |
| | 450 | 499 | 475 | 7.0 | 45 | 38.0 | 10.6 | 3.6 |
| | 500 | 649 | 575 | 8.5 | 50 | 41.5 | 12.8 | 4.3 |
| | 650 | 1199 | 925 | 13.6 | 65 | 51.4 | 20.6 | 7.0 |
| *ER30, BR30, BR40, or ER40 | 400 | 449 | 425 | 6.2 | 40 | 33.8 | 9.4 | 3.2 |
| | 450 | 499 | 475 | 7.0 | 45 | 38.0 | 10.6 | 3.6 |
| | 500 | 649 | 575 | 8.5 | 50 | 41.5 | 12.8 | 4.3 |
| *BR30, BR40, or ER40 | 650 | 1419 | 1035 | 15.2 | 65 | 49.8 | 23.0 | 7.8 |
| *R20 | 400 | 449 | 425 | 6.2 | 40 | 33.8 | 9.4 | 3.2 |
| | 450 | 719 | 585 | 8.6 | 45 | 36.4 | 13.0 | 4.4 |
| *All reflector lamps below lumen ranges specified above | 200 | 299 | 250 | 3.7 | 20 | 16.3 | 5.6 | 1.9 |
| | 300 | 399 | 350 | 5.1 | 30 | 24.9 | 7.8 | 2.6 |

For PAR, MR, and MRX Lamps Types:

For these highly focused directional lamp types, it is necessary to have Center Beam Candle Power (CBCP) and beam angle measurements to accurately estimate the equivalent baseline wattage. The formula below is based on the Energy Star Center Beam Candle Power tool.[724] If CBCP and beam angle information are not available or if the equation below returns a negative value (or undefined), use the manufacturer's recommended baseline wattage equivalent.[725]

$$\text{Wattsbase} = 375.1 - 4.355(D) - \sqrt{227{,}800 - 937.9(D) - 0.9903(D^2) - 1479(BA) - 12.02(D * BA) + 14.69(BA^2) - 16{,}720 * \ln(CBCP)}$$

Where:

D = Bulb diameter (e.g. for PAR20 D = 20)

BA = Beam angle

[724] ENERGY STAR Lamps Center Beam Intensity Benchmark Tool and Calculator

[725] The Energy Star Center Beam Candle Power tool does not accurately model baseline wattages for lamps with certain bulb characteristic combinations – specifically for lamps with very high CBCP.

CBCP = Center beam candle power

The result of the equation above should be rounded DOWN to the nearest wattage established by Energy Star:

| Diameter | Permitted Wattages |
|---|---|
| 16 | 20, 35, 40, 45, 50, 60, 75 |
| 20 | 50 |
| 30S | 40, 45, 50, 60, 75 |
| 30L | 50, 75 |
| 38 | 40, 45, 50, 55, 60, 65, 75, 85, 90, 100, 120, 150, 250 |

Additional EISA non-exempt bulb types:

| Bulb Type | Minimum Lumens | Maximum Lumens | Lumens used to calculate LED Wattage (midpoint) | LED Wattage ($Watts_{EE}$) | Baseline 2014-2023 ($Watts_{Base}$) | Delta Watts 2014-2023 (WattsEE) | Baseline From 1/1/2024 ($Watts_{Base}$)[726] | Delta Watts From 1/1/2024 (WattsEE) |
|---|---|---|---|---|---|---|---|---|
| **Dimmable Twist, Globe (less than 5" in diameter and > 749 lumens), candle (shapes B, BA, CA > 749 lumens), Candelabra Base Lamps (>1049 lumens), Intermediate Base Lamps (>749 lumens)** | 310 | 749 | 530 | 6.7 | 29 | 22.3 | 11.8 | 5.0 |
| | 750 | 1049 | 900 | 11.4 | 43 | 31.6 | 20.0 | 8.6 |
| | 1050 | 1489 | 1270 | 16.1 | 53 | 36.9 | 28.2 | 12.1 |
| | 1490 | 2600 | 2045 | 26.0 | 72 | 46.0 | 45.4 | 19.5 |

Hours = Average hours of use per year are provided in the Reference Table in Section 4.5, Screw based bulb annual operating hours, for each building type. If unknown, use the Miscellaneous value.

WHFe = Waste heat factor for energy to account for cooling energy savings from efficient lighting are provided below for each building type in the Referecne Table in Section 4.5. If unknown, use the Miscellaneous value.

ISR = In Service Rate -the percentage of units rebated that actually get installed.

=100%[727] if application form completed with sign off that equipment is not placed into storage. If sign off form not completed assume the following 3 year ISR assumptions:

| Weighted Average 1st year In Service Rate (ISR) | 2nd year Installations | 3rd year Installations | Final Lifetime In Service Rate |
|---|---|---|---|
| 82.5%[728] | 8.4% | 7.1% | 98.0%[729] |

[726] Calculated as 45lm/W for all EISA non-exempt bulbs

[727] Illinois evaluation of PY1 through PY3 has not found that fixtures or lamps placed into storage to be a significant enough issue to warrant including an “In-Service Rate” when commercial customers complete an application form.

[728] Based on ComEd’s Instant Incentives program data from PY7 and PY9 and Ameren’s Instant Incentives program for PY9, see “IL Commercial Lighting ISR_2018.xlsx”.

[729] In the absence of any data for LEDs specifically it is assumed that the same proportion of bulbs eventually get installed as for CFLS. The 98% CFL assumption is based upon review of two evaluations:

**Mid Life Baseline Adjustment**

During the lifetime of a standard Omnidirectional LED, the baseline incandescent/halogen bulb would need to be replaced multiple times. Since the baseline bulb changes over time (except for <310 and 3300+ lumen lamps) the annual savings claim must be reduced within the life of the measure to account for this baseline shift.

For example, for 60W equivalent bulbs installed in 2018, the full savings (as calculated above in the Algorithm) should be claimed for the first three years, but a reduced annual savings (calculated energy savings above multiplied by the adjustment factor in the table below) claimed for the remainder of the measure life.

| Minimum Lumens | Maximum Lumens | LED Wattage (WattsEE) | Delta Watts 2014-2020 (WattsEE) | Delta Watts From 1/1/2021 (WattsEE) | Mid Life adjustment (made from 1/1/2021) to first year savings |
|---|---|---|---|---|---|
| 2601 | 3300 | 37.5 | 112.5 | 28.1 | 25.0% |
| 1490 | 2600 | 26.0 | 46.0 | 19.5 | 42.3% |
| 1050 | 1489 | 16.1 | 36.9 | 12.1 | 32.8% |
| 750 | 1049 | 11.4 | 31.6 | 8.6 | 27.1% |
| 310 | 749 | 6.7 | 22.3 | 5.0 | 22.6% |

Since the backstop provision now applies to specialty and directional lamps, the annual savings claim for these bulbs must also be reduced within the life of the measure.

| | Bulb Type | Lower Lumen Range | Upper Lumen Range | LED Wattage (Watts$_{EE}$) | Delta Watts 2014-2023 (WattsEE) | Delta Watts From 1/1/2024 (WattsEE) | Mid Life adjustment (made from 1/1/2024) to first year savings |
|---|---|---|---|---|---|---|---|
| Decorative EISA 2014 Exempt, 2020 Non-Exempt | **3-Way** | 250 | 449 | 4.4 | 20.6 | 3.3 | 16.2% |
| | | 450 | 799 | 7.9 | 32.1 | 6.0 | 18.6% |
| | | 800 | 1,099 | 12.1 | 47.9 | 9.0 | 18.9% |
| | | 1,100 | 1,599 | 17.1 | 57.9 | 12.9 | 22.2% |
| | | 1,600 | 1,999 | 22.8 | 77.2 | 17.1 | 22.2% |
| | | 2,000 | 2,549 | 28.9 | 96.1 | 21.7 | 22.5% |
| | | 2,550 | 2,999 | 35.2 | 114.8 | 26.4 | 23.0% |
| | **Globe (medium and intermediate bases less than 750 lumens)** | 90 | 179 | 2.1 | 7.9 | 0.9 | 11.6% |
| | | 180 | 249 | 3.3 | 11.7 | 1.5 | 12.5% |
| | | 250 | 349 | 4.6 | 20.4 | 2.0 | 10.0% |
| | | 350 | 749 | 8.5 | 31.5 | 3.8 | 11.9% |
| | **Decorative (Shapes B, BA, C, CA, DC, F, G, medium and** | 70 | 89 | 1.2 | 8.8 | 0.5 | 6.2% |
| | | 90 | 149 | 1.8 | 13.2 | 0.8 | 6.2% |
| | | 150 | 299 | 3.5 | 21.5 | 1.5 | 7.1% |
| | | 300 | 749 | 8.1 | 31.9 | 3.6 | 11.2% |

‘Nexus Market Research, RLW Analytics and GDS Associates study; “New England Residential Lighting Markdown Impact Evaluation, January 20, 2009’ and ‘KEMA Inc, Feb 2010, Final Evaluation Report: Upstream Lighting Program, Volume 1.’ This implies that only 2% of bulbs purchased are never installed. The second and third year installations are based upon Ameren analysis of the Californian KEMA study showing that 54% of future installs occur in year 2 and 46% in year 3. The 2nd and 3rd year installations should be counted as part of those future program year savings. Note that this Final Install Rate does NOT account for leakage of purchased bulbs being installed outside of the utility territory. EM&V should assess how and if data from evaluation should adjust this final installation rate to account for this impact

| | Bulb Type | Lower Lumen Range | Upper Lumen Range | LED Wattage ($Watts_{EE}$) | Delta Watts 2014-2023 (WattsEE) | Delta Watts From 1/1/2024 (WattsEE) | Mid Life adjustment (made from 1/1/2024) to first year savings |
|---|---|---|---|---|---|---|---|
| | **intermediate bases less than 750 lumens)** | | | | | | |
| | **Globe (candelabra bases less than 1050 lumens)** | 90 | 179 | 2.1 | 7.9 | 0.9 | 11.6% |
| | | 180 | 249 | 3.3 | 11.7 | 1.5 | 12.5% |
| | | 250 | 349 | 4.6 | 20.4 | 2.0 | 10.0% |
| | | 350 | 499 | 6.5 | 33.5 | 2.9 | 8.7% |
| | | 500 | 1,049 | 11.9 | 48.1 | 5.3 | 11.0% |
| | **Decorative (Shapes B, BA, C, CA, DC, F, G, candelabra bases less than 1050 lumens)** | 70 | 89 | 1.2 | 8.8 | 0.5 | 6.2% |
| | | 90 | 149 | 1.8 | 13.2 | 0.8 | 6.2% |
| | | 150 | 299 | 3.5 | 21.5 | 1.5 | 7.1% |
| | | 300 | 499 | 6.1 | 33.9 | 2.7 | 8.1% |
| | | 500 | 1,049 | 11.9 | 48.1 | 5.3 | 11.0% |
| Directional EISA 2014 Exempt, 2020 Non-Exempt | **R, ER, BR with medium screw bases w/ diameter >2.25" (*see exceptions below)** | 420 | 472 | 6.6 | 33.4 | 3.4 | 10.0% |
| | | 473 | 524 | 7.3 | 37.7 | 3.8 | 10.0% |
| | | 525 | 714 | 9.1 | 40.9 | 4.7 | 11.4% |
| | | 715 | 937 | 12.1 | 52.9 | 6.2 | 11.8% |
| | | 938 | 1259 | 16.2 | 58.8 | 8.3 | 14.0% |
| | | 1260 | 1399 | 19.6 | 70.4 | 10.0 | 14.2% |
| | | 1400 | 1739 | 23.1 | 76.9 | 11.8 | 15.3% |
| | | 1740 | 2174 | 28.8 | 91.2 | 14.7 | 16.1% |
| | | 2175 | 2624 | 35.3 | 114.7 | 18.0 | 15.7% |
| | | 2625 | 2999 | 41.3 | 133.7 | 21.1 | 15.8% |
| | | 3000 | 4500 | 55.1 | 144.9 | 28.2 | 19.5% |
| | ***R, BR, and ER with medium screw bases w/ diameter <=2.25"** | 400 | 449 | 6.2 | 33.8 | 3.2 | 9.5% |
| | | 450 | 499 | 7.0 | 38.0 | 3.6 | 9.4% |
| | | 500 | 649 | 8.5 | 41.5 | 4.3 | 10.4% |
| | | 650 | 1199 | 13.6 | 51.4 | 7.0 | 13.5% |
| | ***ER30, BR30, BR40, or ER40** | 400 | 449 | 6.2 | 33.8 | 3.2 | 9.5% |
| | | 450 | 499 | 7.0 | 38.0 | 3.6 | 9.4% |
| | | 500 | 649 | 8.5 | 41.5 | 4.3 | 10.4% |
| | ***BR30, BR40, or ER40** | 650 | 1419 | 15.2 | 49.8 | 7.8 | 15.6% |
| | ***R20** | 400 | 449 | 6.2 | 33.8 | 3.2 | 9.5% |
| | | 450 | 719 | 8.6 | 36.4 | 4.4 | 12.1% |
| | ***All reflector lamps below lumen ranges specified above** | 200 | 299 | 3.7 | 16.3 | 1.9 | 11.5% |
| | | 300 | 399 | 5.1 | 24.9 | 2.6 | 10.6% |
| EISA Non-Exempt | **Dimmable Twist, Globe (less than 5" in diameter and > 749 lumens), candle (shapes B, BA, CA >** | 310 | 749 | 6.7 | 22.3 | 5.0 | 22.6% |
| | | 750 | 1049 | 11.4 | 31.6 | 8.6 | 27.1% |
| | | 1050 | 1489 | 16.1 | 36.9 | 12.1 | 32.8% |
| | | 1490 | 2600 | 26.0 | 46.0 | 19.5 | 42.3% |

| | Bulb Type | Lower Lumen Range | Upper Lumen Range | LED Wattage ($Watts_{EE}$) | Delta Watts 2014-2023 (WattsEE) | Delta Watts From 1/1/2024 (WattsEE) | Mid Life adjustment (made from 1/1/2024) to first year savings |
|---|---|---|---|---|---|---|---|
| | **749 lumens), Candelabra Base Lamps (>1049 lumens), Intermediate Base Lamps (>749 lumens)** | | | | | | |

#### HEATING PENALTY

If electrically heated building:

$$\Delta kWh_{heatpenalty}{}^{730} = (((WattsBase-WattsEE)/1000) * ISR * Hours * -IFkWh$$

Where:

IFkWh = Lighting-HVAC Interation Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficent lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

For example, For example, a 9W LED lamp, 450 lumens, is installed in a heat pump heated office in 2014 and sign off form provided:

$$\Delta kWh_{heatpenalty} = ((29-6.7)/1000)*1.0*3088* -0.151$$

$$= - 10.4 \text{ kWh}$$

#### DEFERRED INSTALLS

As presented above, if a sign off form is not completed the characterization assumes that a percentage of bulbs purchased are not installed until Year 2 and Year 3 (see ISR assumption above). The Illinois Technical Advisory Committee has determined the following methodology for calculating the savings of these future installs.

Year 1 (Purchase Year) installs: Characterized using assumptions provided above or evaluated assumptions if available.

Year 2 and 3 installs: Characterized using delta watts assumption and hours of use from the Install Year i.e. the actual deemed (or evaluated if available) assumptions active in Year 2 and 3 should be applied.

The NTG factor for the Purchase Year should be applied.

#### SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW =( (Watts_{base}-Watts_{EE})/1000) * ISR * WHF_d * CF$$

Where:

[730]Negative value because this is an increase in heating consumption due to the efficient lighting.

WHFd = Waste Heat Factor for Demand to account for cooling savings from efficient lighting in cooled buildings is provided in Referecne Table in Section 4.5. If unknown, use the Miscellaneous value.

CF = Summer Peak Coincidence Factor for measure is provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

For example, a 9W LED lamp, 450 lumens, is installed in an office in 2014 and sign off form provided:

ΔkW = ((29-6.7)/1000)* 1.0*1.3*0.66

= 0.019 kW

**NATURAL GAS ENERGY SAVINGS**

Heating Penalty if fossil fuel heated building (or if heating fuel is unknown):

ΔTherms = (((WattsBase-WattsEE)/1000) * ISR * Hours * - IFTherms

Where:

IFTherms = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Referecne Table in Section 4.5. If unknown, use the Miscellaneous value.

For example, For example, a 9W LED lamp, 450 lumens, is installed in an office in 2014 and sign off form provided:

ΔTherms = ((29-6.7)/1000)*1.0*3088* -0.016

= - 1.10 therms

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

For fixture measures, the individual component lifetimes and costs are provided in the reference table section below[731].

In order to account for the falling EISA Qualified bulb replacement cost provided above, an equivalent annual levelized baseline replacement cost over the lifetime of the LED bulb (assumed to be 15,000/3,612 =4.2 years for commercial and 15,000/5,950 = 2.5 years for multi-family common area installations) is calculated[732]. The key assumptions used in this calculation are documented below[733]:

| Lamp Type | Installation Year | Standard Incandescent | EISA Compliant Halogen | CFL |
|---|---|---|---|---|
| Omnidirectional | 2019 | $0.43 | $1.25 | N/A |
| | 2020 | $0.43 | $1.25 | N/A |
| | 2021 & after | $0.43 | N/A | $2.45 |
| Decorative | 2019 | $1.74 | N/A | N/A |

[731] See IL LED Lighting Systems TRM Reference Tables_2018.xlsx for breakdown of component cost assumptions.

[732] See C&I LED O&M Calc_2018_SpecAdj2024.xlsx" for more information. The commercial values assume the non-residential average hours assumption of 3,612.

[733] Based upon pricing forecast developed by Applied Proactive Technologies Inc (APT) based on industry input and provided to Ameren.

| Lamp Type | Installation Year | Standard Incandescent | EISA Compliant Halogen | CFL |
|---|---|---|---|---|
| | 2020 | $1.74 | N/A | N/A |
| | 2021 & after | $1.74 | N/A | $2.50 |
| Directional | 2019 | $3.53 | N/A | N/A |
| | 2020 | $3.53 | N/A | N/A |
| | 2021 & after | $3.53 | N/A | $4.50 |

The NPV for replacement lamps and annual levelized replacement costs using the societal real discount rate of 0.46% are presented below. It is important to note that for cost-effectiveness screening purposes, the O&M cost adjustments should only be applied in cases where the light bulbs area actually in service and so should be multiplied by the appropriate ISR:

**Omnidirectional Lamps**

| Location | Lumen Level | NPV of replacement costs for period | | | Levelized annual replacement cost savings | | |
|---|---|---|---|---|---|---|---|
| | | 2019 | 2020 | 2021 | 2019 | 2020 | 2021 |
| Commercial | Lumens <310 or >3300 (EISA exempt) | $6.02 | $6.02 | $6.02 | $1.47 | $1.47 | $1.47 |
| | Lumens ≥ 310 and ≤ 23300 (EISA compliant) | $9.64 | $6.04 | $1.23 | $2.35 | $1.47 | $0.30 |
| Multi Family Common Areas | Lumens <310 or >3300 (non-EISA compliant) | $5.92 | $5.92 | $5.92 | $2.37 | $2.37 | $2.37 |
| | Lumens ≥ 310 and ≤ 3300 (EISA compliant) | $14.25 | $8.32 | $1.18 | $5.70 | $3.33 | $0.47 |

**Decorative Lamps**

| Location | NPV of replacement costs for period | | | Levelized annual replacement cost savings | | |
|---|---|---|---|---|---|---|
| | 2019 | 2020 | 2021 | 2019 | 2020 | 2021 |
| Commercial | $24.35 | $23.30 | $18.01 | $5.93 | $5.68 | $4.39 |
| Multi Family Common Areas | $23.94 | $23.94 | $23.94 | $9.57 | $9.57 | $9.57 |

**Directional Lamps**

| Location | NPV of replacement costs for period | | | Levelized annual replacement cost savings | | |
|---|---|---|---|---|---|---|
| | 2019 | 2020 | 2021 | 2019 | 2020 | 2021 |
| Commercial | $49.40 | $47.22 | $36.30 | $12.04 | $11.51 | $8.85 |
| Multi Family Common Areas | $48.56 | $48.56 | $48.56 | $19.42 | $19.42 | $19.42 |

For halogen bulbs, we assume the same replacement cycle as incandescent bulbs.[734] The replacement cycle is based on the miscellaneous hours of use. Both incandescent and halogen lamps are assumed to last for 1,000 hours before needing replacement and CFLs after 10,000 hours.

**REFERENCE TABLES**

**LED Bulb Assumptions**

Wherever possible, actual incremental costs should be used. If unavailable assume the following incremental costs[735]:

| Bulb Type | Year | LED | Incandescent | Incremental Cost |
|---|---|---|---|---|
| **Omnidirectional** | 2017 | $3.21 | $1.25 | $1.96 |
| | 2018 | $3.21 | | $1.96 |
| | 2019 | $3.11 | | $1.86 |
| **Directional** | 2017 | $6.24 | $3.53 | $2.71 |
| | 2018-2019 | $5.18 | | $1.65 |
| **Decorative and Globe** | 2017 | $3.50 | $1.60 | $1.90 |
| | 2018-2019 | $3.40 | $1.74 | $1.66 |

**LED Fixture Wattage and Incremental Cost Assumptions**[736]

| LED Category | EE Measure Description | $Watts_{EE}$ | Baseline Description | $Watts_{BAE}$ | Incremental Cost | T12 Mid Life Savings Adjustment (1/1/2020) |
|---|---|---|---|---|---|---|
| LED Downlight Fixtures | LED Recessed, Surface, Pendant Downlights | 17.6 | Baseline LED Recessed, Surface, Pendant Downlights | 54.3 | $27 | N/A |
| LED Interior Directional | LED Track Lighting | 12.2 | Baseline LED Track Lighting | 60.4 | $59 | N/A |
| | LED Wall-Wash Fixtures | 8.3 | Baseline LED Wall-Wash Fixtures | 17.7 | $59 | N/A |
| LED Display Case | LED Display Case Light Fixture | 7.1 per ft | Baseline LED Display Case Light Fixture | 36.2 per ft | $11/ft | N/A |
| | LED Undercabinet Shelf-Mounted Task Light Fixtures | 7.1 per ft | Baseline LED Undercabinet Shelf-Mounted Task Light Fixtures | 36.2 per ft | $11/ft | N/A |
| | LED Refrigerated Case Light, Horizontal or Vertical | 7.6 per ft | Baseline LED Refrigerated Case Light, | 15.2 per ft | $11/ft | N/A |

[734] The manufacturers of the new minimally compliant EISA Halogens are using regular incandescent lamps with halogen fill gas rather than halogen infrared to meet the standard and so the component rated life is equal to the standard incandescent.

[735] Baseline and LED lamp costs are based on field data collected by CLEAResult and provided by ComEd. See ComEd Pricing Projections 06302016.xlsx for analysis.Given LED prices are expected to continue declining assumed costs should be reassessed on an annual basis and replaced with IL specific LED program information when available.

[736] Watt, lumen, lamp life, and ballast factor assumptions for efficient measures are based upon Consortium for Energy Efficiency (CEE) Commercial Lighting Qualifying Product Lists alongside past Efficiency Vermont projects and PGE refrigerated case study. Watt, lumen, lamp life, and ballast factor assumptions for baseline fixtures are based upon manufacturer specification sheets. Baseline cost data comes from lighting suppliers, past Efficiency Vermont projects, and professional judgment. Efficient cost data comes from 2012 DOE “Energy Savings Potential of Solid-State Lighting in General Illumination Applications”, Table A.1. See "LED Lighting Systems TRM Reference Tables_2018.xlsx" for more information and specific product links.

| LED Category | EE Measure Description | $Watts_{EE}$ | Baseline Description | $Watts_{BAE}$ | Incremental Cost | T12 Mid Life Savings Adjustment (1/1/2020) |
|---|---|---|---|---|---|---|
| | | | Horizontal or Vertical (per foot) | | | |
| | LED Freezer Case Light, Horizontal or Vertical | 7.7 per ft | Baseline LED Freezer Case Light, Horizontal or Vertical (per foot) | 18.7 per ft | $11/ft | N/A |
| LED Linear Replacement Lamps | T8 LED Replacement Lamp (TLED), < 1200 lumens | 8.9 | F17T8 Standard Lamp - 2 foot | 15.0 | $13 | N/A |
| | T8 LED Replacement Lamp (TLED), 1200-2400 lumens | 15.8 | F32T8 Standard Lamp - 4 foot | 28.2 | $15 | N/A |
| | T8 LED Replacement Lamp (TLED), > 2400 lumens | 22.9 | F32T8/HO Standard Lamp - 4 foot | 41.8 | $13 | N/A |
| LED Troffers | LED 2x2 Recessed Light Fixture, 2000-3500 lumens | 25.4 | 18:82; 2-Lamp 34w T12 (BF < 0.85) :2-Lamp 32w T8 (BF < 0.89) | 57.9 | $53 | 97% |
| | LED 2x2 Recessed Light Fixture, 3501-5000 lumens | 36.7 | 18:82; 3-Lamp 34w T12 (BF <0.88) :3-Lamp 32w T8 (BF < 0.88) | 88.7 | $69 | 92% |
| | LED 2x4 Recessed Light Fixture, 3000-4500 lumens | 33.3 | 18:82; 2-Lamp 34w T12 (BF < 0.85) :2-Lamp 32w T8 (BF < 0.89) | 57.9 | $55 | 96% |
| | LED 2x4 Recessed Light Fixture, 4501-6000 lumens | 44.8 | 18:82; 3-Lamp 34w T12 (BF <0.88) :3-Lamp 32w T8 (BF < 0.88) | 88.7 | $76 | 90% |
| | LED 2x4 Recessed Light Fixture, 6001-7500 lumens | 57.2 | 18:82;4-Lamp 34w T12 (BF < 0.88): 4-Lamp 32w T8 (BF < 0.88) | 118.3 | $104 | 91% |
| | LED 1x4 Recessed Light Fixture, 1500-3000 lumens | 21.8 | 18:82; 1-Lamp 34w T12 (BF <0.88) : 1-Lamp 32w T8 (BF <0.91) | 29.5 | $22 | 96% |
| | LED 1x4 Recessed Light Fixture, 3001-4500 lumens | 33.7 | 18:82; 2-Lamp 34w T12 (BF < 0.85) :2-Lamp 32w T8 (BF < 0.89) | 57.9 | $75 | 96% |
| | LED 1x4 Recessed Light Fixture, 4501-6000 lumens | 43.3 | 18:82; 3-Lamp 34w T12 (BF <0.88) :3-Lamp 32w T8 (BF < 0.88) | 88.7 | $83 | 91% |
| LED Linear Ambient Fixtures | LED Surface & Suspended Linear Fixture, <= 3000 lumens | 19.5 | 18:82; 1-Lamp 34w T12 (BF <0.88) : 1-Lamp 32w T8 (BF <0.91) | 29.5 | $10 | 97% |
| | LED Surface & Suspended Linear Fixture, 3001-4500 lumens | 32.1 | 18:82; 2-Lamp 34w T12 (BF < 0.85) :2-Lamp 32w T8 (BF < 0.89) | 57.9 | $52 | 96% |

| LED Category | EE Measure Description | $Watts_{EE}$ | Baseline Description | $Watts_{BAE}$ | Incremental Cost | T12 Mid Life Savings Adjustment (1/1/2020) |
|---|---|---|---|---|---|---|
| | LED Surface & Suspended Linear Fixture, 4501-6000 lumens | 43.5 | 18:82; 3-Lamp 34w T12 (BF <0.88) :3-Lamp 32w T8 (BF < 0.88) | 88.7 | $78 | 91% |
| | LED Surface & Suspended Linear Fixture, 6001-7500 lumens | 56.3 | T5HO 2L-F54T5HO - 4' | 120.0 | $131 | N/A |
| | LED Surface & Suspended Linear Fixture, > 7500 lumens | 82.8 | T5HO 3L-F54T5HO - 4' | 180.0 | $173 | N/A |
| LED High & Low Bay Fixtures | LED Low-Bay Fixtures, <= 10,000 lumens | 61.6 | 3-Lamp T8HO Low-Bay | 157.0 | $44 | N/A |
| | LED High-Bay Fixtures, 10,001-15,000 lumens | 99.5 | 4-Lamp T8HO High-Bay | 196.0 | $137 | N/A |
| | LED High-Bay Fixtures, 15,001-20,000 lumens | 140.2 | 6-Lamp T8HO High-Bay | 294.0 | $202 | N/A |
| | LED High-Bay Fixtures, > 20,000 lumens | 193.8 | 8-Lamp T8HO High-Bay | 392.0 | $264 | N/A |
| LED Agricultural Interior Fixtures | LED Ag Interior Fixtures, <= 2,000 lumens | 12.9 | 25% 73 Watt EISA Inc, 75% 1L T8 | 42.0 | $18 | N/A |
| | LED Ag Interior Fixtures, 2,001-4,000 lumens | 29.7 | 25% 146 Watt EISA Inc, 75% 2L T8 | 81.0 | $48 | N/A |
| | LED Ag Interior Fixtures, 4,001-6,000 lumens | 45.1 | 25% 217 Watt EISA Inc, 75% 3L T8 | 121.0 | $57 | N/A |
| | LED Ag Interior Fixtures, 6,001-8,000 lumens | 59.7 | 25% 292 Watt EISA Inc, 75% 4L T8 | 159.0 | $88 | N/A |
| | LED Ag Interior Fixtures, 8,001-12,000 lumens | 84.9 | 200W Pulse Start Metal Halide | 227.3 | $168 | N/A |
| | LED Ag Interior Fixtures, 12,001-16,000 lumens | 113.9 | 320W Pulse Start Metal Halide | 363.6 | $151 | N/A |
| | LED Ag Interior Fixtures, 16,001-20,000 lumens | 143.7 | 350W Pulse Start Metal Halide | 397.7 | $205 | N/A |
| | LED Ag Interior Fixtures, > 20,000 lumens | 193.8 | (2) 320W Pulse Start Metal Halide | 727.3 | $356 | N/A |
| LED Exterior Fixtures | LED Exterior Fixtures, <= 5,000 lumens | 34.1 | 100W Metal Halide | 113.6 | $80 | N/A |
| | LED Exterior Fixtures, 5,001-10,000 lumens | 67.2 | 175W Pulse Start Metal Halide | 198.9 | $248 | N/A |

| LED Category | EE Measure Description | $Watts_{EE}$ | Baseline Description | $Watts_{BAE}$ | Incremental Cost | T12 Mid Life Savings Adjustment (1/1/2020) |
|---|---|---|---|---|---|---|
| | LED Exterior Fixtures, 10,001-15,000 lumens | 108.8 | 250W Pulse Start Metal Halide | 284.1 | $566 | N/A |
| | LED Exterior Fixtures, > 15,000 lumens | 183.9 | 400W Pulse Start Metal Halide | 454.5 | $946 | N/A |

**LED Fixture Component Costs & Lifetime**[737]

| | | EE Measure | | | | Baseline | | | |
|---|---|---|---|---|---|---|---|---|---|
| LED Category | EE Measure Description | Lamp Life (hrs) | Total Lamp Replacement Cost | LED Driver Life (hrs) | Total LED Driver Replacement Cost | Lamp Life (hrs) | Total Lamp Replacement Cost | Ballast Life (hrs) | Total Ballast Replacement Cost |
| LED Downlight Fixtures | LED Recessed, Surface, Pendant Downlights | 50,000 | $30.75 | 70,000 | $47.50 | 2,500 | $8.86 | 40,000 | $14.40 |
| LED Interior Directional | LED Track Lighting | 50,000 | $39.00 | 70,000 | $47.50 | 2,500 | $12.71 | 40,000 | $11.00 |
| | LED Wall-Wash Fixtures | 50,000 | $39.00 | 70,000 | $47.50 | 2,500 | $9.17 | 40,000 | $27.00 |
| LED Display Case | LED Display Case Light Fixture | 50,000 | $9.75/ft | 70,000 | $11.88/ft | 2,500 | $6.70 | 40,000 | $5.63 |
| | LED Undercabinet Shelf-Mounted Task Light Fixtures | 50,000 | $9.75/ft | 70,000 | $11.88/ft | 2,500 | $6.70 | 40,000 | $5.63 |
| | LED Refrigerated Case Light, Horizontal or Vertical | 50,000 | $8.63/ft | 70,000 | $9.50/ft | 15,000 | $1.13 | 40,000 | $8.00 |
| | LED Freezer Case Light, Horizontal or Vertical | 50,000 | $7.88/ft | 70,000 | $7.92/ft | 12,000 | $0.94 | 40,000 | $6.67 |
| LED Linear Replacement Lamps | T8 LED Replacement Lamp (TLED), < 1200 lumens | 50,000 | $5.76 | 70,000 | $13.67 | 30,000 | $6.17 | 40,000 | $11.96 |
| | T8 LED Replacement Lamp (TLED), 1200-2400 lumens | 50,000 | $8.57 | 70,000 | $13.67 | 24,000 | $6.17 | 40,000 | $11.96 |
| | T8 LED Replacement Lamp (TLED), > 2400 lumens | 50,000 | $8.57 | 70,000 | $13.67 | 18,000 | $6.17 | 40,000 | $11.96 |

[737] Note that some measures have blended baselines (T12:T8 18:82). All values are provided to enable calculation of appropriate O&M impacts. Total costs include lamp, labor and disposal cost assumptions where applicable, see IL LED Lighting Systems TRM Reference Tables_2018.xlsx for more information.

| | | EE Measure | | | | Baseline | | | |
|---|---|---|---|---|---|---|---|---|---|
| LED Category | EE Measure Description | Lamp Life (hrs) | Total Lamp Replacement Cost | LED Driver Life (hrs) | Total LED Driver Replacement Cost | Lamp Life (hrs) | Total Lamp Replacement Cost | Ballast Life (hrs) | Total Ballast Replacement Cost |
| LED Troffers | LED 2x2 Recessed Light Fixture, 2000-3500 lumens | 50,000 | $78.07 | 70,000 | $40.00 | 24,000 | $26.33 | 40,000 | $35.00 |
| | LED 2x2 Recessed Light Fixture, 3501-5000 lumens | 50,000 | $89.23 | 70,000 | $40.00 | 24,000 | $39.50 | 40,000 | $35.00 |
| | LED 2x4 Recessed Light Fixture, 3000-4500 lumens | 50,000 | $96.10 | 70,000 | $40.00 | 24,000 | $12.33 | 40,000 | $35.00 |
| | LED 2x4 Recessed Light Fixture, 4501-6000 lumens | 50,000 | $114.37 | 70,000 | $40.00 | 24,000 | $18.50 | 40,000 | $35.00 |
| | LED 2x4 Recessed Light Fixture, 6001-7500 lumens | 50,000 | $137.43 | 70,000 | $40.00 | 24,000 | $24.67 | 40,000 | $35.00 |
| | LED 1x4 Recessed Light Fixture, 1500-3000 lumens | 50,000 | $65.43 | 70,000 | $40.00 | 24,000 | $6.17 | 40,000 | $35.00 |
| | LED 1x4 Recessed Light Fixture, 3001-4500 lumens | 50,000 | $100.44 | 70,000 | $40.00 | 24,000 | $12.33 | 40,000 | $35.00 |
| | LED 1x4 Recessed Light Fixture, 4501-6000 lumens | 50,000 | $108.28 | 70,000 | $40.00 | 24,000 | $18.50 | 40,000 | $35.00 |
| LED Linear Ambient Fixtures | LED Surface & Suspended Linear Fixture, <= 3000 lumens | 50,000 | $62.21 | 70,000 | $40.00 | 24,000 | $6.17 | 40,000 | $35.00 |
| | LED Surface & Suspended Linear Fixture, 3001-4500 lumens | 50,000 | $93.22 | 70,000 | $40.00 | 24,000 | $12.33 | 40,000 | $35.00 |
| | LED Surface & Suspended Linear Fixture, 4501-6000 lumens | 50,000 | $114.06 | 70,000 | $40.00 | 24,000 | $18.50 | 40,000 | $35.00 |
| | LED Surface & Suspended Linear Fixture, 6001-7500 lumens | 50,000 | $152.32 | 70,000 | $40.00 | 30,000 | $26.33 | 40,000 | $60.00 |
| | LED Surface & Suspended Linear Fixture, > 7500 lumens | 50,000 | $183.78 | 70,000 | $40.00 | 30,000 | $39.50 | 40,000 | $60.00 |
| LED High & Low Bay Fixtures | LED Low-Bay Fixtures, <= 10,000 lumens | 50,000 | $90.03 | 70,000 | $62.50 | 18,000 | $64.50 | 40,000 | $92.50 |

| | | EE Measure | | | | Baseline | | | |
|---|---|---|---|---|---|---|---|---|---|
| LED Category | EE Measure Description | Lamp Life (hrs) | Total Lamp Replacement Cost | LED Driver Life (hrs) | Total LED Driver Replacement Cost | Lamp Life (hrs) | Total Lamp Replacement Cost | Ballast Life (hrs) | Total Ballast Replacement Cost |
| | LED High-Bay Fixtures, 10,001-15,000 lumens | 50,000 | $122.59 | 70,000 | $62.50 | 18,000 | $86.00 | 40,000 | $92.50 |
| | LED High-Bay Fixtures, 15,001-20,000 lumens | 50,000 | $157.22 | 70,000 | $62.50 | 18,000 | $129.00 | 40,000 | $117.50 |
| | LED High-Bay Fixtures, > 20,000 lumens | 50,000 | $228.52 | 70,000 | $62.50 | 18,000 | $172.00 | 40,000 | $142.50 |
| LED Agricultural Interior Fixtures | LED Ag Interior Fixtures, <= 2,000 lumens | 50,000 | $41.20 | 70,000 | $40.00 | 1,000 | $1.23 | 40,000 | $26.25 |
| | LED Ag Interior Fixtures, 2,001-4,000 lumens | 50,000 | $65.97 | 70,000 | $40.00 | 1,000 | $1.43 | 40,000 | $26.25 |
| | LED Ag Interior Fixtures, 4,001-6,000 lumens | 50,000 | $80.08 | 70,000 | $40.00 | 1,000 | $1.62 | 40,000 | $26.25 |
| | LED Ag Interior Fixtures, 6,001-8,000 lumens | 50,000 | $105.54 | 70,000 | $40.00 | 1,000 | $1.81 | 40,000 | $26.25 |
| | LED Ag Interior Fixtures, 8,001-12,000 lumens | 50,000 | $179.81 | 70,000 | $62.50 | 15,000 | $63.00 | 40,000 | $112.50 |
| | LED Ag Interior Fixtures, 12,001-16,000 lumens | 50,000 | $190.86 | 70,000 | $62.50 | 15,000 | $68.00 | 40,000 | $122.50 |
| | LED Ag Interior Fixtures, 16,001-20,000 lumens | 50,000 | $237.71 | 70,000 | $62.50 | 15,000 | $73.00 | 40,000 | $132.50 |
| | LED Ag Interior Fixtures, > 20,000 lumens | 50,000 | $331.73 | 70,000 | $62.50 | 15,000 | $136.00 | 40,000 | $202.50 |
| LED Exterior Fixtures | LED Exterior Fixtures, <= 5,000 lumens | 50,000 | $73.80 | 70,000 | $62.50 | 15,000 | $58.00 | 40,000 | $102.50 |
| | LED Exterior Fixtures, 5,001-10,000 lumens | 50,000 | $124.89 | 70,000 | $62.50 | 15,000 | $63.00 | 40,000 | $112.50 |
| | LED Exterior Fixtures, 10,001-15,000 lumens | 50,000 | $214.95 | 70,000 | $62.50 | 15,000 | $68.00 | 40,000 | $122.50 |
| | LED Exterior Fixtures, > 15,000 lumens | 50,000 | $321.06 | 70,000 | $62.50 | 15,000 | $73.00 | 40,000 | $132.50 |

**MEASURE CODE: CI-LTG-LEDB-V08-190101**

**REVIEW DEADLINE: 1/1/2022**

## 4.5.5 Commercial LED Exit Signs

**DESCRIPTION**

This measure characterizes the savings associated with installing a Light Emitting Diode (LED) exit sign in place of a fluorescent or incandescent exit sign in a Commercial building. Light Emitting Diode exit signs have a string of very small, typically red or green, glowing LEDs arranged in a circle or oval. The LEDs may also be arranged in a line on the side, top or bottom of the exit sign. LED exit signs provide the best balance of safety, low maintenance, and very low energy usage compared to other exit sign technologies.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

The efficient equipment is assumed to be an exit sign illuminated by LEDs.

**DEFINITION OF BASELINE EQUIPMENT**

The baseline equipment is assumed to be an existing fluorescent or incandescent model.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The measure life is assumed to be 5 years[738].

**DEEMED MEASURE COST**

The actual material and labor costs should be used if available. If actual costs are unavailable, assume a total installed cost of at $32.50[739]

**LOADSHAPE**

Loadshape C53 - Flat

**COINCIDENCE FACTOR**

The summer peak coincidence factor for this measure is assumed to be 100%[740].

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

$$\Delta kWh = ((WattsBase - WattsEE) / 1000) * HOURS * WHF_e$$

Where:

WattsBase = Actual wattage if known, if unknown assume the following:

| Baseline Type | $Watts_{Base}$ |
|---|---|
| Incandescent | 35W[741] |

[738] Estimate of remaining life of existing unit being replaced.
[739] Price includes new exit sign/fixture and installation. LED exit cost cost/unit is $22.50 from the NYSERDA Deemed Savings Database and assuming IL labor cost of 15 minutes @ $40/hr.
[740] Assuming continuous operation of an LED exit sign, the Summer Peak Coincidence Factor is assumed to equal 1.0.
[741] Based on review of available product.

| Baseline Type | $Watts_{Base}$ |
|---|---|
| CFL (dual sided) | 14W[742] |
| CFL (single sided) | 7W |
| Unknown | 7W |

WattsEE = Actual wattage if known, if unknown assume 2W for signle sided or unknown type and 4W for dual sided[743]

HOURS = Annual operating hours

= 8766

$WHF_e$ = Waste heat factor for energy to account for cooling energy savings from efficient lighting are provided for each building type in the Referecne Table in Section 4.5. If unknown, use the Miscellaneous value.

> For example, replacing incandescent fixture in an office
>
> ΔkWH = (35 – 2)/1000 * 8766 * 1.25
>
> = 362 kWh
>
> For example, replacing single sided fluorescent fixture in a hospital
>
> ΔkWH = (7– 2)/1000 * 8766 * 1.35
>
> = 59.2 kWh

**HEATING PENALTY**

If electrically heated building:

$\Delta kWh_{heatpenalty}$[744] = (((WattsBase-WattsEE)/1000) * Hours * -IFkWh

Where:

IFkWh = Lighting-HVAC Interation Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficent lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

> For example, replacing incandescent fixture in a heat pump heated office
>
> $\Delta kWh_{heatpenalty}$ = (35 – 2)/1000 * 8766 * -0.151
>
> = -43.7 kWh
>
> For example, replacing single sided fluorescent fixture in a heat pump heated hospital
>
> $\Delta kWh_{heatpenalty}$ = (7 – 2)/1000 * 8766 * -0.104
>
> = -4.6 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = ((WattsBase - WattsEE) / 1000) * $WHF_d$ * CF

742 Average CFL single sided (5W, 7W, 9W) from Appendix B 2013-14 Table of Standard Fixture Wattages.
743 Average LED single sided (2W) from Appendix B 2013-14 Table of Standard Fixture Wattages.
744 Negative value because this is an increase in heating consumption due to the efficient lighting.

Where:

$WHF_d$ = Waste heat factor for demand to account for cooling savings from efficient lighting in cooled buildings is provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value..

CF = Summer Peak Coincidence Factor for measure

= 1.0

For example, replacing incandescent fixture in an office

ΔkW = (35 – 2)/1000 * 1.3 * 1.0

= 0.043 kW

For example, replacing single sided fluorescent fixture in a hospital

ΔkW = (7 – 2)/1000 * 1.69 * 1.0

= 0.0085 kW

**NATURAL GAS SAVINGS**

Heating Penalty if natural gas heated building (or if heating fuel is unknown):

Δtherms = (((WattsBase-WattsEE)/1000) * Hours *- IFTherms

Where:

IFTherms = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Referecne Table in Section 4.5. If unknown, use the Miscellaneous value.

For example, replacing incandescent fixture in an office

ΔTherms = (35 – 2)/1000 * 8766 * -0.016

= -4.63 Therms

For example, replacing single sided fluorescent fixture in a hospital

ΔTherms = (7 – 2)/1000 * 8766 * -0.011

= - 0.48 Therms

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

The annual O&M Cost Adjustment savings should be calculated using the following component costs and lifetimes.

| | Baseline Measures | |
|---|---|---|
| Component | Cost | Life (yrs) |
| Lamp | $12.45[745] | 1.37 years[746] |

[745] Consistent with assumption for a Standard CFL bulb ($2.45) with an estimated labor cost of $10 (assuming $40/hour and a task time of 15 minutes).

[746] Assumes a lamp life of 12,000 hours and 8766 run hours 12000/8766 = 1.37 years.

**MEASURE CODE: CI-LTG-LEDE-V03-190101**

**REVIEW DEADLINE: 1/1/2024**

## 4.5.6 LED Traffic and Pedestrian Signals

### Description

Traffic and pedestrian signals are retrofitted to be illuminated with light emitting diodes (LED) instead of incandescent lamps. Incentive applies for the replacement or retrofit of existing incandescent traffic signals with new LED traffic and pedestrian signal lamps. Each lamp can have no more than a maximum LED module wattage of 25. Incentives are not available for spare lights. Lights must be hardwired and single lamp replacements are not eligible, with the exception of pedestrian hand signals. Eligible lamps must meet the Energy Star Traffic Signal Specification and the Institute for Transportation Engineers specification for traffic signals.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

Refer to the Table titled 'Traffic Signals Technology Equivalencies' for efficient technology wattage and savings assumptions.

### Definition of Baseline Equipment

Refer to the Table titled 'Traffic Signals Technology Equivalencies' for baseline efficiencies and savings assumptions.

### Deemed Lifetime of Efficient Equipment

The assumed lifetime of an LED traffic signal is 100,000 hours (manufacturer's estimate), capped at 10 years.[747] The life in years is calculated by dividing 100,000 hrs by the annual operating hours for the particular signal type.

### Deemed Measure Cost

The actual measure installation cost should be used (including material and labor).

### Loadshape

Loadshape C24 - Traffic Signal - Red Balls, always changing or flashing
Loadshape C25 - Traffic Signal - Red Balls, changing day, off night
Loadshape C26 - Traffic Signal - Green Balls, always changing
Loadshape C27 - Traffic Signal - Green Balls, changing day, off night
Loadshape C28 - Traffic Signal - Red Arrows
Loadshape C29 - Traffic Signal - Green Arrows
Loadshape C30 - Traffic Signal - Flashing Yellows
Loadshape C31 - Traffic Signal - "Hand" Don't Walk Signal
Loadshape C32 - Traffic Signal - "Man" Walk Signal
Loadshape C33 - Traffic Signal - Bi-Modal Walk/Don't Walk

### Coincidence Factor[748]

The summer peak coincidence factor (CF) for this measure is dependent on lamp type as below:

| Lamp Type | CF |
|---|---|
| Red Round, always changing or flashing | 0.55 |
| Red Arrows | 0.90 |

[747] ACEEE, (1998) A Market Transformation Opportunity Assessment for LED Traffic Signals
[748] Ibid

| Lamp Type | CF |
|---|---|
| Green Arrows | 0.10 |
| Yellow Arrows | 0.03 |
| Green Round, always changing or flashing | 0.43 |
| Flashing Yellow | 0.50 |
| Yellow Round, always changing | 0.02 |
| “Hand” Don’t Walk Signal | 0.75 |
| “Man” Walk Signal | 0.21 |

## Algorithm

### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

$\Delta$kWh = ($W_{base}$ - $W_{eff}$) x HOURS / 1000

Where:

Wbase =The connected load of the baseline equipment

= see Table ‘Traffic Signals Technology Equivalencies’

Weff =The connected load of the baseline equipment

= see Table ‘Traffic Signals Technology Equivalencies’

EFLH = annual operating hours of the lamp

= see Table ‘Traffic Signals Technology Equivalencies’

1000 = conversion factor (W/kW)

**EXAMPLE**

For example, an 8 inch red, round signal:

$\Delta$kWh = ((69 - 7) x 4818) / 1000

= 299 kWh

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta$kW = (Wbase– Weff) x CF / 1000

Where:

Wbase =The connected load of the baseline equipment

= see Table ‘Traffic Signals Technology Equivalencies’

Weff =The connected load of the efficient equipment

= see Table ‘Traffic Signals Technology Equivalencies’

CF = Summer Peak Coincidence Factor for measure

**EXAMPLE**

For example, an 8 inch red, round signal:

$\Delta$kW = ((69 – 7) x 0.55) / 1000

= 0.0341 kW

## Natural Gas Energy Savings

N/A

## Water Impact Descriptions and Calculation

N/A

## Reference Tables

Traffic Signals Technology Equivalencies[749]

| Traffic Fixture Type | Fixture Size and Color | Efficient Lamps | Baseline Lamps | HOURS | Efficient Fixture Wattage | Baseline Fixture Wattage | Energy Savings (in kWh) |
|---|---|---|---|---|---|---|---|
| Round Signals | 8” Red | LED | Incandescent | 4818 | 7 | 69 | 299 |
| Round Signals | 12” Red | LED | Incandescent | 4818 | 6 | 150 | 694 |
| Flashing Signal[750] | 8” Red | LED | Incandescent | 4380 | 7 | 69 | 272 |
| Flashing Signal | 12” Red | LED | Incandescent | 4380 | 6 | 150 | 631 |
| Flashing Signal | 8” Yellow | LED | Incandescent | 4380 | 10 | 69 | 258 |
| Flashing Signal | 12” Yellow | LED | Incandescent | 4380 | 13 | 150 | 600 |
| Round Signals | 8” Yellow | LED | Incandescent | 175 | 10 | 69 | 10 |
| Round Signals | 12” Yellow | LED | Incandescent | 175 | 13 | 150 | 24 |
| Round Signals | 8” Green | LED | Incandescent | 3767 | 9 | 69 | 266 |
| Round Signals | 12” Green | LED | Incandescent | 3767 | 12 | 150 | 520 |
| Turn Arrows | 8” Yellow | LED | Incandescent | 701 | 7 | 116 | 76 |
| Turn Arrows | 12” Yellow | LED | Incandescent | 701 | 9 | 116 | 75 |
| Turn Arrows | 8” Green | LED | Incandescent | 701 | 7 | 116 | 76 |
| Turn Arrows | 12” Green | LED | Incandescent | 701 | 7 | 116 | 76 |
| Pedestrian Sign | 12” Hand/Man | LED | Incandescent | 8766 | 8 | 116 | 946 |

Reference specifications for above traffic signal wattages are from the following manufacturers:

1. 8” Incandescent traffic signal bulb: General Electric Traffic Signal Model 17325-69A21/TS
2. 12” Incandescent traffic signal bulb: General Electric Signal Model 35327-150PAR46/TS
3. Incandescent Arrows & Hand/Man Pedestrian Signs: General Electric Traffic Signal Model 19010-116A21/TS
4. 8” and 12” LED traffic signals: Leotek Models TSL-ES08 and TSL-ES12
5. 8” LED Yellow Arrow: General Electric Model DR4-YTA2-01A
6. 8” LED Green Arrow: General Electric Model DR4-GCA2-01A
7. 12” LED Yellow Arrow: Dialight Model 431-3334-001X
8. 12: LED Green Arrow: Dialight Model 432-2324-001X
9. LED Hand/Man Pedestrian Sign: Dialight 430-6450-001X

## Measure Code: CI-LTG-LEDT-V01-120601

## Review Deadline: 1/1/2019

[749] Technical Reference Manual for Pennsylvania Act 129 Energy Efficiency and Conservation Program and Act 213 Alternative Energy Portfolio Standards. Pennsylvania Public Utility Commission. May 2009
[750] Technical Reference Manual for Ohio, August 6, 2010

## 4.5.7 Lighting Power Density

### DESCRIPTION

This measure relates to installation of efficient lighting systems in new construction or substantial renovation of commercial buildings excluding low rise (three stories or less) residential buildings. Substantial renovation is when two or more building systems are renovated, such as shell and heating, heating and lighting, etc. State Energy Code specifies a lighting power density level by building type for both the interior and the exterior. Either the Building Area Method or Space by Space method as defined in IECC 2012, 2015 or 2018, depending on the IECC in effect on the date of the building permit (if unknown assume IECC 2015), can be used for calculating the Interior Lighting Power Density[751]. The measure consists of a design that is more efficient (has a lower lighting power density in watts/square foot) than code requires. The IECC applies to both new construction and renovation.

This measure was developed to be applicable to the following program types: NC.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the lighting system must be more efficient than the baseline Energy Code lighting power density in watts/square foot for either the interior space or exterior space.

### DEFINITION OF BASELINE EQUIPMENT

The baseline is assumed to be a lighting power density that meets IECC 2012 or 2015, depending on the IECC in effect on the date of the building permit (if unknown assume IECC 2015).

Note IECC 2018 is scheduled to become effective March 1, 2019 and will become baseline for all New Construction permits from that date.

### DEEMED CALCULATION FOR THIS MEASURE

Annual kWh Savings

$$\Delta kWh = (WSFbase - WSFeffic)/1000 * SF * Hours * WHF_e$$

Summer Coincident Peak kW Savings

$$\Delta kW = (WSFbase - WSFeffic)/1000 * SF * CF * WHF_d$$

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years[752]

### DEEMED MEASURE COST

The actual incremental cost over a baseline system will be collected from the customer if possible or developed on a fixture by fixture basis.

### LOADSHAPE

Loadshape C06 - Commercial Indoor Lighting

Loadshape C07 - Grocery/Conv. Store Indoor Lighting

Loadshape C08 - Hospital Indoor Lighting

---

[751] Refer to the referenced code documents for specifics on calculating lighting power density using either the whole building method (IECC) or the Space by Space method (current ASHRAE 90.1).

[752] Measure Life Report, Residential and Commercial/Industrial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.

Loadshape C09 - Office Indoor Lighting
Loadshape C10 - Restaurant Indoor Lighting
Loadshape C11 - Retail Indoor Lighting
Loadshape C12 - Warehouse Indoor Lighting
Loadshape C13 - K-12 School Indoor Lighting
Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights)
Loadshape C15 - Indust. 2-shift (16/5) (e.g., comp. air, lights)
Loadshape C16 - Indust. 3-shift (24/5) (e.g., comp. air, lights)
Loadshape C17 - Indust. 4-shift (24/7) (e.g., comp. air, lights)
Loadshape C18 - Industrial Indoor Lighting
Loadshape C19 - Industrial Outdoor Lighting
Loadshape C20 - Commercial Outdoor Lighting

**COINCIDENCE FACTOR**

The summer peak coincidence factor for this measure is dependent on the building type.

## Algorithm

**CALCULATION OF SAVINGS**

**ENERGY SAVINGS**

$$\Delta kWh = (WSF_{base} - WSF_{effic})/1000 * SF * Hours * WHF_e$$

Where:

$WSF_{base}$ = Baseline lighting watts per square foot or linear foot as determined by building or space type. Whole building analysis values are presented in the Reference Tables below.[753]

$WSF_{effic}$ = The actual installed lighting watts per square foot or linear foot.

SF = Provided by customer based on square footage of the building area applicable to the lighting design for new building.

Hours = Annual site-specific hours of operation of the lighting equipment collected from the customer. If not available, use building area type as provided in the Reference Table in Section 4.5, Fixture annual operating hours.

$WHF_e$ = Waste Heat Factor for Energy to account for cooling savings from efficient lighting is as provided in the Reference Table in Section 4.5 by buidling type. If building is not cooled $WHF_e$ is 1.

**HEATING PENALTY**

If electrically heated building:

$$\Delta kWh_{heatpenalty}{}^{754} = (WSF_{base} - WSF_{effic})/1000 * SF * Hours * -IFkWh$$

Where:

IFkWh = Lighting-HVAC Interation Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected

[753] See IECC 2012 and 2015 - Reference Code documentation for additional information.
[754] Negative value because this is an increase in heating consumption due to the efficient lighting.

by the efficent lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$$\Delta kW = (WSF_{base}-WSF_{effic})/1000 * SF * CF * WHF_d$$

Where:

$WHF_d$ = Waste Heat Factor for Demand to account for cooling savings from efficient lighting in cooled buildings is as provided in the Reference Table in Section 4.5 by buidling type. If building is not cooled WHFd is 1.

CF = Summer Peak Coincidence Factor for measure is as provided in the Reference Table in Section 4.5 by buidling type. If the building type is unknown, use the Miscellaneous value of 0.66.

Other factors as defined above

**NATURAL GAS ENERGY SAVINGS**

$$\Delta Therms = (WSF_{base}-WSF_{effic})/1000 * SF * Hours * - IFTherms$$

Where:

IFTherms = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. This value is provided in the Reference Table in Section 4.5 by buidling type.

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**REFERENCE TABLES**

Lighting Power Density Values from IECC 2012 and 2015 for Interior Commercial New Construction and Substantial Renovation Building Area Method:

| Building Area Type [755] | IECC 2012 Lighting Power Density (w/ft$^2$) | IECC 2015 Lighting Power Density (w/ft$^2$) |
|---|---|---|
| Automotive Facility | 0.9 | 0.80 |
| Convention Center | 1.2 | 1.01 |
| Court House | 1.2 | 1.01 |
| Dining: Bar Lounge/Leisure | 1.3 | 1.01 |
| Dining: Cafeteria/Fast Food | 1.4 | 0.9 |
| Dining: Family | 1.6 | 0.95 |
| Dormitory | 1.0 | 0.57 |
| Exercise Center | 1.0 | 0.84 |
| Fire station | 0.8 | 0.67 |
| Gymnasium | 1.1 | 0.94 |

[755] In cases where both a general building area type and a more specific building area type are listed, the more specific building area type shall apply.

| Building Area Type [755] | IECC 2012 Lighting Power Density (w/ft$^2$) | IECC 2015 Lighting Power Density (w/ft$^2$) |
|---|---|---|
| Healthcare – clinic | 1.0 | 0.90 |
| Hospital | 1.2 | 1.05 |
| Hotel | 1.0 | 0.87 |
| Library | 1.3 | 1.19 |
| Manufacturing Facility | 1.3 | 1.17 |
| Motel | 1.0 | 0.87 |
| Motion Picture Theater | 1.2 | 0.76 |
| Multifamily | 0.7 | 0.51 |
| Museum | 1.1 | 1.02 |
| Office | 0.9 | 0.82 |
| Parking Garage | 0.3 | 0.21 |
| Penitentiary | 1.0 | 0.81 |
| Performing Arts Theater | 1.6 | 1.39 |
| Police Station | 1.0 | 0.87 |
| Post Office | 1.1 | 0.87 |
| Religious Building | 1.3 | 1.0 |
| Retail[756] | 1.4 | 1.26 |
| School/University | 1.2 | 0.87 |
| Sports Arena | 1.1 | 0.91 |
| Town Hall | 1.1 | 0.89 |
| Transportation | 1.0 | 0.70 |
| Warehouse | 0.6 | 0.66 |
| Workshop | 1.4 | 1.19 |

[756] Where lighting equipment is specified to be installed to highlight specific merchandise in addition to lighting equipment specified for general lighting and is switched or dimmed on circuits different from the circuits for general lighting, the small of the actual wattage of the lighting equipment installed specifically for merchandise, or additional lighting power as determined below shall be added to the interior lighting power determined in accordance with this line item.

Lighting Power Density Values from IECC 2018 for Interior Commercial New Construction and Substantial Renovation Building Area Method:

TABLE C405.3.2(1)
INTERIOR LIGHTING POWER ALLOWANCES: BUILDING AREA METHOD

| BUILDING AREA TYPE | LPD (w/ft$^2$) |
|---|---|
| Automotive facility | 0.71 |
| Convention center | 0.76 |
| Courthouse | 0.90 |
| Dining: bar lounge/leisure | 0.90 |
| Dining: cafeteria/fast food | 0.79 |
| Dining: family | 0.78 |
| Dormitory[a, b] | 0.61 |
| Exercise center | 0.65 |
| Fire station[a] | 0.53 |
| Gymnasium | 0.68 |
| Health care clinic | 0.82 |
| Hospital[a] | 1.05 |
| Hotel/Motel[a, b] | 0.75 |
| Library | 0.78 |
| Manufacturing facility | 0.90 |
| Motion picture theater | 0.83 |
| Multifamily[c] | 0.68 |
| Museum | 1.06 |
| Office | 0.79 |
| Parking garage | 0.15 |
| Penitentiary | 0.75 |
| Performing arts theater | 1.18 |
| Police station | 0.80 |
| Post office | 0.67 |
| Religious building | 0.94 |
| Retail | 1.06 |
| School/university | 0.81 |
| Sports arena | 0.87 |
| Town hall | 0.80 |
| Transportation | 0.61 |
| Warehouse | 0.48 |
| Workshop | 0.90 |

a. Where sleeping units are excluded from lighting power calculations by application of Section R405.1, neither the area of the sleeping units nor the wattage of lighting in the sleeping units is counted.

b. Where dwelling units are excluded from lighting power calculations by application of Section R405.1, neither the area of the dwelling units nor the wattage of lighting in the dwelling units is counted.

c. Dwelling units are excluded. Neither the area of the dwelling units nor the wattage of lighting in the dwelling units is counted.

Lighting Power Density Values from IECC 2012 for Interior Commercial New Construction and Substantial Renovation Space by Space Method:



**TABLE C405.5.2(2)**
**INTERIOR LIGHTING POWER ALLOWANCES:**
**SPACE-BY-SPACE METHOD**

| COMMON SPACE-BY-SPACE TYPES | LPD (w/ft²) |
|---|---|
| Atrium – First 40 feet in height | 0.03 per ft. ht. |
| Atrium – Above 40 feet in height | 0.02 per ft. ht. |
| Audience/seating area – permanent | |
| For auditorium | 0.9 |
| For performing arts theater | 2.6 |
| For motion picture theater | 1.2 |
| Classroom/lecture/training | 1.30 |
| Conference/meeting/multipurpose | 1.2 |
| Corridor/transition | 0.7 |
| Dining area | |
| Bar/lounge/leisure dining | 1.40 |
| Family dining area | 1.40 |
| Dressing/fitting room performing arts theater | 1.1 |
| Electrical/mechanical | 1.10 |
| Food preparation | 1.20 |
| Laboratory for classrooms | 1.3 |
| Laboratory for medical/industrial/research | 1.8 |
| Lobby | 1.10 |
| Lobby for performing arts theater | 3.3 |
| Lobby for motion picture theater | 1.0 |
| Locker room | 0.80 |
| Lounge recreation | 0.8 |
| Office – enclosed | 1.1 |
| Office – open plan | 1.0 |
| Restroom | 1.0 |
| Sales area | 1.6[a] |
| Stairway | 0.70 |
| Storage | 0.8 |
| Workshop | 1.60 |
| Courthouse/police station/penetentiary | |
| Courtroom | 1.90 |
| Confinement cells | 1.1 |
| Judge chambers | 1.30 |
| Penitentiary audience seating | 0.5 |
| Penitentiary classroom | 1.3 |
| Penitentiary dining | 1.1 |
| **BUILDING SPECIFIC SPACE-BY-SPACE TYPES** | |
| Automotive – service/repair | 0.70 |
| Bank/office – banking activity area | 1.5 |
| Dormitory living quarters | 1.10 |
| Gymnasium/fitness center | |
| Fitness area | 0.9 |
| Gymnasium audience/seating | 0.40 |
| Playing area | 1.40 |

*(continued)*

**TABLE C405.5.2(2)—continued**
**INTERIOR LIGHTING POWER ALLOWANCES:**
**SPACE-BY-SPACE METHOD**

| COMMON SPACE-BY-SPACE TYPES | LPD (w/ft²) |
|---|---|
| Healthcare clinic/hospital | |
| Corridors/transition | 1.00 |
| Exam/treatment | 1.70 |
| Emergency | 2.70 |
| Public and staff lounge | 0.80 |
| Medical supplies | 1.40 |
| Nursery | 0.9 |
| Nurse station | 1.00 |
| Physical therapy | 0.90 |
| Patient room | 0.70 |
| Pharmacy | 1.20 |
| Radiology/imaging | 1.3 |
| Operating room | 2.20 |
| Recovery | 1.2 |
| Lounge/recreation | 0.8 |
| Laundry – washing | 0.60 |
| Hotel | |
| Dining area | 1.30 |
| Guest rooms | 1.10 |
| Hotel lobby | 2.10 |
| Highway lodging dining | 1.20 |
| Highway lodging guest rooms | 1.10 |
| Library | |
| Stacks | 1.70 |
| Card file and cataloguing | 1.10 |
| Reading area | 1.20 |
| Manufacturing | |
| Corridors/transition | 0.40 |
| Detailed manufacturing | 1.3 |
| Equipment room | 1.0 |
| Extra high bay (> 50-foot floor-ceiling height) | 1.1 |
| High bay (25- – 50-foot floor-ceiling height) | 1.20 |
| Low bay (< 25-foot floor-ceiling height) | 1.2 |
| Museum | |
| General exhibition | 1.00 |
| Restoration | 1.70 |
| Parking garage – garage areas | 0.2 |
| Convention center | |
| Exhibit space | 1.50 |
| Audience/seating area | 0.90 |
| Fire stations | |
| Engine room | 0.80 |
| Sleeping quarters | 0.30 |
| Post office | |
| Sorting area | 0.9 |
| Religious building | |
| Fellowship hall | 0.60 |
| Audience seating | 2.40 |
| Worship pulpit/choir | 2.40 |
| Retail | |
| Dressing/fitting area | 0.9 |
| Mall concourse | 1.6 |
| Sales area | 1.6[a] |

*(continued)*

**TABLE C405.5.2(2)—continued**
**INTERIOR LIGHTING POWER ALLOWANCES:**
**SPACE-BY-SPACE METHOD**

| BUILDING SPECIFIC SPACE-BY-SPACE TYPES | LPD (w/ft$^2$) |
|---|---|
| Sports arena | |
| Audience seating | 0.4 |
| Court sports area – Class 4 | 0.7 |
| Court sports area – Class 3 | 1.2 |
| Court sports area – Class 2 | 1.9 |
| Court sports area – Class 1 | 3.0 |
| Ring sports area | 2.7 |
| Transportation | |
| Air/train/bus baggage area | 1.00 |
| Airport concourse | 0.60 |
| Terminal – ticket counter | 1.50 |
| Warehouse | |
| Fine material storage | 1.40 |
| Medium/bulky material | 0.60 |

Lighting Power Density Values from IECC 2015 for Interior Commercial New Construction and Substantial Renovation Space by Space Method:

**TABLE C405.4.2(2)
INTERIOR LIGHTING POWER ALLOWANCES:
SPACE-BY-SPACE METHOD**

| COMMON SPACE TYPES[a] | LPD (watts/sq.ft) |
|---|---|
| Atrium | |
| Less than 40 feet in height | 0.03 per foot in total height |
| Greater than 40 feet in height | 0.40 + 0.02 per foot in total height |
| Audience seating area | |
| In an auditorium | 0.63 |
| In a convention center | 0.82 |
| In a gymnasium | 0.65 |
| In a motion picture theater | 1.14 |
| In a penitentiary | 0.28 |
| In a performing arts theater | 2.43 |
| In a religious building | 1.53 |
| In a sports arena | 0.43 |
| Otherwise | 0.43 |
| Banking activity area | 1.01 |
| Breakroom (See Lounge/Breakroom) | |
| Classroom/lecture hall/training room | |
| In a penitentiary | 1.34 |
| Otherwise | 1.24 |
| Conference/meeting/multipurpose room | 1.23 |
| Copy/print room | 0.72 |
| Corridor | |
| In a facility for the visually impaired (and not used primarily by the staff)[b] | 0.92 |
| In a hospital | 0.79 |
| In a manufacturing facility | 0.41 |
| Otherwise | 0.66 |
| Courtroom | 1.72 |
| Computer room | 1.71 |
| Dining area | |
| In a penitentiary | 0.96 |
| In a facility for the visually impaired (and not used primarily by the staff)[b] | 1.9 |
| In bar/lounge or leisure dining | 1.07 |
| In cafeteria or fast food dining | 0.65 |
| In family dining | 0.89 |
| Otherwise | 0.65 |
| Electrical/mechanical room | 0.95 |
| Emergency vehicle garage | 0.56 |

*(continued)*

**TABLE C405.4.2(2)—continued
INTERIOR LIGHTING POWER ALLOWANCES:
SPACE-BY-SPACE METHOD**

| COMMON SPACE TYPES[a] | LPD (watts/sq.ft) |
|---|---|
| Food preparation area | 1.21 |
| Guest room | 0.47 |
| Laboratory | |
| In or as a classroom | 1.43 |
| Otherwise | 1.81 |
| Laundry/washing area | 0.6 |
| Loading dock, interior | 0.47 |
| Lobby | |
| In a facility for the visually impaired (and not used primarily by the staff)[b] | 1.8 |
| For an elevator | 0.64 |
| In a hotel | 1.06 |
| In a motion picture theater | 0.59 |
| In a performing arts theater | 2.0 |
| Otherwise | 0.9 |
| Locker room | 0.75 |
| Lounge/breakroom | |
| In a healthcare facility | 0.92 |
| Otherwise | 0.73 |
| Office | |
| Enclosed | 1.11 |
| Open plan | 0.98 |
| Parking area, interior | 0.19 |
| Pharmacy area | 1.68 |
| Restroom | |
| In a facility for the visually impaired (and not used primarily by the staff[b] | 1.21 |
| Otherwise | 0.98 |
| Sales area | 1.59 |
| Seating area, general | 0.54 |
| Stairway (See space containing stairway) | |
| Stairwell | 0.69 |
| Storage room | 0.63 |
| Vehicular maintenance area | 0.67 |
| Workshop | 1.59 |
| **BUILDING TYPE SPECIFIC SPACE TYPES[a]** | **LPD (watts/sq.ft)** |
| Facility for the visually impaired[b] | |
| In a chapel (and not used primarily by the staff) | 2.21 |
| In a recreation room (and not used primarily by the staff) | 2.41 |
| Automotive (See Vehicular Maintenance Area above) | |
| Convention Center—exhibit space | 1.45 |
| Dormitory—living quarters | 0.38 |
| Fire Station—sleeping quarters | 0.22 |
| Gymnasium/fitness center | |
| In an exercise area | 0.72 |
| In a playing area | 1.2 |

*(continued)*

**TABLE C405.4.2(2)—continued**
**INTERIOR LIGHTING POWER ALLOWANCES:**
**SPACE-BY-SPACE METHOD**

| BUILDING TYPE SPECIFIC SPACE TYPES[a] | LPD (watts/sq.ft) |
|---|---|
| healthcare facility | |
| In an exam/treatment room | 1.66 |
| In an imaging room | 1.51 |
| In a medical supply room | 0.74 |
| In a nursery | 0.88 |
| In a nurse's station | 0.71 |
| In an operating room | 2.48 |
| In a patient room | 0.62 |
| In a physical therapy room | 0.91 |
| In a recovery room | 1.15 |
| Library | |
| In a reading area | 1.06 |
| In the stacks | 1.71 |
| Manufacturing facility | |
| In a detailed manufacturing area | 1.29 |
| In an equipment room | 0.74 |
| In an extra high bay area (greater than 50′ floor-to-ceiling height) | 1.05 |
| In a high bay area (25-50′ floor-to-ceiling height) | 1.23 |
| In a low bay area (less than 25′ floor-to-ceiling height) | 1.19 |
| Museum | |
| In a general exhibition area | 1.05 |
| In a restoration room | 1.02 |
| Performing arts theater—dressing room | 0.61 |
| Post Office—Sorting Area | 0.94 |
| Religious buildings | |
| In a fellowship hall | 0.64 |
| In a worship/pulpit/choir area | 1.53 |
| Retail facilities | |
| In a dressing/fitting room | 0.71 |
| In a mall concourse | 1.1 |
| Sports arena—playing area | |
| For a Class I facility | 3.68 |
| For a Class II facility | 2.4 |
| For a Class III facility | 1.8 |
| For a Class IV facility | 1.2 |
| Transportation facility | |
| In a baggage/carousel area | 0.53 |
| In an airport concourse | 0.36 |
| At a terminal ticket counter | 0.8 |
| Warehouse—storage area | |
| For medium to bulky, palletized items | 0.58 |
| For smaller, hand-carried items | 0.95 |

a. In cases where both a common space type and a building area specific space type are listed, the building area specific space type shall apply

b. A 'Facility for the Visually Impaired' is a facility that is licensed or will be licensed by local or state authorities for senior long-term care, adult daycare, senior support or people with special visual needs.

Lighting Power Density Values from IECC 2018 for Interior Commercial New Construction and Substantial Renovation Space by Space Method:

TABLE C405.3.2(2)
INTERIOR LIGHTING POWER ALLOWANCES: SPACE-BY-SPACE METHOD

| COMMON SPACE TYPES[a] | LPD (watts/sq.ft) |
|---|---|
| Atrium | |
| Less than 40 feet in height | 0.03 per foot in total height |
| Greater than 40 feet in height | 0.40 + 0.02 per foot in total height |
| Audience seating area | |
| In an auditorium | 0.63 |
| In a convention center | 0.82 |
| In a gymnasium | 0.65 |
| In a motion picture theater | 1.14 |
| In a penitentiary | 0.28 |
| In a performing arts theater | 2.03 |
| In a religious building | 1.53 |
| In a sports arena | 0.43 |
| Otherwise | 0.43 |
| Banking activity area | 0.86 |
| Breakroom (See Lounge/breakroom) | |
| Classroom/lecture hall/training room | |
| In a penitentiary | 1.34 |
| Otherwise | 0.96 |
| Computer room | 1.33 |
| Conference/meeting/multipurpose room | 1.07 |
| Copy/print room | 0.56 |
| Corridor | |
| In a facility for the visually impaired (and not used primarily by the staff)[b] | 0.92 |
| In a hospital | 0.92 |
| In a manufacturing facility | 0.29 |
| Otherwise | 0.66 |
| Courtroom | 1.39 |
| Dining area | |
| In bar/lounge or leisure dining | 0.93 |
| In cafeteria or fast food dining | 0.63 |
| In a facility for the visually impaired (and not used primarily by the staff)[b] | 2.00 |
| In family dining | 0.71 |
| In a penitentiary | 0.96 |
| Otherwise | 0.63 |
| Electrical/mechanical room | 0.43 |
| Emergency vehicle garage | 0.41 |
| Food preparation area | 1.06 |
| Guestroom[c, d] | 0.77 |
| Laboratory | |
| In or as a classroom | 1.20 |
| Otherwise | 1.45 |

| | |
|---|---|
| Laundry/washing area | 0.43 |
| Loading dock, interior | 0.58 |
| Lobby | |
| For an elevator | 0.68 |
| In a facility for the visually impaired (and not used primarily by the staff)[b] | 2.03 |
| In a hotel | 1.06 |
| In a motion picture theater | 0.45 |
| In a performing arts theater | 1.70 |
| Otherwise | 1.0 |
| Locker room | 0.48 |
| Lounge/breakroom | |
| In a healthcare facility | 0.78 |
| Otherwise | 0.62 |
| Office | |
| Enclosed | 0.93 |
| Open plan | 0.81 |
| Parking area, interior | 0.14 |
| Pharmacy area | 1.34 |
| Restroom | |
| In a facility for the visually impaired (and not used primarily by the staff[b] | 0.96 |
| Otherwise | 0.85 |
| Sales area | 1.22 |
| Seating area, general | 0.42 |
| Stairway (see Space containing stairway) | |
| Stairwell | 0.58 |
| Storage room | 0.46 |
| Vehicular maintenance area | 0.56 |
| Workshop | 1.14 |

| BUILDING TYPE SPECIFIC SPACE TYPES[a] | LPD (watts/sq.ft) |
|---|---|
| Automotive (see Vehicular maintenance area) | |
| Convention Center—exhibit space | 0.88 |
| Dormitory—living quarters[c, d] | 0.54 |
| Facility for the visually impaired[b] | |
| In a chapel (and not used primarily by the staff) | 1.06 |
| In a recreation room (and not used primarily by the staff) | 1.80 |
| Fire Station—sleeping quarters[c] | 0.20 |
| Gymnasium/fitness center | |
| In an exercise area | 0.50 |
| In a playing area | 0.82 |
| Healthcare facility | |
| In an exam/treatment room | 1.68 |
| In an imaging room | 1.06 |
| In a medical supply room | 0.54 |
| In a nursery | 1.00 |
| In a nurse's station | 0.81 |
| In an operating room | 2.17 |
| In a patient room[c] | 0.62 |
| In a physical therapy room | 0.84 |
| In a recovery room | 1.03 |
| Library | |
| In a reading area | 0.82 |
| In the stacks | 1.20 |
| Manufacturing facility | |
| In a detailed manufacturing area | 0.93 |
| In an equipment room | 0.65 |
| In an extra-high-bay area (greater than 50' floor-to-ceiling height) | 1.05 |
| In a high-bay area (25-50' floor-to-ceiling height) | 0.75 |
| In a low-bay area (less than 25' floor-to-ceiling height) | 0.96 |
| Museum | |
| In a general exhibition area | 1.05 |
| In a restoration room | 0.85 |
| Performing arts theater—dressing room | 0.36 |
| Post office—sorting area | 0.68 |
| Religious buildings | |
| In a fellowship hall | 0.55 |
| In a worship/pulpit/choir area | 1.53 |

| | |
|---|---|
| Retail facilities | |
| In a dressing/fitting room | 0.50 |
| In a mall concourse | 0.90 |
| Sports arena—playing area | |
| For a Class I facility[e] | 2.47 |
| For a Class II facility[f] | 1.96 |
| For a Class III facility[g] | 1.70 |
| For a Class IV facility[h] | 1.13 |
| Transportation facility | |
| In a baggage/carousel area | 0.45 |
| In an airport concourse | 0.31 |
| At a terminal ticket counter | 0.62 |
| Warehouse—storage area | |
| For medium to bulky, palletized items | 0.35 |
| For smaller, hand-carried items | 0.69 |

a. In cases where both a common space type and a building area specific space type are listed, the building area specific space type shall apply

b. A 'Facility for the Visually Impaired' is a facility that is licensed or will be licensed by local or state authorities for senior long-term care, adult daycare, senior support or people with special visual needs.

c. Where sleeping units are excluded from lighting power calculations by application of Section R405.1, neither the area of the sleeping units nor the wattage of lighting in the sleeping units is counted.

d. Where dwelling units are excluded from lighting power calculations by application of Section R405.1, neither the area of the dwelling units nor the wattage of lighting in the dwelling units is counted.

e. Class I facilities consist of professional facilities; and semiprofessional, collegiate, or club facilities with seating for 5,000 or more spectators.

f. Class II facilities consist of collegiate and semiprofessional facilities with seating for fewer than 5,000 spectators; club facilities with seating for between 2,000 and 5,000 spectators; and amateur league and high-school facilities with seating for more than 2,000 spectators.

g. Class III facilities consist of club, amateur league and high-school facilities with seating for 2,000 or fewer spectators.

h. Class IV facilities consist of elementary school and recreational facilities; and amateur league and high-school facilities without provision for spectators.

The exterior lighting design will be based on the building location and the applicable "Lighting Zone" as defined in IECC 2015 Table C405.5.2(1) which follows. This table is identical to IECC 2012 Table C405.62(1) and IECC 2018 Table C405.4.2(1).

**TABLE C405.5.2(1)**
**EXTERIOR LIGHTING ZONES**

| LIGHTING ZONE | DESCRIPTION |
|---|---|
| 1 | Developed areas of national parks, state parks, forest land, and rural areas |
| 2 | Areas predominantly consisting of residential zoning, neighborhood business districts, light industrial with limited nighttime use and residential mixed-use areas |
| 3 | All other areas not classified as lighting zone 1, 2 or 4 |
| 4 | High-activity commercial districts in major metropolitan areas as designated by the local land use planning authority |

The lighting power density savings will be based on reductions below the allowable design levels as specified in IECC 2012 Table C405.6.2(2) or IECC 2015 Table C405.5.2(2).

<u>Allowable Design Levels from IECC 2012</u>

**TABLE C405.6.2(2)**
**INDIVIDUAL LIGHTING POWER ALLOWANCES FOR BUILDING EXTERIORS**

| | | LIGHTING ZONES | | | |
|---|---|---|---|---|---|
| | | **Zone 1** | **Zone 2** | **Zone 3** | **Zone 4** |
| Base Site Allowance (Base allowance is usable in tradable or nontradable surfaces.) | | 500 W | 600 W | 750 W | 1300 W |
| Tradable Surfaces (Lighting power densities for uncovered parking areas, building grounds, building entrances and exits, canopies and overhangs and outdoor sales areas are tradable.) | **Uncovered Parking Areas** | | | | |
| | Parking areas and drives | 0.04 W/ft$^2$ | 0.06 W/ft$^2$ | 0.10 W/ft$^2$ | 0.13 W/ft$^2$ |
| | Building Grounds | | | | |
| | Walkways less than 10 feet wide | 0.7 W/linear foot | 0.7 W/linear foot | 0.8 W/linear foot | 1.0 W/linear foot |
| | Walkways 10 feet wide or greater, plaza areas special feature areas | 0.14 W/ft$^2$ | 0.14 W/ft$^2$ | 0.16 W/ft$^2$ | 0.2 W/ft$^2$ |
| | Stairways | 0.75 W/ft$^2$ | 1.0 W/ft$^2$ | 1.0 W/ft$^2$ | 1.0 W/ft$^2$ |
| | Pedestrian tunnels | 0.15 W/ft$^2$ | 0.15 W/ft$^2$ | 0.2 W/ft$^2$ | 0.3 W/ft$^2$ |
| | **Building Entrances and Exits** | | | | |
| | Main entries | 20 W/linear foot of door width | 20 W/linear foot of door width | 30 W/linear foot of door width | 30 W/linear foot of door width |
| | Other doors | 20 W/linear foot of door width | 20 W/linear foot of door width | 20 W/linear foot of door width | 20 W/linear foot of door width |
| | Entry canopies | 0.25 W/ft$^2$ | 0.25 W/ft$^2$ | 0.4 W/ft$^2$ | 0.4 W/ft$^2$ |
| | **Sales Canopies** | | | | |
| | Free-standing and attached | 0.6 W/ft$^2$ | 0.6 W/ft$^2$ | 0.8 W/ft$^2$ | 1.0 W/ft$^2$ |
| | **Outdoor Sales** | | | | |
| | Open areas (including vehicle sales lots) | 0.25 W/ft$^2$ | 0.25 W/ft$^2$ | 0.5 W/ft$^2$ | 0.7 W/ft$^2$ |
| | Street frontage for vehicle sales lots in addition to "open area" allowance | No allowance | 10 W/linear foot | 10 W/linear foot | 30 W/linear foot |
| Nontradable Surfaces (Lighting power density calculations for the following applications can be used only for the specific application and cannot be traded between surfaces or with other exterior lighting. The following allowances are in addition to any allowance otherwise permitted in the "Tradable Surfaces" section of this table.) | Building facades | No allowance | 0.1 W/ft$^2$ for each illuminated wall or surface or 2.5 W/linear foot for each illuminated wall or surface length | 0.15 W/ft$^2$ for each illuminated wall or surface or 3.75 W/linear foot for each illuminated wall or surface length | 0.2 W/ft$^2$ for each illuminated wall or surface or 5.0 W/linear foot for each illuminated wall or surface length |
| | Automated teller machines and night depositories | 270 W per location plus 90 W per additional ATM per location | 270 W per location plus 90 W per additional ATM per location | 270 W per location plus 90 W per additional ATM per location | 270 W per location plus 90 W per additional ATM per location |
| | Entrances and gatehouse inspection stations at guarded facilities | 0.75 W/ft$^2$ of covered and uncovered area | 0.75 W/ft$^2$ of covered and uncovered area | 0.75 W/ft$^2$ of covered and uncovered area | 0.75 W/ft$^2$ of covered and uncovered area |
| | Loading areas for law enforcement, fire, ambulance and other emergency service vehicles | 0.5 W/ft$^2$ of covered and uncovered area | 0.5 W/ft$^2$ of covered and uncovered area | 0.5 W/ft$^2$ of covered and uncovered area | 0.5 W/ft$^2$ of covered and uncovered area |
| | Drive-up windows/doors | 400 W per drive-through | 400 W per drive-through | 400 W per drive-through | 400 W per drive-through |
| | Parking near 24-hour retail entrances | 800 W per main entry | 800 W per main entry | 800 W per main entry | 800 W per main entry |

For SI: 1 foot = 304.8 mm, 1 watt per square foot = W/0.0929 m$^2$.

Allowable Design Levels from IECC 2015

TABLE C405.5.2(2)
INDIVIDUAL LIGHTING POWER ALLOWANCES FOR BUILDING EXTERIORS

| | | LIGHTING ZONES | | | |
|---|---|---|---|---|---|
| | | Zone 1 | Zone 2 | Zone 3 | Zone 4 |
| Base Site Allowance (Base allowance is usable in tradable or nontradable surfaces.) | | 500 W | 600 W | 750 W | 1300 W |
| Tradable Surfaces (Lighting power densities for uncovered parking areas, building grounds, building entrances and exits, canopies and overhangs and outdoor sales areas are tradable.) | Uncovered Parking Areas | | | | |
| | Parking areas and drives | 0.04 W/ft² | 0.06 W/ft² | 0.10 W/ft² | 0.13 W/ft² |
| | Building Grounds | | | | |
| | Walkways less than 10 feet wide | 0.7 W/linear foot | 0.7 W/linear foot | 0.8 W/linear foot | 1.0 W/linear foot |
| | Walkways 10 feet wide or greater, plaza areas special feature areas | 0.14 W/ft² | 0.14 W/ft² | 0.16 W/ft² | 0.2 W/ft² |
| | Stairways | 0.75 W/ft² | 1.0 W/ft² | 1.0 W/ft² | 1.0 W/ft² |
| | Pedestrian tunnels | 0.15 W/ft² | 0.15 W/ft² | 0.2 W/ft² | 0.3 W/ft² |
| | Building Entrances and Exits | | | | |
| | Main entries | 20 W/linear foot of door width | 20 W/linear foot of door width | 30 W/linear foot of door width | 30 W/linear foot of door width |
| | Other doors | 20 W/linear foot of door width | 20 W/linear foot of door width | 20 W/linear foot of door width | 20 W/linear foot of door width |
| | Entry canopies | 0.25 W/ft² | 0.25 W/ft² | 0.4 W/ft² | 0.4 W/ft² |
| | Sales Canopies | | | | |
| | Free-standing and attached | 0.6 W/ft² | 0.6 W/ft² | 0.8 W/ft² | 1.0 W/ft² |
| | Outdoor Sales | | | | |
| | Open areas (including vehicle sales lots) | 0.25 W/ft² | 0.25 W/ft² | 0.5 W/ft² | 0.7 W/ft² |
| | Street frontage for vehicle sales lots in addition to "open area" allowance | No allowance | 10 W/linear foot | 10 W/linear foot | 30 W/linear foot |
| Nontradable Surfaces (Lighting power density calculations for the following applications can be used only for the specific application and cannot be traded between surfaces or with other exterior lighting. The following allowances are in addition to any allowance otherwise permitted in the "Tradable Surfaces" section of this table.) | Building facades | No allowance | 0.075 W/ft² of gross above-grade wall area | 0.113 W/ft² of gross above-grade wall area | 0.15 W/ft² of gross above-grade wall area |
| | Automated teller machines (ATM) and night depositories | 270 W per location plus 90 W per additional ATM per location | 270 W per location plus 90 W per additional ATM per location | 270 W per location plus 90 W per additional ATM per location | 270 W per location plus 90 W per additional ATM per location |
| | Entrances and gatehouse inspection stations at guarded facilities | 0.75 W/ft² of covered and uncovered area | 0.75 W/ft² of covered and uncovered area | 0.75 W/ft² of covered and uncovered area | 0.75 W/ft² of covered and uncovered area |
| | Loading areas for law enforcement, fire, ambulance and other emergency service vehicles | 0.5 W/ft² of covered and uncovered area | 0.5 W/ft² of covered and uncovered area | 0.5 W/ft² of covered and uncovered area | 0.5 W/ft² of covered and uncovered area |
| | Drive-up windows/doors | 400 W per drive-through | 400 W per drive-through | 400 W per drive-through | 400 W per drive-through |
| | Parking near 24-hour retail entrances | 800 W per main entry | 800 W per main entry | 800 W per main entry | 800 W per main entry |

For SI: 1 foot = 304.8 mm, 1 watt per square foot = W/0.0929 m².
W = watts.

Allowable Design Levels from IECC 2018

**TABLE C405.4.2(2)**
**LIGHTING POWER ALLOWANCES FOR BUILDING EXTERIORS**

| | LIGHTING ZONES | | | |
|---|---|---|---|---|
| | Zone 1 | Zone 2 | Zone 3 | Zone 4 |
| Base Site Allowance | 350 W | 400 W | 500 W | 900 W |
| Uncovered Parking Areas | | | | |
| Parking areas and drives | 0.03W/ft² | 0.04 W/ft² | 0.06 W/ft² | 0.08 W/ft² |
| Building Grounds | | | | |
| Walkways and ramps less than 10 feet wide | 0.5 W/linear foot | 0.5 W/linear foot | 0.6 W/linear foot | 0.7 W/linear foot |
| Walkways and ramps 10 feet wide or greater, plaza areas, special feature areas | 0.10 W/ft² | 0.10 W/ft² | 0.11 W/ft² | 0.14 W/ft² |
| Dining areas | 0.65 W/ft² | 0.65 W/ft² | 0.75 W/ft² | 0.95 W/ft² |
| Stairways | 0.6 W/ft² | 0.7 W/ft² | 0.7 W/ft² | 0.7 W/ft² |
| Pedestrian tunnels | 0.12 W/ft² | 0.12 W/ft² | 0.14 W/ft² | 0.21 W/ft² |
| Landscaping | 0.03 W/ft² | 0.04 W/ft² | 0.04 W/ft² | 0.04 W/ft² |
| Building Entrances and Exits | | | | |
| Pedestrian and vehicular entrances and exits | 14 W/linear foot of opening | 14 W/linear foot of opening | 21 W/linear foot of opening | 21 W/linear foot of opening |
| Entry canopies | 0.02 W/ft² | 0.25 W/ft² | 0.4 W/ft² | 0.4 W/ft² |
| Loading docks | 0.35 W/ft² | 0.35 W/ft² | 0.35 W/ft² | 0.35 W/ft² |
| Sales Canopies | | | | |
| Free-standing and attached | 0.04 W/ft² | 0.04 W/ft² | 0.6 W/ft² | 0.7 W/ft² |
| Outdoor Sales | | | | |
| Open areas (including vehicle sales lots) | 0.02 W/ft² | 0.02 W/ft² | 0.35 W/ft² | 0.05 W/ft² |
| Street frontage for vehicle sales lots in addition to "open area" allowance | No allowance | 7 W/linear foot | 7 W/linear foot | 21 W/linear foot |

For SI: 1 foot = 304.8 mm, 1 watt per square foot = W/0.0929 m².

W = watts.

**TABLE C405.4.2(3)**
**INDIVIDUAL LIGHTING POWER ALLOWANCES FOR BUILDING EXTERIORS**

| | LIGHTING ZONES | | | |
|---|---|---|---|---|
| | Zone 1 | Zone 2 | Zone 3 | Zone 4 |
| Building facades | No allowance | 0.075 W/ft² of gross above-grade wall area | 0.113 W/ft² of gross above-grade wall area | 0.15 W/ft² of gross above-grade wall area |
| Automated teller machines (ATM) and night depositories | 135 W per location plus 45 W per additional ATM per location | | | |
| Uncovered entrances and gatehouse inspection stations at guarded facilities | 0.5 W/ft² of area | | | |
| Uncovered loading areas for law enforcement, fire, ambulance and other emergency service vehicles | 0.35 W/ft² of area | | | |
| Drive-up windows and doors | 200 W per drive through | | | |
| Parking near 24-hour retail entrances. | 400 W per main entry | | | |

For SI: For SI: 1 watt per square foot = W/0.0929 m².

W = watts.

**MEASURE CODE: CI-LTG-LPDE-V04-190101**

**REVIEW DEADLINE: 1/1/2020**

## 4.5.8 Miscellaneous Commercial/Industrial Lighting

### DESCRIPTION

This measure is designed to calculate savings from energy efficient lighting upgrades that are not captured in other measures within the TRM. If a lighting project fits the measure description in sections 4.5.1-4.5.4, then those criteria, definitions, and calculations should be used.

Unlike other lighting measures this one applies only to RF applications (because there is no defined baseline for TOS or NC applications).

### DEFINITION OF EFFICIENT EQUIPMENT

A lighting fixture that replaces an existing fixture to provide the same or greater lumen output at a lower kW consumption.

### DEFINITION OF BASELINE EQUIPMENT

The definition of baseline equipment is the existing lighting fixture.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The lifetime of the efficient equipment fixture is the rated fixture life divided by hours of use. If unknown the default lifetime, regardless of program type is 12 years[757].

### DEEMED MEASURE COST

The actual cost of the efficient light fixture should be used.

### LOADSHAPE

Loadshape C06 - Commercial Indoor Lighting
Loadshape C07 - Grocery/Conv. Store Indoor Lighting
Loadshape C08 - Hospital Indoor Lighting
Loadshape C09 - Office Indoor Lighting
Loadshape C10 - Restaurant Indoor Lighting
Loadshape C11 - Retail Indoor Lighting
Loadshape C12 - Warehouse Indoor Lighting
Loadshape C13 - K-12 School Indoor Lighting
Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights)
Loadshape C15 - Indust. 2-shift (16/5) (e.g., comp. air, lights)
Loadshape C16 - Indust. 3-shift (24/5) (e.g., comp. air, lights)
Loadshape C17 - Indust. 4-shift (24/7) (e.g., comp. air, lights)
Loadshape C18 - Industrial Indoor Lighting
Loadshape C19 - Industrial Outdoor Lighting
Loadshape C20 - Commercial Outdoor Lighting

[757] 12 years is based on average of mostly CEE lamp products (9 years), T5 lamps (10.7 years) and GDS Measure Life Report, June 2007, (15 years), as recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.

### COINCIDENCE FACTOR

The summer peak coincidence factor for this measure is dependent on the location type. Values are provided for each building type in section 4.5.

## Algorithm

### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

$$\Delta kWh = ((Watts_{base} - Watts_{EE})/1000) * Hours * WHF_e * ISR$$

Where:

$Watts_{base}$ = Input wattage of the existing system which depends on the baseline fixture configuration (number and type of lamp) and ballast factor (if applicable) and number of fixtures.

=Actual

$Watts_{EE}$ = New Input wattage of EE fixture which depends on new fixture configuration (number of lamps) and ballast factor (if applicable) (if applicable) and number of fixtures.

= Actual

Hours = Average hours of use per year as provided by the customer or selected from the Reference Table in Section 4.5, Fixture annual operating hours, by building type. If hours or building type are unknown, use the Miscellaneous value.

$WHF_e$ = Waste heat factor for energy to account for cooling energy savings from efficient lighting is selected from the Reference Table in Section 4.5 for each building type. If building is un-cooled, the value is 1.0.

ISR = In Service Rate or the percentage of units rebated that get installed.

=100%[758] if application form completed with sign off that equipment is not placed into storage. If sign off form not completed assume the following 3 year ISR assumptions:

| Weigted Average 1st year In Service Rate (ISR) | 2nd year Installations | 3rd year Installations | Final Lifetime In Service Rate |
|---|---|---|---|
| 75.5%759 | 12.1% | 10.3% | 98.0%760 |

### HEATING PENALTY

If electrically heated building:

$$\Delta kWh_{heatpenalty}{}^{761} = (((WattsBase - WattsEE)/1000) * ISR * Hours * -IFkWh$$

[758] Illinois evaluation of PY1 through PY3 has not found that fixtures or lamps placed into storage to be a significant enough issue to warrant including an "In-Service Rate" when commercial customers complete an application form.

[759] 1st year in service rate is based upon review of PY4-5 evaluations from ComEd's commercial lighting program (BILD) (see 'IL Commercial Lighting ISR.xls' for more information. The average first year ISR was calculated weighted by the number of bulbs sold.

[760] The 98% Lifetime ISR assumption is based upon review of two evaluations:
'Nexus Market Research, RLW Analytics and GDS Associates study; "New England Residential Lighting Markdown Impact Evaluation, January 20, 2009' and 'KEMA Inc, Feb 2010, Final Evaluation Report:, Upstream Lighting Program, Volume 1.' This implies that only 2% of bulbs purchased are never installed. The second and third year installations are based upon Ameren analysis of the Californian KEMA study showing that 54% of future installs occur in year 2 and 46% in year 3. The 2nd and 3rd year installations should be counted as part of those future program year savings.

[761] Negative value because this is an increase in heating consumption due to the efficient lighting.

Where:

IFkWh = Lighting-HVAC Interation Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficent lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

**DEFERRED INSTALLS**

As presented above, if a sign off form is not completed the characterization assumes that a percentage of bulbs purchased are not installed until Year 2 and Year 3 (see ISR assumption above). The Illinois Technical Advisory Committee has determined the following methodology for calculating the savings of these future installs.

Year 1 (Purchase Year) installs: Characterized using assumptions provided above or evaluated assumptions if available.

Year 2 and 3 installs: Characterized using delta watts assumption and hours of use from the Install Year i.e. the actual deemed (or evaluated if available) assumptions active in Year 2 and 3 should be applied.

The NTG factor for the Purchase Year should be applied.

**SUMMER COINCIDENT DEMAND SAVINGS**

$$\Delta kW = ((Watts_{base} - Watts_{EE})/1000) * WHF_d * CF * ISR$$

Where:

WHFd = Waste Heat Factor for Demand to account for cooling savings from efficient lighting in cooled buildings is selected from the Reference Table in Section 4.5 for each building type. If the building is not cooled WHFd is 1.

CF = Summer Peak Coincidence Factor for measure is selected from the Reference able in Section 4.5 for each building type. If the building type is unknown, use the Miscellaneous value of 0.66.

Other factors as defined above

**NATURAL GAS ENERGY SAVINGS**

ΔTherms[762] = (((WattsBase-WattsEE)/1000) * ISR * Hours * - IFTherms

Where:

IFTherms = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. This value is selected from the Reference Table in Section 6.5 for each building type.

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

If there are differences between the maintenance of the efficient and baseline lighting system then they should be evaluated on a project-by-project basis.

[762] Negative value because this is an increase in heating consumption due to the efficient lighting.

**MEASURE CODE: CI-LTG-MSCI-V03-190101**

**REVIEW DEADLINE: 1/1/2021**

## 4.5.9 Multi-Level Lighting Switch

**DESCRIPTION**

This measure relates to the installation new multi-level lighting switches on an existing lighting system.

This measure can only relate to the adding of a new control in an existing building, since multi-level switching is required in the Commercial new construction building energy code (IECC 2012/2015/2018).

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

In order for this characterization to apply, the efficient system is assumed to be a lighting system controlled by multi-level lighting controls.

**DEFINITION OF BASELINE EQUIPMENT**

The baseline equipment is assumed to be an uncontrolled lighting system where all lights in a given area are on the same circuit or all circuits come on at the same time.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected measure life for all lighting controls is assumed to be 8 years[763].

**DEEMED MEASURE COST**

When available, the actual cost of the measure shall be used. When not available, the incremental capital cost for this measure is assumed to be $274[764].

**LOADSHAPE**

Loadshape C06 - Commercial Indoor Lighting
Loadshape C07 - Grocery/Conv. Store Indoor Lighting
Loadshape C08 - Hospital Indoor Lighting
Loadshape C09 - Office Indoor Lighting
Loadshape C10 - Restaurant Indoor Lighting
Loadshape C11 - Retail Indoor Lighting
Loadshape C12 - Warehouse Indoor Lighting
Loadshape C13 - K-12 School Indoor Lighting
Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights)
Loadshape C15 - Indust. 2-shift (16/5) (e.g., comp. air, lights)
Loadshape C16 - Indust. 3-shift (24/5) (e.g., comp. air, lights)
Loadshape C17 - Indust. 4-shift (24/7) (e.g., comp. air, lights)
Loadshape C18 - Industrial Indoor Lighting
Loadshape C19 - Industrial Outdoor Lighting
Loadshape C20 - Commercial Outdoor Lighting

---

[763] Consistent with Occupancy Sensor control measure.
[764] Goldberg et al, State of Wisconsin Public Service Commission of Wisconsin, Focus on Energy Evaluation, Business Programs: Incremental Cost Study, KEMA, October 28, 2009.

**COINCIDENCE FACTOR**

The summer peak coincidence factor for this measure is dependent on the location type. Values are provided for each building type in the reference section below.

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

$$\Delta kWh = KW_{Controlled} * Hours * ESF * WHF_e$$

Where:

$KW_{Controlled}$ = Total lighting load connected to the control in kilowatts.

= Actual

Hours = total operating hours of the controlled lighting circuit before the lighting controls are installed. This number should be collected from the customer. Average hours of use per year are provided in the Reference Table in Section 4.5, Fixture annual operating hours, for each building type if customer specific information is not collected. If unknown buidling type, use the Miscellaneous value.

ESF = Energy Savings factor (represents the percentage reduction to the KWcontrolled due to the use of multi-level switching).

= Dependent on building type[765]:

| Building Type | Energy Savings Factor (ESF) |
|---|---|
| Private Office | 21.6% |
| Open Office | 16.0% |
| Retail | 14.8% |
| Classrooms | 8.3% |
| Unknown, average | 15% |

$WHF_e$ = Waste heat factor for energy to account for cooling energy savings from efficient lighting is provided in the Reference Table in Section 4.5 for each building type. If building is un-cooled, the value is 1.0.

**HEATING PENALTY**

If electrically heated building:

$$\Delta kWh_{heatpenalty}{}^{766} = KW_{Controlled} * Hours * ESF * -IFkWh$$

Where:

IFkWh = Lighting-HVAC Interation Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficent lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

[765] Based on results from "Lighting Controls Effectiveness Assessment: Final Report on Bi-Level Lighting Study" published by the California Public Utilities Commission (CPUC), prepared by ADM Associates.

[766]Negative value because this is an increase in heating consumption due to the efficient lighting.

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = KW_{controlled} * ESF * WHF_d * CF$$

Where:

$WHF_d$ = Waste Heat Factor for Demand to account for cooling savings from efficient lighting in cooled buildings is provided in the Reference Table in Section 4.5. If the building is un-cooled WHFd is 1.

CF = Summer Peak Coincidence Factor for measure is provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value of 0.66[767].

### NATURAL GAS ENERGY SAVINGS

$$\Delta therms = KW_{Controlled} * Hours * ESF * - IFTherms$$

Where:

IFTherms = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting and provided in the Reference Table in Section 4.5 by buidling type.

### WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

### DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

### MEASURE CODE: CI-LTG-MLLC-V04-190101

### REVIEW DEADLINE: 1/1/2021

[767] By applying the ESF and the same coincidence factor for general lighting savings we are in essence assuming that the savings from multi-level switching are as likely during peak periods as any other time. In the absence of better information this seems like a reasonable assumption and if anything may be on the conservative side since you might expect the peak periods to be generally sunnier and therefore more likely to have lower light levels. It is also consistent with the control type reducing the wattage lighting load, the same as the general lighting measures.

## 4.5.10 Lighting Controls

### DESCRIPTION

This measure relates to the installation of new occupancy or daylighting sensors on a new or existing lighting system. Lighting control types covered by this measure include wall, ceiling, fixture mounted or integrated controls. Passive infrared, ultrasonic detectors and fixture-mounted sensors or sensors with a combination thereof are eligible. Lighting controls required by state energy codes are not eligible. This must be a new installation and may not replace an existing lighting occupancy sensor control.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the existing system is assumed to be manually controlled or an uncontrolled lighting system which is being controlled by one of the lighting controls systems listed above. This measure is intended for controlling interior lighting only.

A subset of occupancy sensors are those that are programmed as “vacancy” sensors. To qualify as a vacancy sensor, the control must be configured such that manual input is required to turn on the controlled lighting and the control automatically turns the lighting off. Additional savings are achieved compared to standard occupancy sensors because lighting does not automatically turn on and occupants may decide to not turn it on. Note that vacancy sensors are not a viable option for many applications where standard occupancy sensors should be used instead.

### DEFINITION OF BASELINE EQUIPMENT

The baseline is assumed to be a lighting system uncontrolled by occupancy.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for all lighting controls is assumed to be 8 years[768].

### DEEMED MEASURE COST

When available, the actual cost of the measure shall be used. When not available, the following default values are provided:

| Lighting Control Type | Incremental Cost769 |
|---|---|
| Wall Switch Occupancy Sensor | $55.00 |
| Fixture-Mounted Occupancy Sensor | $67.00 |
| Remote or Wall-Mounted Occupancy Sensor | $125.00 |
| Fixture-Mounted Daylight Sensor | $ 50.00 |
| Remote or Wall-Mounted Daylight Sensor | $65.00 |
| Integrated Occupancy for LED Interior Fixtures < 10,000 Lumens | $40.00 |
| Integrated Occupancy for LED Interior Fixtures >= 10,000 Lumens | $40.00 |
| Integrated Dual Occupancy & Daylight Sensor for LED Interior Fixtures < 10,000 Lumens | $50.00 |
| Integrated Dual Occupancy & Daylight Sensor for LED Interior Fixtures >= 10,000 Lumens | $50.00 |
| Fixture-Mounted Dual Occupancy & Daylight Sensor for LED Interior Fixtures < 10,000 Lumens | $ 100.00 |

[768] DEER 2008

[769] Based on indicative product cost review as performed for Efficiency Vermont TRM.

| Lighting Control Type | Incremental Cost769 |
|---|---|
| Fixture-Mounted Dual Occupancy & Daylight Sensor for LED Interior Fixtures >= 10,000 Lumens | $ 100.00 |
| Exterior Occupancy Sensor | $82.00 |

### LOADSHAPE

Loadshape C06 - Commercial Indoor Lighting
Loadshape C07 - Grocery/Conv. Store Indoor Lighting
Loadshape C08 - Hospital Indoor Lighting
Loadshape C09 - Office Indoor Lighting
Loadshape C10 - Restaurant Indoor Lighting
Loadshape C11 - Retail Indoor Lighting
Loadshape C12 - Warehouse Indoor Lighting
Loadshape C13 - K-12 School Indoor Lighting
Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights)
Loadshape C15 - Indust. 2-shift (16/5) (e.g., comp. air, lights)
Loadshape C16 - Indust. 3-shift (24/5) (e.g., comp. air, lights)
Loadshape C17 - Indust. 4-shift (24/7) (e.g., comp. air, lights)
Loadshape C18 - Industrial Indoor Lighting
Loadshape C19 - Industrial Outdoor Lighting
Loadshape C20 - Commercial Outdoor Lighting

### COINCIDENCE FACTOR

The summer peak coincidence factor for this measure is dependent on location.

## Algorithm

### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

$$\Delta kWh = KW_{Controlled} * Hours * ESF * WHF_e$$

Where:

$Kw_{Controlled}$ = Total lighting load connected to the control in kilowatts. Savings is per control. The total connected load per control should be collected from the customer or the default values presented below used;

| Lighting Control Type770 | Wattage Unit | Default kW Controlled |
|---|---|---|
| Wall Switch Occupancy Sensor | per control | 0.084 |
| Fixture-Mounted Occupancy Sensor | per fixture | 0.081 |
| Remote or Wall-Mounted Occupancy Sensor | per control | 0.338 |
| Fixture-Mounted Daylight Sensor | per fixture | 0.095 |
| or Wall-Mounted Daylight Sensor | per control | 0.239 |

[770] Estimates of watts controlled are based on Efficency Vermont data as provided in the 2018 TRM. Future evaluation should determine appropriate assumptions based on Illinois program data.

| Lighting Control Type[770] | Wattage Unit | Default kW Controlled |
|---|---|---|
| Integrated Occupancy for LED Interior Fixtures < 10,000 Lumens | per fixture | 0.031 |
| Integrated Occupancy for LED Interior Fixtures >= 10,000 Lumens | per fixture | 0.118 |
| Integrated Dual Occupancy & Daylight Sensor for LED Interior Fixtures < 10,000 Lumens | per control | 0.031 |
| Integrated Dual Occupancy & Daylight Sensor for LED Interior Fixtures >= 10,000 Lumens | per control | 0.118 |
| Fixture-Mounted Dual Occupancy & Daylight Sensor for LED Interior Fixtures < 10,000 Lumens | per control | 0.031 |
| Fixture-Mounted Dual Occupancy & Daylight Sensor for LED Interior Fixtures >= 10,000 Lumens | per control | 0.118 |
| Exterior Occupancy Sensor | per fixture | 0.086 |

Hours = total operating hours of the controlled lighting circuit before the lighting controls are installed. This number should be collected from the customer. Average hours of use per year are provided in the Reference Table in Section 4.5, Fixture annual operating hours, for each building type if customer specific information is not collected. If unknown buidling type, use the Miscellaneous value.

ESF = Energy Savings factor (represents the percentage reduction to the operating Hours from the non-controlled baseline lighting system).

| Lighting Control Type | Energy Savings Factor[771] |
|---|---|
| Wall Switch Occupancy Sensor | 24% |
| Fixture-Mounted Occupancy Sensor | 24% |
| Remote or Wall-Mounted Occupancy Sensor | 24% |
| Fixture-Mounted Daylight Sensor | 28% |
| Remote or Wall-Mounted Daylight Sensor | 28% |
| Integrated Occupancy for LED Interior Fixtures < 10,000 Lumens | 24% |
| Integrated Occupancy for LED Interior Fixtures >= 10,000 Lumens | 24% |
| Integrated Dual Occupancy & Daylight Sensor for LED Interior Fixtures < 10,000 Lumens | 38% |
| Integrated Dual Occupancy & Daylight Sensor for LED Interior Fixtures >= 10,000 Lumens | 38% |
| Fixture-Mounted Dual Occupancy & Daylight Sensor for LED Interior Fixtures < 10,000 Lumens | 38% |
| Fixture-Mounted Dual Occupancy & Daylight Sensor for LED Interior Fixtures >= 10,000 Lumens | 38% |
| Exterior Occupancy Sensor | 41% |

$WHF_e$ = Waste heat factor for energy to account for cooling energy savings from efficient lighting is provided in the Reference Table in Section 4.5 for each building type. If building is un-cooled, the value is 1.0.

[771] Interior controls % savings based on LBNL, Williams et al, "Lighting Controls in Commercial Buildings", 2012, p172. Case occupancy sensors are based on case studies of controls installed in Wal-Mart and Krogers refrigerator/freezer LED case lighting controls and exterior sensors are based upon data from "Application Assessment of Bi-Level LED Parking Lot Lighting" p6.

**HEATING PENALTY**

If electrically heated building:

$$\Delta kWh_{heatpenalty}{}^{772} = KW_{Controlled} * Hours * ESF * -IFkWh$$

Where:

IFkWh = Lighting-HVAC Interation Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficent lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$$\Delta kW = KW_{controlled} * WHF_d * (CFbaseline - CFos)$$

Where:

$WHF_d$ = Waste Heat Factor for Demand to account for cooling savings from efficient lighting in cooled buildings is provided in the Reference Table in Section 4.5. If the building is un-cooled WHFd is 1.

CFbaseline = Baseline Summer Peak Coincidence Factor for the lighting system without Occupancy Sensors installed selected from the Reference Table in Section 4.5 for each building type. If the building type is unknown, use the Miscellaneous value of 0.66

CFos = Retrofit Summer Peak Coincidence Factor the lighting system with Occupancy Sensors installed is 0.15 regardless of building type.[773]

**NATURAL GAS ENERGY SAVINGS**

$$\Delta therms = KW_{Controlled} * Hours * ESF * - IFTherms$$

Where:

IFTherms = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting and provided in the Reference Table in Section 4.5 by buidling type.

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-LTG-OSLC-V05-190101**

**REVIEW DEADLINE: 1/1/2021**

[772] Negative value because this is an increase in heating consumption due to the efficient lighting.
[773] Coincidence Factor Study Residential and Commercial Industrial Lighting Measures, RLW Analytics, Spring 2007. Note, the connected load used in the calculation of the CF for occupancy sensor lights includes the average ESF.

## 4.5.11 Solar Light Tubes

### Description

A tubular skylight which is 10" to 21" in diameter with a prismatic or translucent lens is installed on the roof of a commercial facility. The lens reflects light captured from the roof opening through a highly specular reflective tube down to the mounted fixture height. When in use, a light tube fixture resembles a metal halide fixture. Uses include grocery, school, retail and other single story commercial buildings.

In order that the savings characterized below apply, the electric illumination in the space must be automatically controlled to turn off or down when the tube is providing enough light.

This measure was developed to be applicable to the following program types: TOS, NC, RF.

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

The efficient equipment is assumed to be a tubular skylight that concentrates and directs light from the roof to an area inside the facility.

### Definition of Baseline Equipment

The baseline equipment for this measure is a fixture with comparable luminosity. The specifications for the baseline lamp depend on the size of the Light Tube being installed.

### Deemed Lifetime of Efficient Equipment

The estimated useful life for a light tube commercial skylight is 10 years[774].

### Deemed Measure Cost

If available, the actual incremental cost should be used. For analysis purposes, assume an incremental cost for a light tube commercial skylight is $500[2].

### Loadshape

Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights)[775]

### Coincidence Factor

The summer peak coincidence factor for this measure is dependent on location.

**Algorithm**

### Calculation of Savings

### Electric Energy Savings

$$\Delta kWh = kW_f * HOURS * WHFe$$

Where:

$kW_f$ = Connected load of the fixture the solar tube replaces

[774] Equal to the manufacturers standard warranty

[775] The savings from solar light tubes are only realized during the sunlight hours. It is therefore appropriate to apply the single shift (8/5) loadshape to this measure.

| Size of Tube | Average Lumen output for Chicago Illinois (minimum)[776] | Equivalent fixture | kW |
|---|---|---|---|
| 21” | 9,775 (4,179) | 50% 3 x 2 32W lamp CFL (207W, 9915 lumens)<br>50% 4 lamp F32 w/Elec 4’ T8 (114W, 8895 lumens) | 0.161 |
| 14” | 4,392 (1,887) | 50% 2 42W lamp CFL (94W, 4406 lumens)<br>50% 2 lamp F32 w/Elec 4’ T8 (59W, 4448 lumens) | 0.077 |
| 10” | 2,157 (911) | 50% 1 42W lamp CFL (46W, 2203 lumens)<br>50% 1 lamp F32 w/Elec 4’ T8 (32W, 2224 lumens) | 0.039 |
| | | **AVERAGE** | **0.092** |

HOURS = Equivalent full load hours

= 2400 [777]

$WHF_e$ = Waste heat factor for energy to account for cooling energy savings from efficient lighting is selected from the Reference Table in Section 4.5 for each building type. If building is un-cooled, the value is 1.0.

**HEATING PENALTY**

If electrically heated building:

$$\Delta kWh_{heatpenalty}{}^{778} = kW_f * HOURS * -IFkWh$$

Where:

IFkWh = Lighting-HVAC Interation Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficent lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$$\Delta kW = \Delta kW_f * WHFd * CF$$

Where:

WHFd = Waste Heat Factor for Demand to account for cooling savings from efficient lighting in cooled buildings is selected from the Reference Table in Section 4.5 for each building type. If the building is not cooled WHFd is 1.

CF = Summer Peak Coincidence Factor for measure is selected from the Reference Table in Section 4.5 for each building type. If the building type is unknown, use the Miscellaneous value of 0.66.

**NATURAL GAS SAVINGS**

$$\Delta Therms^{779} = \Delta kW_f * HOURS * - IFTherms$$

Where:

[776] Solatube Test Report (2005). http://www.mainegreenbuilding.com/files/file/solatube/stb_lumens_datasheet.pdf
[777] Ibid. The lumen values presented in the kW table represent the average of the lightest 2400 hours.
[778]Negative value because this is an increase in heating consumption due to the efficient lighting.
[779]Negative value because this is an increase in heating consumption due to the efficient lighting.

IFTherms = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Please select from the Reference Table in Section 4.5 for each building type.

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-LTG-STUB-V02-140601**

**REVIEW DEADLINE: 1/1/2020**

## 4.5.12 T5 Fixtures and Lamps

### DESCRIPTION

T5 Lamp/ballast systems have higher lumens per watt than a standard T8 or an existing T8 or T12 system. The smaller lamp diameter allows for better optical systems, and more precise control of lighting. These characteristics result in light fixtures that produce equal or greater light than standard T8 or T12 fixtures, while using fewer watts.

This measure applies to the installation of new equipment with efficiencies that exceed that of the equipment that would have been installed following standard market practices and is applicable to time of sale as well as retrofit measures.

If the implementation strategy does not allow for the installation location to be known, a deemed split of 99% Commercial and 1% Residential should be used[780].

This measure was developed to be applicable to the following program types: TOS, RF, DI.

If applied to other program types, the measure savings should be verified.

The measure applies to all commercial T5 installations excluding new construction and substantial renovation or change of use measures (see lighting power density measure). Lookup tables have been provided to account for various installations. Actual existing equipment wattages should be compared to new fixture wattages whenever possible while maintaining lumen equivalent designs. Default new and baseline assumptions are provided if existing equipment cannot be determined. Actual costs and hours of use should be utilized when available. Default component costs and lifetimes have been provided for Operating and Maintenance Calculations. Please see the Definition Table to determine applicability for each program. Configurations not included in the TRM may be included in custom program design using the provided algorithms as long as energy savings is achieved. The following table defines the applicability for different programs:

| Time of Sale (TOS) | Retrofit (RF) and DI |
|---|---|
| This program applies to installations where customer and location of equipment is not known, or at time of burnout of existing equipment. T5 Lamp/ballast systems have higher lumens per watt than a standard T8 system. The smaller lamp diameter allows for better optical systems, and more precise control of lighting. These characteristics result in light fixtures that produce equal or greater light than standard T8 fixtures, while using fewer watts. | For installations that upgrade installations before the end of their useful life. T5 Lamp/ballast systems have higher lumens per watt than a standard T8 or T12 system. The smaller lamp diameter allows for better optical systems, and more precise control of lighting. These characteristics result in light fixtures that produce equal or greater light than standard T8 or T12 fixtures, while using fewer watts and having longer life. |

### DEFINITION OF EFFICIENT EQUIPMENT

The definition of efficient equipment varies based on the program and is defined below:

| Time of Sale (TOS) | Retrofit (RF) and DI |
|---|---|
| 4' fixtures must use a T5 lamp and ballast configuration. 1' and 3' lamps are not eligible. High Performance Troffers must be 85% efficient or greater. T5 HO high bay fixtures must be 3, 4 or 6 lamps and 90% efficient or better. | 4' fixtures must use a T5 lamp and ballast configuration. 1' and 3' lamps are not eligible. High Performance Troffers must be 85% efficient or greater. T5 HO high bay fixtures must be 3, 4 or 6 lamps and 90% efficient or better. |

[780] Based on weighted average of Final ComEd's BILD program data from PY5 and PY6. For Residential installations, hours of use assumptions from '5.5 Interior Hardwired Compact Fluorescent Lamp (CFL) Fixture' measure should be used.

**DEFINITION OF BASELINE EQUIPMENT**

The definition of baseline equipment varies based on the program and is defined below:

| Time of Sale (TOS) | Retrofit (RF) and DI |
|---|---|
| The baseline is T8 with equivalent lumen output. In high-bay applications, the baseline is pulse start metal halide systems. | The baseline is the existing system.<br>In July 14, 2012, Federal Standards were enacted that were expected to eliminate T-12s as an option for linear fluorescent fixtures. Through v3.0 of the TRM, it was assumed that the T-12 would no longer be baseline for retrofits from 1/1/2016. However, due to significant loopholes in the legislation, T-12 compliant product is still freely available and in Illinois T-12s continue to hold a significant share of the existing and replacement lamp market. Therefore the timing of the sunsetting of T-12s as a viable baseline has been pushed back in v7.0 until 1/1/2020 and will be revisited in future update sessions.<br>There will be a baseline shift applied to all measures installed before 2020 in years remaining in the measure life. See table C-1. |

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The lifetime of the efficient equipment fixture should be the rated life of the fixture divided by hours of use. If unknown default is, regardless of program type is 12 years[781].

**LOADSHAPE**

Loadshape C06 - Commercial Indoor Lighting

Loadshape C07 - Grocery/Conv. Store Indoor Lighting

Loadshape C08 - Hospital Indoor Lighting

Loadshape C09 - Office Indoor Lighting

Loadshape C10 - Restaurant Indoor Lighting

Loadshape C11 - Retail Indoor Lighting

Loadshape C12 - Warehouse Indoor Lighting

Loadshape C13 - K-12 School Indoor Lighting

Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights)

Loadshape C15 - Indust. 2-shift (16/5) (e.g., comp. air, lights)

Loadshape C16 - Indust. 3-shift (24/5) (e.g., comp. air, lights)

Loadshape C17 - Indust. 4-shift (24/7) (e.g., comp. air, lights)

Loadshape C18 - Industrial Indoor Lighting

Loadshape C19 - Industrial Outdoor Lighting

Loadshape C20 - Commercial Outdoor Lighting

[781] 12 years is based on average of mostly CEE lamp products (9 years), T5 lamps (10.7 years) and GDS Measure Life Report, June 2007, (15 years), as recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.

## Algorithm

### Calculation of Savings

### Electric Energy Savings

$$\Delta kWh = ((Watts_{base} - Watts_{EE})/1000) * Hours * WHF_e * ISR$$

Where:

$Watts_{base}$ = Input wattage of the existing system which depends on the baseline fixture configuration (number and type of lamp) and number of fixtures. Value can be selected from the appropriate reference table as shown below, of a custom value can be entered if the configurations in the tables is not representative of the exisitng system.

$Watts_{EE}$ = New Input wattage of EE fixture which depends on new fixture configuration (number of lamps) and ballast factor and number of fixtures. Value can be selected from the appropriate reference table as shown below, of a custom value can be entered if the configurations in the tables is not representative of the exisitng system.

| Program | Reference Table |
|---|---|
| Time of Sale | A-1: T5 New and Baseline Assumptions |
| Retrofit, DI | A-2: T5 New and Baseline Assumptions |

Hours = Average hours of use per year as provided by the customer or selected from the Reference Table in Section 4.5, Fixture annual operating hours, by building type. If hours or building type are unknown, use the Miscellaneous value.

$WHF_e$ = Waste heat factor for energy to account for cooling energy savings from efficient lighting is selected from the Reference Table in Section 4.5 for each building type. If building is un-cooled, the value is 1.0.

ISR = In Service Rate or the percentage of units rebated that get installed.

=100%[782] if application form completed with sign off that equipment is not placed into storage. If sign off form not completed assume the following 3 year ISR assumptions:

| Weigted Average 1st year In Service Rate (ISR) | 2nd year Installations | 3rd year Installations | Final Lifetime In Service Rate |
|---|---|---|---|
| 98%[783] | 0% | 0% | 98.0%[784] |

### Heating Penalty

If electrically heated building:

[782]Illinois evaluation of PY1 through PY3 has not found that fixtures or lamps placed into storage to be a significant enough issue to warrant including an "In-Service Rate" when commercial customers complete an application form.

[783] 1st year in service rate is based upon review of PY5-6 evaluations from ComEd's commercial lighting program (BILD) (see 'IL Commercial Lighting ISR_2014.xls' for more information

[784] The 98% Lifetime ISR assumption is based upon review of two evaluations:
'Nexus Market Research, RLW Analytics and GDS Associates study; "New England Residential Lighting Markdown Impact Evaluation, January 20, 2009' and 'KEMA Inc, Feb 2010, Final Evaluation Report: Upstream Lighting Program, Volume 1.' This implies that only 2% of bulbs purchased are never installed. The second and third year installations are based upon Ameren analysis of the Californian KEMA study showing that 54% of future installs occur in year 2 and 46% in year 3. The 2nd and 3rd year installations should be counted as part of those future program year savings.

$\Delta kWh_{heatpenalty}$[785] = (((WattsBase-WattsEE)/1000) * ISR * Hours * -IFkWh

Where:

IFkWh = Lighting-HVAC Interation Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficent lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

### SUMMER COINCIDENT DEMAND SAVINGS

$\Delta kW = ((Watts_{base}-Watts_{EE})/1000) * WHF_d*CF*ISR$

Where:

WHFd = Waste Heat Factor for Demand to account for cooling savings from efficient lighting in cooled buildings is selected from the Reference Table in Section 4.5 for each building type. If the building is not cooled WHFd is 1.

CF = Summer Peak Coincidence Factor for measure is selected from the Reference Table in Section 4.5 for each building type. If the building type is unknown, use the Miscellaneous value.

### NATURAL GAS ENERGY SAVINGS

$\Delta Therms$[786] = (((WattsBase-WattsEE)/1000) * ISR * Hours *- IFTherms

Where:

IFTherms = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. This value is selected from the Reference Table in Section 4.5 for each building type.

### WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

### DEEMED O&M COST ADJUSTMENT CALCULATION

See Reference tables for Operating and Maintenance Values

| Program | Reference Table |
|---|---|
| Time of Sale | B-1: T5 Component Costs and Lifetime |
| Retrofit, DI | B-2: T5 Component Costs and Lifetime |

### REFERENCE TABLES

See following page.

785Negative value because this is an increase in heating consumption due to the efficient lighting.
786Negative value because this is an increase in heating consumption due to the efficient lighting.

A-1: Time of Sale: T5 New and Baseline Assumptions[787]

| EE Measure Description | EE Cost | $Watts_{EE}$ | Baseline Description | Base Cost | $Watts_{BASE}$ | Measure Cost | $Watts_{SAVE}$ |
|---|---|---|---|---|---|---|---|
| 2-Lamp T5 High-Bay | $200.00 | 180 | 200 Watt Pulse Start Metal-Halide | $100.00 | 232 | $100.00 | 52 |
| 3-Lamp T5 High-Bay | $200.00 | 180 | 200 Watt Pulse Start Metal-Halide | $100.00 | 232 | $100.00 | 52 |
| 4-Lamp T5 High-Bay | $225.00 | 240 | 320 Watt Pulse Start Metal-Halide | $125.00 | 350 | $100.00 | 110 |
| 6-Lamp T5 High-Bay | $250.00 | 360 | Proportionally Adjusted according to 6-Lamp HPT8 Equivalent to 320 PSMH | $150.00 | 476 | $100.00 | 116 |
| | | | | | | | |
| 1-Lamp T5 Troffer/Wrap | $100.00 | 32 | Proportionally adjusted according to 2-Lamp T5 Equivalent to 3-Lamp T8 | $60.00 | 44 | $40.00 | 12 |
| 2-Lamp T5 Troffer/Wrap | $100.00 | 64 | 3-Lamp F32T8 Equivalent w/ Elec. Ballast | $60.00 | 88 | $40.00 | 24 |
| | | | | | | | |
| 1-Lamp T5 Industrial/Strip | $70.00 | 32 | Proportionally adjusted according to 2-Lamp T5 Equivalent to 3-Lamp T8 | $40.00 | 44 | $30.00 | 12 |
| 2-Lamp T5 Industrial/Strip | $70.00 | 64 | 3-Lamp F32T8 Equivalent w/ Elec. Ballast | $40.00 | 88 | $30.00 | 24 |
| 3-Lamp T5 Industrial/Strip | $70.00 | 96 | Proportionally adjusted according to 2-Lamp T5 Equivalent to 3-Lamp T8 | $40.00 | 132 | $30.00 | 36 |
| 4-Lamp T5 Industrial/Strip | $70.00 | 128 | Proportionally adjusted according to 2-Lamp T5 Equivalent to 3-Lamp T8 | $40.00 | 178 | $30.00 | 50 |
| | | | | | | | |
| 1-Lamp T5 Indirect | $175.00 | 32 | Proportionally adjusted according to 2-Lamp T5 Equivalent to 3-Lamp T8 | $145.00 | 44 | $30.00 | 12 |
| 2-Lamp T5 Indirect | $175.00 | 64 | 3-Lamp F32T8 Equivalent w/ Elec. Ballast | $145.00 | 88 | $30.00 | 24 |

[787] Adapted from Efficiency Vermont Technical Reference User Manual (TRM) Measure Savings Algorithms and Cost Assumptions, October 26, 2011.

A-2: Retrofit T5 New and Baseline Assumptions[788]

| EE Measure Description | EE Cost | $Watts_{EE}$ |
|---|---|---|
| 3-Lamp T5 High-Bay | $200.00 | 180 |
| 4-Lamp T5 High-Bay | $225.00 | 234 |
| 6-Lamp T5 High-Bay | $250.00 | 358 |
| | | |
| 1-Lamp T5 Troffer/Wrap | $100.00 | 32 |
| 2-Lamp T5 Troffer/Wrap | $100.00 | 64 |
| | | |
| 1-Lamp T5 Industrial/Strip | $70.00 | 32 |
| 2-Lamp T5 Industrial/Strip | $70.00 | 64 |
| 3-Lamp T5 Industrial/Strip | $70.00 | 96 |
| 4-Lamp T5 Industrial/Strip | $70.00 | 128 |
| | | |
| 1-Lamp T5 Indirect | $175.00 | 32 |
| 2-Lamp T5 Indirect | $175.00 | 64 |

| Baseline Description | $Watts_{BASE}$ |
|---|---|
| 200 Watt Pulse Start Metal-Halide | 232 |
| 250 Watt Metal-Halide | 295 |
| 320 Watt Pulse Start Metal-Halide | 350 |
| 400 Watt Metal-Halide | 455 |
| 400 Watt Pulse Start Metal-Halide | 476 |
| | |
| 1-Lamp F34T12 w/ EEMag Ballast | 40 |
| 2-Lamp F34T12 w/ EEMag Ballast | 68 |
| 3-Lamp F34T12 w/ EEMag Ballast | 110 |
| 4-Lamp F34T12 w/ EEMag Ballast | 139 |
| | |
| 1-Lamp F40T12 w/ EEMag Ballast | 48 |
| 2-Lamp F40T12 w/ EEMag Ballast | 82 |
| 3-Lamp F40T12 w/ EEMag Ballast | 122 |
| 4-Lamp F40T12 w/ EEMag Ballast | 164 |
| | |
| 1-Lamp F40T12 w/ Mag Ballast | 57 |
| 2-Lamp F40T12 w/ Mag Ballast | 94 |
| 3-Lamp F40T12 w/ Mag Ballast | 147 |
| 4-Lamp F40T12 w/ Mag Ballast | 182 |
| | |
| 1-Lamp F32T8 | 32 |
| 2-Lamp F32T8 | 59 |
| 3-Lamp F32T8 | 88 |
| 4-Lamp F32T8 | 114 |

[788]Ibid.

## B-1: Time of Sale T5 Component Costs and Lifetime[789]

| EE Measure Description | EE Lamp Cost | EE Lamp Life (hrs) | EE Lamp Rep. Labor Cost per lamp | EE Ballast Cost | EE Ballast Life (hrs) | EE Ballast Rep. Labor Cost | Baseline Description | # Base Lamps | Base Lamp Cost | Base Lamp Life (hrs) | Base Lamp Rep. Labor Cost | # Base Ballasts | Base Ballast Cost | Base Ballast Life (hrs) | Base Ballast Rep. Labor Cost |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3-Lamp T5 High-Bay | $12.00 | 20000 | $6.67 | $52.00 | 70000 | $22.50 | 200 Watt Pulse Start Metal-Halide | 1.00 | $21.00 | 10000 | $6.67 | 1.00 | $87.75 | 40000 | $22.50 |
| 4-Lamp T5 High-Bay | $12.00 | 20000 | $6.67 | $52.00 | 70000 | $22.50 | 320 Watt Pulse Start Metal-Halide | 1.00 | $21.00 | 20000 | $6.67 | 1.00 | $109.35 | 40000 | $22.50 |
| 6-Lamp T5 High-Bay | $12.00 | 20000 | $6.67 | $52.00 | 70000 | $22.50 | Adjusted according to 6-Lamp HPT8 Equivalent to 320 | 1.36 | $21.00 | 20000 | $6.67 | 1.50 | $109.35 | 40000 | $22.50 |
| | | | | | | | | | | | | | | | |
| 1-Lamp T5 Troffer/Wrap | $12.00 | 20000 | $2.67 | $52.00 | 70000 | $15.00 | Proportionally adjusted according to 2-Lamp T5 Equivalent to 3-Lamp T8 | 1.50 | $2.50 | 20000 | $2.67 | 0.50 | $15.00 | 70000 | $15.00 |
| 2-Lamp T5 Troffer/Wrap | $12.00 | 20000 | $2.67 | $52.00 | 70000 | $15.00 | 3-Lamp F32T8 Equivalent w/ Elec. Ballast | 3.00 | $2.50 | 20000 | $2.67 | 1.00 | $15.00 | 70000 | $15.00 |
| | | | | | | | | | | | | | | | |
| 1-Lamp T5 Industrial/Strip | $12.00 | 20000 | $2.67 | $52.00 | 70000 | $15.00 | Proportionally adjusted according to 2-Lamp T5 Equivalent to 3-Lamp T8 | 1.50 | $2.50 | 20000 | $2.67 | 0.50 | $15.00 | 70000 | $15.00 |
| 2-Lamp T5 Industrial/Strip | $12.00 | 20000 | $2.67 | $52.00 | 70000 | $15.00 | 3-Lamp F32T8 Equivalent w/ Elec. Ballast | 3.00 | $2.50 | 20000 | $2.67 | 1.00 | $15.00 | 70000 | $15.00 |
| 3-Lamp T5 Industrial/Strip | $12.00 | 20000 | $2.67 | $52.00 | 70000 | $15.00 | Proportionally adjusted according to 2-Lamp T5 Equivalent | 4.50 | $2.50 | 20000 | $2.67 | 1.50 | $15.00 | 70000 | $15.00 |
| 4-Lamp T5 Industrial/Strip | $12.00 | 20000 | $2.67 | $52.00 | 70000 | $15.00 | Proportionally adjusted according to 2-Lamp T5 Equivalent to 3-Lamp T8 | 6.00 | $2.50 | 20000 | $2.67 | 2.00 | $15.00 | 70000 | $15.00 |
| | | | | | | | | | | | | | | | |
| 1-Lamp T5 Indirect | $12.00 | 20000 | $2.67 | $52.00 | 70000 | $15.00 | Proportionally adjusted according to 2-Lamp T5 Equivalent to 3-Lamp T8 | 1.50 | $2.50 | 20000 | $2.67 | 0.50 | $15.00 | 70000 | $15.00 |
| 2-Lamp T5 Indirect | $12.00 | 20000 | $2.67 | $52.00 | 70000 | $15.00 | 3-Lamp F32T8 Equivalent w/ Elec. Ballast | 3.00 | $2.50 | 20000 | $2.67 | 1.00 | $15.00 | 70000 | $15.00 |

789 Adapted from Efficiency Vermont Technical Reference User Manual (TRM) Measure Savings Algorithms and Cost Assumptions, October 26, 2011.

B-2: T5 Retrofit Component Costs and Lifetime[790]

| EE Measure Description | EE Lamp Cost | EE Lamp Life (hrs) | EE Lamp Rep. Labor Cost per lamp | EE Ballast Cost | EE Ballast Life (hrs) | EE Ballast Rep. Labor Cost | Baseline Description | # Base Lamps | Base Lamp Cost | Base Lamp Life (hrs) | Base Lamp Rep. Labor Cost | # Base Ballasts | Base Ballast Cost | Base Ballast Life (hrs) | Base Ballast Rep. Labor Cost |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3-Lamp T5 High-Bay | $12.00 | 20000 | $6.67 | $52.00 | 70000 | $22.50 | 200 Watt Pulse Start Metal-Halide | 1.00 | $21.00 | 10000 | $6.67 | 1.00 | $ 88 | 40000 | $22.50 |
| | | | | | | | 250 Watt Metal Halide | 1.00 | $21.00 | 10000 | $6.67 | 1.00 | $ 92 | 40000 | $22.50 |
| 4-Lamp T5 High-Bay | $12.00 | 20000 | $6.67 | $52.00 | 70000 | $22.50 | 320 Watt Pulse Start Metal-Halide | 1.00 | $72.00 | 20000 | $6.67 | 1.00 | $ 109 | 40000 | $22.50 |
| | | | | | | | 400 Watt Metal Halide | 1.00 | $17.00 | 20000 | $6.67 | 1.00 | $ 114 | 40000 | $22.50 |
| 6-Lamp T5 High-Bay | $12.00 | 20000 | $6.67 | $52.00 | 70000 | $22.50 | Proportionally Adjusted according to 6-Lamp HPT8 Equivalent to 320 PSMH | 1.36 | $72.00 | 20000 | $6.67 | 1.50 | $ 109 | 40000 | $22.50 |
| 1-Lamp T5 Troffer/Wrap | $12.00 | 20000 | $2.67 | $52.00 | 70000 | $15.00 | Proportionally adjusted according to 2-Lamp T5 Equivalent to 3-Lamp T8 | 1.50 | $2.50 | 20000 | $2.67 | 0.50 | $ 15 | 70000 | $15.00 |
| 2-Lamp T5 Troffer/Wrap | $12.00 | 20000 | $2.67 | $52.00 | 70000 | $15.00 | 3-Lamp F32T8 Equivalent w/ Elec. Ballast | 3.00 | $2.50 | 20000 | $2.67 | 1.00 | $ 15 | 70000 | $15.00 |
| 1-Lamp T5 Industrial/Strip | $12.00 | 20000 | $2.67 | $52.00 | 70000 | $15.00 | Proportionally adjusted according to 2-Lamp T5 Equivalent to 3-Lamp T8 | 1.50 | $2.50 | 20000 | $2.67 | 0.50 | $ 15 | 70000 | $15.00 |
| 2-Lamp T5 Industrial/Strip | $12.00 | 20000 | $2.67 | $52.00 | 70000 | $15.00 | 3-Lamp F32T8 Equivalent w/ Elec. Ballast | 3.00 | $2.50 | 20000 | $2.67 | 1.00 | $ 15 | 70000 | $15.00 |
| 3-Lamp T5 Industrial/Strip | $12.00 | 20000 | $2.67 | $52.00 | 70000 | $15.00 | Proportionally adjusted according to 2-Lamp T5 Equivalent to 3-Lamp T8 | 4.50 | $2.50 | 20000 | $2.67 | 1.50 | $ 15 | 70000 | $15.00 |
| 4-Lamp T5 Industrial/Strip | $12.00 | 20000 | $2.67 | $52.00 | 70000 | $15.00 | Proportionally adjusted according to 2-Lamp T5 Equivalent to 3-Lamp T8 | 6.00 | $2.50 | 20000 | $2.67 | 2.00 | $ 15 | 70000 | $15.00 |
| 1-Lamp T5 Indirect | $12.00 | 20000 | $2.67 | $52.00 | 70000 | $15.00 | Proportionally adjusted according to 2-Lamp T5 Equivalent to 3-Lamp T8 | 1.50 | $2.50 | 20000 | $2.67 | 0.50 | $ 15 | 70000 | $15.00 |
| 2-Lamp T5 Indirect | $12.00 | 20000 | $2.67 | $52.00 | 70000 | $15.00 | 3-Lamp F32T8 Equivalent w/ Elec. Ballast | 3.00 | $2.50 | 20000 | $2.67 | 1.00 | $ 15 | 70000 | $15.00 |

[790] Efficiency Vermont Technical Reference User Manual (TRM) Measure Savings Algorithms and Cost Assumptions, October 26, 2011
EPE Program Downloads. (Copy of LSF_2012_v4.04_250rows.xls). Kuiken et al, Focus on Energy Evaluation. Business Programs: Deemed Savings Manual v1.0, Kema, March 22, 2010.

C-1: T12 Baseline Adjustment:

For measures installed up to 1/1/2020, the full savings (as calculated above in the Algorithm section) will be claimed up to 1/1/2020. A savings adjustment will be applied to the annual savings for the remainder of the measure life. The adjustment to be applied for each measure is listed in the reference table below.

Savings Adjustment Factors

| | watts | Equivalent T12 watts adjusted for lumen equivalency-34 w and 40 w with EEMag ballast | Equivalent T12 watts adjusted for lumen equivalency-40 w with EEMag ballast | Equivalent T12 watts adjusted for lumen equivalency-40 w with Mag ballast | Prportionally Adjusted for Lumens wattage for T8 equivalent |
|---|---|---|---|---|---|
| 1-Lamp T5 Industrial/Strip | 32 | 61 | 73 | 82 | 44 |
| 2-Lamp T5 Industrial/Strip | 64 | 103 | 125 | 135 | 88 |
| 3-Lamp T5 Industrial/Strip | 96 | 167 | 185 | 211 | 132 |
| 4-Lamp T5 Industrial/Strip | 128 | 211 | 249 | 226 | 178 |
| | | Savings Factor Adjustment to the T8 baseline | Savings Factor Adjustment to the T8 baseline | Savings Factor Adjustment to the T8 baseline | |
| 1-Lamp T5 Industrial/Strip | | 42% | 29% | 24% | |
| 2-Lamp T5 Industrial/Strip | | 61% | 40% | 34% | |
| 3-Lamp T5 Industrial/Strip | | 51% | 40% | 31% | |
| 4-Lamp T5 Industrial/Strip | | 60% | 41% | 51% | |

**MEASURE CODE: CI-LTG-T5FX-V06-190101**

**REVIEW DEADLINE: 1/1/2021**

## 4.5.13 Occupancy Controlled Bi-Level Lighting Fixtures

### Description

This measure relates to replacing existing uncontrolled continuous lighting fixtures with new bi-level lighting fixtures. This measure can only relate to replacement in an existing building, since multi-level switching is required in the Commercial new construction building energy code (IECC 2012/2015/2018).

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

In order for this characterization to apply, the efficient system is assumed to be an occupancy controlled lighting fixture that reduces light level during unoccupied periods.

### Definition of Baseline Equipment

The baseline equipment is assumed to be an uncontrolled lighting system on continuously, e.g. in stairwells and corridors for health and safety reasons.

### Deemed Lifetime of Efficient Equipment

The expected measure life for all lighting controls is assumed to be 8 years[791].

### Deemed Measure Cost

When available, the actual cost of the measure shall be used. When not available, the assumed measure cost is $274[792].

### Loadshape

Loadshape C06 - Commercial Indoor Lighting
Loadshape C07 - Grocery/Conv. Store Indoor Lighting
Loadshape C08 - Hospital Indoor Lighting
Loadshape C09 - Office Indoor Lighting
Loadshape C10 - Restaurant Indoor Lighting
Loadshape C11 - Retail Indoor Lighting
Loadshape C12 - Warehouse Indoor Lighting
Loadshape C13 - K-12 School Indoor Lighting
Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights)
Loadshape C15 - Indust. 2-shift (16/5) (e.g., comp. air, lights)
Loadshape C16 - Indust. 3-shift (24/5) (e.g., comp. air, lights)
Loadshape C17 - Indust. 4-shift (24/7) (e.g., comp. air, lights)
Loadshape C18 - Industrial Indoor Lighting
Loadshape C19 - Industrial Outdoor Lighting
Loadshape C20 - Commercial Outdoor Lighting

[791] DEER 2008.
[792] Consistent with the Multi-level Fixture measure with reference to Goldberg et al, State of Wisconsin Public Service Commission of Wisconsin, Focus on Energy Evaluation, Business Programs: Incremental Cost Study, KEMA, October 28, 2009. Also consistent with field experience of about $250 per fixture and $25 install labor.

**COINCIDENCE FACTOR**

The summer peak coincidence factor for this measure is dependent on the location type. Values are provided for each building type in the reference section below.

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

$\Delta kWh = (KW_{Baseline} - (KW_{Controlled} * (1 - ESF))) * Hours * WHF_e$

Where:

$KW_{Baseline}$ = Total baseline lighting load of the existing/baseline fixture

= Actual

Note that if the existing fixture is only being retrofit with bi-level occpuancy controls and not being replaced $KW_{Baseline}$ will equal $KW_{Controlled}$ .

$KW_{Controlled}$ = Total contolled lighting load at full light output of the new bi-level fixture

= Actual

Hours = Number of hours lighting is on. This measure is limited to 24/7 operation.

= 8,766

ESF = Energy Savings factor (represents the percentage reduction to the $KW_{Controlled}$ due to the occupancy control).

= % Standby Mode * (1 - % Full Light at Standby Mode)

% Standby Mode = Represents the percentage of the time the fixture is operating in standby (i.e. low-wattage) mode.

% Full Light at Standby Mode = Represents the assumed wattage consumption during standby mode relative to the full wattage consumption. Can be achieved either through dimming or a stepped control strategy.

= Dependent on application. If participant provided or metered data is available for both or either of these inputs a custom savings factor should be calculated. If not defaults are provided below:

| Application | % Standby Mode | % Full Light at Standby Mode | Energy Savings Factor (ESF) |
|---|---|---|---|
| Stairwells | 78.5%[793] | 50% | 39.3% |
| | | 33% | 52.6% |
| | | 10% | 70.7% |
| | | 5% | 74.6% |
| Corridors | 50.0%[794] | 50% | 25.0% |
| | | 33% | 33.5% |

[793] Average found from the four buildings in the State of California Energy Commission Lighting Research Program Bi-Level Stairwell Fixture Performance Final Report, October 2005.

[794] Value determined from the Pacific Gas and Electric Company: Bi-Level Lighting Control Credits study for Interior Corridors of Hotels, Motels and High Rise Residential, June 2002.

| Application | % Standby Mode | % Full Light at Standby Mode | Energy Savings Factor (ESF) |
|---|---|---|---|
| | | 10% | 45.0% |
| | | 5% | 47.5% |
| Other 24/7 Space Type | 50.0%[795] | 50% | 25.0% |
| | | 33% | 33.5% |
| | | 10% | 45.0% |
| | | 5% | 47.5% |

$WHF_e$ = Waste heat factor for energy to account for cooling energy savings from efficient lighting is provided in the Reference Table in Section 4.5 for each building type. If building is un-cooled, the value is 1.0.

**HEATING PENALTY**

If electrically heated building:

$$\Delta kWh_{heatpenalty}{}^{796} = (KW_{Baseline} - (KW_{Controlled} * (1 - ESF))) * Hours * -IFkWh$$

Where:

IFkWh = Lighting-HVAC Interation Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficent lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$$\Delta kW = (KW_{Baseline} - (KW_{Controlled} * (1 - ESF))) * WHF_d * (CF_{baseline} - CF_{os})$$

Where:

$WHF_d$ = Waste Heat Factor for Demand to account for cooling savings from efficient lighting in cooled buildings is provided in the Reference Table in Section 4.5. If the building is un-cooled WHFd is 1.

$CF_{baseline}$ = Baseline Summer Peak Coincidence Factor for the lighting system without Occupancy Sensors installed selected from the Reference Table in Section 4.5 for each building type. If the building type is unknown, use the Miscellaneous value of 0.66

$CF_{os}$ = Retrofit Summer Peak Coincidence Factor the lighting system with Occupancy Sensors installed is 0.15 regardless of building type.[797]

**NATURAL GAS HEATING PENALTY**

If natural gas heating:

$$\Delta therms = (KW_{Baseline} - (KW_{Controlled} * (1 - ESF))) * Hours * - IFTherms$$

Where:

IFTherms = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting and provided in the Reference Table in Section 4.5 by buidling type.

[795] Conservative estimate.
[796] Negative value because this is an increase in heating consumption due to the efficient lighting.
[797] Coincidence Factor Study Residential and Commercial Industrial Lighting Measures, RLW Analytics, Spring 2007. Note, the connected load used in the calculation of the CF for occupancy sensor lights includes the average ESF.

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-LTG-OCBL-V03-190101**

**REVIEW DEADLINE: 1/1/2021**

## 4.5.14 Commercial ENERGY STAR Specialty Compact Fluorescent Lamp (CFL)

**NOTE: THIS MEASURE IS EFFECTIVE UNTIL 12/31/2018. IT IS LEFT IN THE MANUAL FOR REFERENCE PURPOSES AND FOR CALCULATION OF CARRY OVER SAVINGS.**

### DESCRIPTION

A qualified specialty compact fluorescent bulb is installed in place of an incandescent specialty bulb in a commercial location.

Note a new ENERGY STAR specification v2.0 becomes effective on 1/2/2017 .[798] The efficacy requirements can not currently be met by Compact Fluorescent Lamps, and therefore this specification has been removed. ENERGY STAR will maintain a list on their website with the final qualifying list of products prior to this change and it is strongly recommended that programs continue to use this list as qualifying criteria for products in the programs.

If the implementation strategy does not allow for the installation location to be known a deemed split should be used. For Residential targeted programs (e.g. an upstream retail program), a deemed split of 95% Residential and 5% Commercial assumptions should be used[799], and for Commercial targeted programs a deemed split of 4% Residential and 96% Commercial should be used[800].

This measure was developed to be applicable to the following program types: TOS, NC, RF.
If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the high-efficiency equipment must be a qualified specialty compact fluorescent lamp.

### DEFINITION OF BASELINE EQUIPMENT

The baseline is a specialty incandescent light bulb including those exempt of the EISA 2007 standard: three-way, plant light, daylight bulb, bug light, post light, globes G40 (<40W), candelabra base (<60W), vibration service bulb, decorative candle with medium or intermediate base (<40W), shatter resistant and reflector bulbs and standard bulbs greater than 2601 lumens, and those non-exempt from EISA 2007: dimmable, globes (less than 5" diameter and >40W), candle (shapes B, BA, CA >40W, candelabra base lamps (>60W) and intermediate base lamps (>40W).

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life (number of years that savings should be claimed) should be calculated by dividing the rated life of the bulb (10,000 hours[801]) by the run hours. For example using Miscellaneous at 3612 hours would give 2.8 years. For non-exempt bulbs, when the number of years exceeds 2021, the number of years to that date should be used.

### DEEMED MEASURE COST

For the Retail (Time of Sale) measure, the incremental capital cost for this measure is $5[802].

---

[798] ENERGY STAR Program Requirements Product Specifications for Lamps (Light Bulbs), version 2.1, effective January 2, 2017
[799] RES v C&I split is based on a weighted (by sales volume) average of ComEd PY6, PY7 and PY8 and Ameren PY5, PY6 and PY8 in store intercept survey results. See 'RESvCI Split_112015.xls'.
[800] Based upon final weighted (by sales volume) average of the BILD program (ComEd's commercial lighting program) for PY 4 and PY5 and PY6.
[801] Energy Star bulbs have a rated life of at least 8000 hours. In commercial settings you expect significantly less on/off switching than residential and so a rated life assumption of 10,000 hours is used.
[802] NEEP Residential Lighting Survey, 2011

For the Retrofit measures, the full cost of $8.50 should be used plus $5 labor[803] for a total of $13.50. However actual program delivery costs should be utilized if available.

#### LOADSHAPE

Loadshape C06 - Commercial Indoor Lighting
Loadshape C07 - Grocery/Conv. Store Indoor Lighting
Loadshape C08 - Hospital Indoor Lighting
Loadshape C09 - Office Indoor Lighting
Loadshape C10 - Restaurant Indoor Lighting
Loadshape C11 - Retail Indoor Lighting
Loadshape C12 - Warehouse Indoor Lighting
Loadshape C13 - K-12 School Indoor Lighting
Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights)
Loadshape C15 - Indust. 2-shift (16/5) (e.g., comp. air, lights)
Loadshape C16 - Indust. 3-shift (24/5) (e.g., comp. air, lights)
Loadshape C17 - Indust. 4-shift (24/7) (e.g., comp. air, lights)
Loadshape C18 - Industrial Indoor Lighting
Loadshape C19 - Industrial Outdoor Lighting
Loadshape C20 - Commercial Outdoor Lighting

#### COINCIDENCE FACTOR

The summer peak coincidence factor for this measure is dependent on the location type. Values are provided for each building type in section 4.5.

## Algorithm

#### CALCULATION OF SAVINGS

#### ELECTRIC ENERGY SAVINGS

ΔkWh = ((WattsBase - WattsEE) / 1000) * ISR * Hours * WHFe

Where:

WattsBase = Actual wattage equivalent of incandescent specialty bulb, use the tables below to obtain the incandescent bulb equivalent wattage[804]; use 60W if unknown[805]

EISA exempt bulb types:

| Bulb Type | Lower Lumen Range | Upper Lumen Range | WattsBase |
|---|---|---|---|
| **Standard Spirals >=2601** | 2601 | 2999 | 150 |
| | 3000 | 5279 | 200 |

[803] Based on 15 minutes at $20 per hour.
[804] Based upon the ENERGY STAR specification for lamps, ENERGY STAR Program Requirements Product Specifications for Lamps (Light Bulbs), version 1.1, effective August 28, 2014 and the Energy Policy and Conservation Act of 2012.
[805] A 2006-2008 California Upstream Lighting Evaluation found an average incandescent wattage of 61.7 Watts (KEMA, Inc, The Cadmus Group, Itron, Inc, PA Consulting Group, Jai J. Mitchell Analytics, Draft Evaluation Report: Upstream Lighting Program. Prepared for the California Public Utilities Commission, Energy Division. December 10, 2009)

| Bulb Type | Lower Lumen Range | Upper Lumen Range | WattsBase |
|---|---|---|---|
| | 5280 | 6209 | 300 |
| **3-Way** | 250 | 449 | 25 |
| | 450 | 799 | 40 |
| | 800 | 1099 | 60 |
| | 1100 | 1599 | 75 |
| | 1600 | 1999 | 100 |
| | 2000 | 2549 | 125 |
| | 2550 | 2999 | 150 |
| **Globe (medium and intermediate bases less than 750 lumens)** | 90 | 179 | 10 |
| | 180 | 249 | 15 |
| | 250 | 349 | 25 |
| | 350 | 749 | 40 |
| **Decorative (Shapes B, BA, C, CA, DC, F, G, medium and intermediate bases less than 750 lumens)** | 70 | 89 | 10 |
| | 90 | 149 | 15 |
| | 150 | 299 | 25 |
| | 300 | 749 | 40 |
| **Globe (candelabra bases less than 1050 lumens)** | 90 | 179 | 10 |
| | 180 | 249 | 15 |
| | 250 | 349 | 25 |
| | 350 | 499 | 40 |
| | 500 | 1049 | 60 |
| **Decorative (Shapes B, BA, C, CA, DC, F, G, candelabra bases less than 1050 lumens)** | 70 | 89 | 10 |
| | 90 | 149 | 15 |
| | 150 | 299 | 25 |
| | 300 | 499 | 40 |
| | 500 | 1049 | 60 |

EISA non-exempt bulb types:

| Bulb Type | Lower Lumen Range | Upper Lumen Range | Incandescent Equivalent Post-EISA 2007 (WattsBase) |
|---|---|---|---|
| **Dimmable Twist, Globe (less than 5" in diameter and > 749 lumens), candle (shapes B, BA, CA > 749 lumens), Candelabra Base Lamps (>1049 lumens), Intermediate Base Lamps (>749 lumens)** | 310 | 749 | 29 |
| | 750 | 1049 | 43 |
| | 1050 | 1489 | 53 |
| | 1490 | 2600 | 72 |

**Directional Lamps -** ENERGY STAR Minimum Luminous Efficacy = 40Lm/W for lamps with rated wattages less than 20Wand 50 Lm/W for lamps with rated wattages >= 20 watts[806].

For Directional R, BR, and ER lamp types[807]:

[806] From pg 10 of the Energy Star Specification for lamps v1.1
[807] From pg 11 of the Energy Star Specification for lamps v1.1

| Bulb Type | Lower Lumen Range | Upper Lumen Range | $Watts_{Base}$ |
|---|---|---|---|
| **R, ER, BR with medium screw bases w/ diameter >2.25" (*see exceptions below)** | 420 | 472 | 40 |
| | 473 | 524 | 45 |
| | 525 | 714 | 50 |
| | 715 | 937 | 65 |
| | 938 | 1259 | 75 |
| | 1260 | 1399 | 90 |
| | 1400 | 1739 | 100 |
| | 1740 | 2174 | 120 |
| | 2175 | 2624 | 150 |
| | 2625 | 2999 | 175 |
| | 3000 | 4500 | 200 |
| ***R, BR, and ER with medium screw bases w/ diameter <=2.25"** | 400 | 449 | 40 |
| | 450 | 499 | 45 |
| | 500 | 649 | 50 |
| | 650 | 1199 | 65 |
| ***ER30, BR30, BR40, or ER40** | 400 | 449 | 40 |
| | 450 | 499 | 45 |
| | 500 | 649 | 50 |
| ***BR30, BR40, or ER40** | 650 | 1419 | 65 |
| ***R20** | 400 | 449 | 40 |
| | 450 | 719 | 45 |
| ***All reflector lamps below lumen ranges specified above** | 200 | 299 | 20 |
| | 300 | 399 | 30 |

Directional lamps are exempt from EISA regulations.

For PAR, MR, and MRX Lamps Types:

For these highly focused directional lamp types, it is necessary to have Center Beam Candle Power (CBCP) and beam angle measurements to accurately estimate the equivalent baseline wattage. The formula below is based on the Energy Star Center Beam Candle Power tool.[808] If CBCP and beam angle information are not available or if the equation below returns a negative value (or undefined), use the manufacturer's recommended baseline wattage equivalent.[809]

Wattsbase =

[808] http://energystar.supportportal.com/link/portal/23002/23018/Article/32655/

[809] The Energy Star Center Beam Candle Power tool does not accurately model baseline wattages for lamps with certain bulb characteristic combinations – specifically for lamps with very high CBCP.

$$375.1 - 4.355(D) - \sqrt{227{,}800 - 937.9(D) - 0.9903(D^2) - 1479(BA) - 12.02(D * BA) + 14.69(BA^2) - 16{,}720 * \ln(CBCP)}$$

Where:

D = Bulb diameter (e.g. for PAR20 D = 20)

BA = Beam angle

CBCP = Center beam candle power

The result of the equation above should be rounded DOWN to the nearest wattage established by Energy Star:

| Diameter | Permitted Wattages |
|---|---|
| 16 | 20, 35, 40, 45, 50, 60, 75 |
| 20 | 50 |
| 30S | 40, 45, 50, 60, 75 |
| 30L | 50, 75 |
| 38 | 40, 45, 50, 55, 60, 65, 75, 85, 90, 100, 120, 150, 250 |

EISA non-exempt bulb types:

| Bulb Type | Lower Lumen Range | Upper Lumen Range | Incandescent Equivalent Post-EISA 2007 (WattsBase) |
|---|---|---|---|
| **Dimmable Twist, Globe (less than 5" in diameter and > 749 lumens), candle (shapes B, BA, CA > 749 lumens), Candelabra Base Lamps (>1049 lumens), Intermediate Base Lamps (>749 lumens)** | 310 | 749 | 29 |
| | 750 | 1049 | 43 |
| | 1050 | 1489 | 53 |
| | 1490 | 2600 | 72 |

WattsEE = Actual wattage of energy efficient specialty bulb purchased, use 15W if unknown[810]

ISR = In Service Rate or the percentage of units rebated that get installed.

=100%[811] if application form completed with sign off that equipment is not placed into storage

If sign off form not completed assume the following 3 year ISR assumptions:

[810] An evaluation, (Energy Efficiency / Demand Response Plan: Plan Year 2 (6/1/2009-5/31/2010) Evaluation Report: Residential Energy Star ® Lighting, presented to Commonwealth Edison Company by Navigant, December 2010), reported 13-17W as the most common specialty CFL wattage (69% of program bulbs). 2009 California data also reported an average CFL wattage of 15.5 Watts (KEMA, Inc, The Cadmus Group, Itron, Inc, PA Consulting Group, Jai J. Mitchell Analytics, Draft Evaluation Report: Upstream Lighting Program, Prepared for the California Public Utilities Commission, Energy Division. December 10, 2009).

[811] Illinois evaluation of PY1 through PY3 has not found that fixtures or lamps placed into storage to be a significant enough issue to warrant including an "In-Service Rate" when commercial customers complete an application form.

| Weigted Average 1st year In Service Rate (ISR) | 2nd year Installations | 3rd year Installations | Final Lifetime In Service Rate |
|---|---|---|---|
| 71.2%[812] | 14.5% | 12.3% | 98.0%[813] |

Hours = Average hours of use per year are provided in Reference Table in Section 4.5, Screw based bulb annual operating hours, for each building type[814]. If unknown use the Miscellaneous value.

WHFe = Waste heat factor for energy to account for cooling energy savings from efficient lighting are provided below for each building type in Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

**DEFERRED INSTALLS**

As presented above, the characterization assumes that a percentage of bulbs purchased are not installed until Year 2 and Year 3 (see ISR assumption above). The Illinois Technical Advisory Committee has determined the following methodology for calculating the savings of these future installs.

Year 1 (Purchase Year) installs: Characterized using assumptions provided above or evaluated assumptions if available.

Year 2 and 3 installs: Characterized using delta watts assumption and hours of use from the Install Year i.e. the actual deemed (or evaluated if available) assumptions active in Year 2 and 3 should be applied.

The NTG factor for the Purchase Year should be applied.

**EXAMPLE**

For example, for a 14W 500 lumen R20 reflector lamp is installed in an office and sign off form provided.

$\Delta kWh$ = (((45 - 14)/1000) * 1.0 * 3088 * 1.25

= 119.7 kWh

**HEATING PENALTY**

If electrically heated building:

$\Delta kWh_{heatpenalty}$[815] = (((WattsBase-WattsEE)/1000) * ISR * Hours * -IFkWh

Where:

IFkWh = Lighting-HVAC Interation Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficent

[812] 1st year in service rate is based upon review of PY4-6 evaluations from ComEd's commercial lighting program (BILD) (see 'IL Commercial Lighting ISR_2014.xls' for more information. The average first year ISR was calculated weighted by the number of bulbs sold.

[813] The 98% Lifetime ISR assumption is based upon review of two evaluations: 'Nexus Market Research, RLW Analytics and GDS Associates study; "New England Residential Lighting Markdown Impact Evaluation, January 20, 2009' and 'KEMA Inc, Feb 2010, Final Evaluation Report: Upstream Lighting Program, Volume 1.' This implies that only 2% of bulbs purchased are never installed. The second and third year installations are based upon Ameren analysis of the Californian KEMA study showing that 54% of future installs occur in year 2 and 46% in year 3. The 2nd and 3rd year installations should be counted as part of those future program year savings. Note that this Final Install Rate does NOT account for leakage of purchased bulbs being installed outside of the utility territory. EM&V should assess how and if data from evaluation should adjust this final installation rate to account for this impact

[814] Based on ComEd analysis taking DEER 2008 values and averaging with PY1 and PY2 evaluation results.

[815] Negative value because this is an increase in heating consumption due to the efficient lighting.

lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

**EXAMPLE**

For example, for a 14W 500 lumen R20 reflector lamp is installed in a heat pump heated office and sign off form provided.

$\Delta kWh_{heatpenalty}$ = (((45 - 14)/1000) * 1.0 * 3088 * -0.183

= - 17.5 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = ((WattsBase-WattsEE)/1000) * ISR * WHFd * CF

Where:

WHFd = Waste heat factor for demand to account for cooling savings from efficient lighting in cooled buildings is provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value..

CF = Summer Peak Coincidence Factor for measure is provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value..

Other factors as defined above

**EXAMPLE**

For example, for a 14W 500 lumen R20 reflector lamp is installed in an office and sign off form provided.

ΔkW = ((45 - 14)/1000) * 1.0 * 1.3 * 0.66

= 0.027kW

**NATURAL GAS SAVINGS**

Heating Penalty if fossil fuel heated building (or if heating fuel is unknown):

ΔTherms[816] = (((WattsBase-WattsEE)/1000) * ISR * Hours *- IFTherms

Where:

IFTherms = Lighting-HVAC Interation Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficent lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

Other factors as defined above

**EXAMPLE**

For example, for a 14W 500 lumen R20 reflector lamp is installed in a gas heated office and sign off form provided.

ΔTherms = (((45 - 14)/1000) * 1.0 * 3088 * -0.016

= - 1.5 Therms

[816] Negative value because this is an increase in heating consumption due to the efficient lighting.

## WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

## DEEMED O&M COST ADJUSTMENT CALCULATION

The following O&M assumptions should be used: Life of the baseline bulb is assumed to be (1000/HOURS) year; baseline replacement cost is assumed to be $3.5 for those bulbs types exempt from EISA and $5 for non-exempt EISA bulb types defined above[817]. It is important to note that for cost-effectiveness screening purposes, the O&M cost adjustments should only be applied in cases where the light bulbs area actually in service and so should be multiplied by the appropriate ISR.

**MEASURE CODE: CI-LTG-SCFL-V04-190101**

**REVIEW DEADLINE: 1/1/2020**

[817] NEEP Residential Lighting Survey, 2011

## 4.5.15 LED Open Sign

### Description

LED open signs must replace an existing neon open sign. LED drivers can be either electronic switching or linear magnetic, with the electronic switching supplies being the most efficient. The on/off power switch may be found on either the power line or load side of the driver, with the line side location providing significantly lower standby losses when the sign is turned off and is not operating. All new open signs must meet UL-84 (UL-844) requirements.

Replacement signs cannot use more than 20% of the input power of the sign that is being replaced.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

The efficient product is an LED type illuminated open sign.

### Definition of Baseline Equipment

The baseline equipment is a neon type illuminated open sign.

### Deemed Lifetime of Efficient Equipment

The estimated useful life is 15 years. [818]

### Deemed Measure Cost

The actual measure installation cost should be used (including material and labor).

### Loadshape

Loadshape C06 - Commercial Indoor Lighting
Loadshape C07 - Grocery/Conv. Store Indoor Lighting
Loadshape C08 - Hospital Indoor Lighting
Loadshape C09 - Office Indoor Lighting
Loadshape C10 - Restaurant Indoor Lighting
Loadshape C11 - Retail Indoor Lighting
Loadshape C12 - Warehouse Indoor Lighting
Loadshape C13 - K-12 School Indoor Lighting
Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights)
Loadshape C15 - Indust. 2-shift (16/5) (e.g., comp. air, lights)
Loadshape C16 - Indust. 3-shift (24/5) (e.g., comp. air, lights)
Loadshape C17 - Indust. 4-shift (24/7) (e.g., comp. air, lights)
Loadshape C18 - Industrial Indoor Lighting
Loadshape C19 - Industrial Outdoor Lighting
Loadshape C20 - Commercial Outdoor Lighting

[818] 15 years from GDS Measure Life Report, June 2007

### COINCIDENCE FACTOR

The summer peak coincidence factor for this measure is dependent on the location type. Values are provided for each building type in the reference section in Section 4.5.

## Algorithm

### CALCULATION OF ENERGY SAVINGS

### ELECTRIC ENERGY SAVINGS

The following equation was used to determine the energy savings from installing LED open signs:

$$\Delta kWh = (Watts_{base} – Watts_{ee}) / 1{,}000 * Hours * WHFe$$

Where:

$Watts_{base}$ = Wattage of neon sign with magnetic high voltage transformer

= Actual; if unknown use 46.0W[819]

$Watts_{ee}$ = Wattage of LED sign with low voltage transformer

= Actual; if unknown use 14.9W[820]

Hours = Annual hours of operation, assumed to be consistent with operating hours. Values are provided in the Reference Table in Section 4.5.

WHFe = Waste heat factor for energy to account for cooling energy savings from efficient lighting are provided below for each building type in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

### HEATING PENALTY

If electrically heated building:

$$\Delta kWh_{heatpenalty}{}^{821} = ((WattsBase-WattsEE)/1000) * Hours * -IFkWh$$

Where:

IFkWh = Lighting-HVAC Interation Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficent lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

### DEMAND SAVINGS

$$\Delta kW = ((Watts_{base} – Watt_{see})/ 1000) * CF * WHF_d$$

Where:

WHFd = Waste Heat Factor for Demand to account for cooling savings from efficient lighting in cooled buildings is provided in Referecne Table in Section 4.5. If unknown, use the Miscellaneous value.

CF = Summer Peak Coincidence Factor for measure is provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

---

819 Measured average demand data. Southern California Edison, “Replace Neon Open Sign with LED Open Sign”, Workpaper SCE13LG070, Revision 2, October 2015. Pg. 10

820 Ibid.

821 Negative value because this is an increase in heating consumption due to the efficient lighting.

Other variables as provided above.

Based on defaults provided above, the deemed energy savings are provided below:

**Electric Energy and Coincident Peak Demand Savings**

| Building Types[822] | Energy Savings (kWh) | $\Delta kWh_{heatpenalty}$ (if electric heat) | Coincident Demand Savings (kW) |
|---|---|---|---|
| Convenience Store | 158 | -120 | 0.0298 |
| Grocery | 152 | -74 | 0.0277 |
| Healthcare Clinic | 169 | -17 | 0.0374 |
| Hotel/Motel - Common | 229 | -143 | 0.0282 |
| Movie Theater | 121 | -73 | 0.0227 |
| Restaurant | 203 | -85 | 0.0277 |
| Retail - Department Store | 191 | -88 | 0.0387 |
| Miscellaneous | 115 | -55 | 0.0245 |

### NATURAL GAS SAVINGS

Heating Penalty if fossil fuel heated building (or if heating fuel is unknown):

ΔTherms[823] = ((WattsBase-WattsEE)/1000) * Hours *- IFTherms

Where:

IFTherms = Lighting-HVAC Interation Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficent lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

Other factors as defined above

Based on defaults provided above, the deemed penalty is provided below:

| Building Type | $\Delta Therms_{heatpenalty}$ (if gas heat) |
|---|---|
| Convenience Store | -5.1 |
| Grocery | -3.2 |
| Healthcare Clinic | -0.7 |
| Hotel/Motel - Common | -6.1 |
| Movie Theater | -3.2 |
| Restaurant | -3.6 |
| Retail - Department Store | -3.7 |
| Miscellaneous | -2.3 |

### WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION

N/A

### DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

[822] Savings can be calculated for additional building types using the default values provided in the Reference Table in Section 4.5.
[823] Negative value because this is an increase in heating consumption due to the efficient lighting.

**MEASURE CODE: CI-LTG-OPEN-V01-180101**

**REVIEW DEADLINE: 1/1/2022**

## 4.5.16 LED Streetlighting

### Description

Existing streetlights are retrofitted to be illuminated with light emitting diodes (LED) instead of less efficient lamps. Incentive applies for the replacement or retrofit of existing streetlights with new LED lamps.

This measure was developed to be applicable to the following program types: EREP.
If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

The efficient equipment is the installed streetlight illuminated by LEDs.

### Definition of Baseline Equipment

The baseline equipment is the existing streetlight for the its' remaining useful life, and a new baseline High Pressure Sodium lamp for the remainder of the measure life.

### Deemed Lifetime of Efficient Equipment

The assumed effective useful life (EUL) of a new LED streetlight is 12 years for standard operation or 6 years for 8766 hour lighting[824].

For early replacement, it is assumed the existing unit has a remaining useful life (RUL) of 4 years[825].

### Deemed Measure Cost

The actual measure installation cost should be used (including material and labor). The assume deferred cost (after 4 years) of replacing the existing lamp with a new High Pressure Sodium lamp is assumed to be $44[826]. This cost should be discounted to present value using the nominal discount rate.

### Loadshape

Loadshape C20 - Commercial Outdoor Lighting

### Coincidence Factor

The summer peak coincidence factor for this measure is assumed to be 0 for standard usage or 1.0 for 8766 hour lighting[827].

## Algorithm

### Calculation of Energy Savings

### Electric Energy Savings

For remaining useful life ($1^{st}$ 4 years) of existing equipment:

$$\Delta kWh = (W_{exist} - W_{eff}) * HOURS / 1000$$

[824] DLC streetlighting measure, PGE workpaper, and current TRM values for exterior lighting all have a measure lives in the 11-12 year range. Assuming 50,000 hours of operation, and an annual operating hours of 4,303 hours results in a lifetime of 11.6 years or 5.7 years for 8760 operation. Typical streetlighting spec sheets suggest a longer measure life than 50,000 hours so we recommend the 12 year EUL for this measure.
[825] Standard RUL assumption of a third of the EUL of the measure.
[826] High Pressure Sodium replacement cost (lamp and labor) was provided by ComEd based on their composite maintenance rate.
[827] Assuming standard operation of streetlight occurs outside the summer peak period of 1-5 PM. Coincidence Factor is assumed to equal 0.

For remaining life of measure (next 8 years):

$\Delta kWh = (W_{base} - W_{eff}) * HOURS / 1000$

Where:

$W_{exist}$ =the connected load of the existing equipment

= actual existing equipment wattage

$W_{base}$ =the connected load of the baseline equipment

= assume appropriate High Pressure Sodium lamp wattage for application.

$W_{eff}$ =the connected load of the efficient equipment

= actual efficient equipment wattage

EFLH = annual operating hours of the lamp

= 4,303 hours for standard operation[828]

= 8,766 hours for always on lighting

1000 = conversion factor (W/kW)

**EXAMPLE**

For example, an existing 469 watts mercury vapor streetlight is replaced by an LED light of 161 watts. High Pressure Sodium equivalent is 295 watts:

ΔkWh (first four years) = ((469 - 161) * 4,303) / 1000

= 1,325.3 kWh

ΔkWh (remaining eight years) = ((295 - 161) * 4,303) / 1000

= 576.6 kWh

Therefore a midlife adjustment of 43.5% (576.6/1325.3) would be applied after 4 years.

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta kW = (W_{base} - W_{eff}) / 1000 * CF$

Where:

CF = Summer Peak Coincidence Factor for measure

= 0 for Standard operation

= 1 for 8766 lighting

### NATURAL GAS SAVINGS

N/A

### WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION

N/A

[828] Based on Navigant verified value using 2014 Astronomical Applications Department, U.S. Naval Observatory data for ComEd's service territory. See Navigant Memorandum 'RE: LED Street Lighting Program Hours of Use for the ComEd and DCEO Programs. June 21, 2017'.

### DEEMED O&M COST ADJUSTMENT CALCULATION

To calculate an O&M adjustment, in addition to the deferred HPS replacement after 4 years, assume one additional HPS replacement costing $44 in year ten for standard operation or every 2.7 years for 8,766 hour lighting[829].

### MEASURE CODE: CI-LTG-STRT-V01-190101

### REVIEW DEADLINE: 1/1/2022

[829] Assumes a rated life of the High Pressure Sodium lamp of 24,000 hours. High Pressure Sodium replacement cost (lamp and labor) was provided by ComEd based on their composite maintenance rate.

# 4.6 Refrigeration End Use

## 4.6.1 Automatic Door Closer for Walk-In Coolers and Freezers

### DESCRIPTION

This measure is for installing an auto-closer to the main insulated opaque door(s) of a walk-in cooler or freezer. The auto-closer must firmly close the door when it is within 1 inch of full closure.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

This measure consists of the installation of an automatic, hydraulic-type door closer on main walk-in cooler or freezer doors. These closers save energy by reducing the infiltration of warm outside air into the refrigeration itself.

### DEFINITION OF BASELINE EQUIPMENT

In order for this characterization to apply, the baseline condition is assumed to be a walk in cooler or freezer without an automatic closure.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The deemed measure life is 8 years.[830]

### DEEMED MEASURE COST

The deemed measure cost is $156.82 for a walk-in cooler or freezer.[831]

### LOADSHAPE

Loadshape C22 - Commercial Refrigeration

### COINCIDENCE FACTOR

The measure has deemed kW savings therefore a coincidence factor does not apply.

**Algorithm**

### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

Savings calculations are based on values from through PG&E's Workpaper PGECOREF110.1 – Auto-Closers for Main Cooler or Freezer Doors. Savings are averaged across all California climate zones and vintages[832].

| Annual Savings | kWh |
|---|---|
| Walk in Cooler | 943 |
| Walk in Freezer | 2307 |

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

| Annual Savings | kW |
|---|---|
| Walk in Cooler | 0.137 |

[830] Source: DEER 2014
[831] Ibid.
[832] Measure savings from ComEd TRM developed by KEMA. June 1, 2010

| Annual Savings | kW |
|---|---|
| Walk in Freezer | 0.309 |

**NATURAL GAS ENERGY SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-RFG-ATDC-V02-190101**

**REVIEW DEADLINE: 1/1/2023**

## 4.6.2 Beverage and Snack Machine Controls

**DESCRIPTION**

This measure relates to the installation of new controls on refrigerated beverage vending machines, non-refrigerated snack vending machines, and glass front refrigerated coolers. Controls can significantly reduce the energy consumption of vending machine and refrigeration systems. Qualifying controls must power down these systems during periods of inactivity but, in the case of refrigerated machines, must always maintain a cool product that meets customer expectations. This measure relates to the installation of a new control on a new or existing unit. This measure should **not** be applied to ENERGY STAR qualified vending machines, as they already have built-in controls.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

In order for this characterization to apply, the efficient equipment is assumed to be a standard efficiency refrigerated beverage vending machine, non-refrigerated snack vending machine, or glass front refrigerated cooler with a control system capable of powering down lighting and refrigeration systems during periods of inactivity.

**DEFINITION OF BASELINE EQUIPMENT**

In order for this characterization to apply, the baseline equipment is assumed to be a standard efficiency refrigerated beverage vending machine, non-refrigerated snack vending machine, or glass front refrigerated cooler without a control system capable of powering down lighting and refrigeration systems during periods of inactivity

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected measure life is assumed to be 5 years [833].

**DEEMED MEASURE COST**

The actual measure installation cost should be used (including material and labor), but the following can be assumed for analysis purposes[834]:

Refrigerated Vending Machine and Glass Front Cooler: $180.00

Non-Refrigerated Vending Machine: $80.00

**LOADSHAPE**

Loadshape C52 - Beverage and Snack Machine Controls

**COINCIDENCE FACTOR**

The summer peak coincidence factor for this measure is assumed to be 0[835].

[833] Measure Life Study, prepared for the Massachusetts Joint Utilities, Energy & Resource Solutions, November 2005.
[834] ComEd workpapers, 8—15-11.pdf
[835] Assumed that the peak period is coincident with periods of high traffic diminishing the demand reduction potential of occupancy based controls.

**Algorithm**

## CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

ΔkWh = WATTSbase / 1000 * HOURS * ESF

Where:

WATTSbase = connected W of the controlled equipment; see table below for default values by connected equipment type:

| Equipment Type | WATTSbase[836] |
|---|---|
| Refrigerated Beverage Vending Machines | 400 |
| Non-Refrigerated Snack Vending Machines | 85 |
| Glass Front Refrigerated Coolers | 460 |

1000 = conversion factor (W/kW)

HOURS = operating hours of the connected equipment; assumed that the equipment operates 24 hours per day, 365.25 days per year

= 8766

ESF = Energy Savings Factor; represents the percent reduction in annual kWh consumption of the equipment controlled; see table below for default values:

| Equipment Type | Energy Savings Factor (ESF)[837] |
|---|---|
| Refrigerated Beverage Vending Machines | 46% |
| Non-Refrigerated Snack Vending Machines | 46% |
| Glass Front Refrigerated Coolers | 30% |

**EXAMPLE**

For example, adding controls to a refrigerated beverage vending machine:

ΔkWh = WATTSbase / 1000 * HOURS * ESF

=400/1000* 8766* 0.46

= 1613 kWh

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

### NATURAL GAS ENERGY SAVINGS

N/A

### WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

[836] USA Technologies Energy Management Product Sheets, July 2006; cited September 2009.
[837] Ibid.

**Deemed O&M Cost Adjustment Calculation**

N/A

**Measure Code: CI-RFG-BEVM-V03-190101**

**Review Deadline: 1/1/2022**

## 4.6.3 Door Heater Controls for Cooler or Freezer

### Description

By installing a control device to turn off door heaters when there is little or no risk of condensation, one can realize significant energy savings. There are two commercially available control strategies that achieve "on-off" control of door heaters based on either (1) the relative humidity of the air in the store or (2) the "conductivity" of the door (which drops when condensation appears). In the first strategy, the system activates your door heaters when the relative humidity in your store rises above a specific setpoint, and turns them off when the relative humidity falls below that setpoint. In the second strategy, the sensor activates the door heaters when the door conductivity falls below a certain setpoint, and turns them off when the conductivity rises above that setpoint.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

In order for this characterization to apply, the efficient equipment is assumed to be a door heater control on a commercial glass door cooler or refrigerator utilizing humidity or conductivity control.

### Definition of Baseline Equipment

In order for this characterization to apply, the baseline condition is assumed to be a commercial glass door cooler or refrigerator with a standard heated door with no controls installed.

### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 10 years [838].

### Deemed Measure Cost

The incremental capital cost for a humidity-based control is $300 per circuit regardless of the number of doors controlled. The incremental cost for conductivity-based controls is $200[839].

### Loadshape

Loadshape C51 - Door Heater Control

### Coincidence Factor[840]

The summer peak coincidence factor for this measure is assumed to be 0%[841].

**Algorithm**

### Calculation of Savings

### Electric Energy Savings

ΔkWH = kWbase * NUMdoors * ESF * BF * 8766

Where:

---

[838] As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.

[839] Efficiency Vermont Technical Reference User Manual (TRM) Measure Savings Algorithms and Cost Assumptions, February, 19, 2010

[840] Source partial list from DEER 2008

[841] Based on the assumption that humidity levels will most likely be relatively high during the peak period, reducing the likelihood of demand savings from door heater controls.

kWbase[842] = connected load kW for typical reach-in refrigerator or freezer door and frame with a heater.

= If actual kWbase is unknown, assume 0.195 kW for freezers and 0.092 kW for coolers.

NUMdoors = number of reach-in refrigerator or freezer doors controlled by sensor

= Actual installed

ESF[843] = Energy Savings Factor; represents the percentage of hours annually that the door heater is powered off due to the controls.

= assume 55% for humidity-based controls, 70% for conductivity-based controls

BF[844] = Bonus Factor; represents the increased savings due to reduction in cooling load inside the cases, and the increase in cooling load in the building space to cool the additional heat generated by the door heaters.

| Definition | Representative Evaporator Temperature Range, °F[845] | Typical Uses | BF |
|---|---|---|---|
| Low | -35 to 0 | Freezers for times such as frozen pizza, ice cream, etc. | 1.36 |
| Medium | 0 – 20 | Coolers for items such as meat, milk, dairy, etc | 1.22 |
| High | 20 – 45 | Coolers for items such as floral, produce and meat preperation rooms | 1.15 |

8766 = annual hours of operation

### Summer Coincident Peak Demand Savings

N/A

### Natural Gas Energy Savings

N/A

### Water Impact Descriptions and Calculation

N/A

### Deemed O&M Cost Adjustment Calculation

N/A

842 A review of TRM methodologies from Vermont, New York, Wisconsin, and Connecticut reveals several different sources for this factor. Connecticut requires site-specific information, whereas New York's characterization does not explicitly identify the kWbase. Connecticut and Vermont provide values that are very consistent, and the simple average of these two values has been used for the purposes of this characterization.

843 A review of TRM methodologies from Vermont, New York, Wisconsin, and Connecticut reveals several different estimates of ESF. Vermont is the only TRM that provides savings estimates dependent on the control type. Additionally, these estimates are the most conservative of all TRMs reviewed. These values have been adopted for the purposes of this characterization.

844 Efficiency Vermont Technical Reference User Manual (TRM) Measure Savings Algorithms and Cost Assumptions, February, 19, 2010

845 Energy Efficiency Supermarket Refrigeration, Wisconsin Electric Power Company, July 23, 1993

**MEASURE CODE: CI-RFG-DHCT-V02-190101**

**REVIEW DEADLINE: 1/1/2022**

## 4.6.4 Electronically Commutated Motors (ECM) for Walk-in and Reach-in Coolers / Freezers

### Description

This measure is applicable to the replacement of an existing, uncontrolled, and continuously operating standard-efficiency shaded-pole evaporator fan motor in refrigerated display cases or fan coil in walk-ins.

This measure achieves savings by installing a more efficient motor, the result of which produces less waste heat that the cooling system must reject.

If applicable, savings from this measure may be claimed in combination with measure 4.6.6 Evaporator Fan Control for Electrically Commutated Motors.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

This measure applies to the replacement of an existing standard-efficiency shaded-pole evaporator fan motor in refrigerated display cases or fan coil in walk-ins. The replacement unit must be an electronically commutated motor (ECM) with a minimum efficiency of 66%. If controls are added as part of the motor upgrade to reduce annual run time, additional savings may potentially be claimed using measure 4.6.6 Evaporator Fan Control.

### Definition of Baseline Equipment

The baseline is the existing shaded-pole motor(s) with no fan control operating 8760 hours continuously in a refrigerated display case or fan coil unit of a walk-in cooling unit.

### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 15 years[846]

### Deemed Measure Cost

The measure cost is assumed to be $177 per motor for a walk in cooler and walk in freezer. [847]

### Loadshape

Loadshape C53 - Flat

### Coincidence Factor

The peak kW coincidence factor is 100%.

**Algorithm**

### Calculation of Savings

### Electric Energy Savings

$$\Delta kWh = \text{Savings per motor} * \text{motors}$$

Where:

Savings per motor = based on the motor rating of the ECM motor:

[846] DEER

[847] Difference in the fully installed cost ($468) for ECM motor and controller, listed in Work Paper PGE3PREF126, “ECM for Walk-In Evaporator with Fan Controller,” June 20,2012, and the measure cost specified in 4.6.6 ($291)

| Evaporator Fan Motor Rating (of ECM) | Annual kWh Savings/motor |
|---|---|
| 16W | 408 |
| 1/15 - 1/20HP | 1,064 |
| 1/5HP | 1,409 |
| 1/3HP | 1,994 |
| 1/2HP | 2,558 |
| 3/4HP | 2,782 |

motors = number of fan motors replaced

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = ΔkWh/ Hours * CF * motors

Where:

ΔkWh = Gross customer annual kWh savings for the measure, as listed above

Hours = Full Load hours per year

= 8760

CF = Summer Peak Coincident Factor

= 1.0

Other variables as defined above.

The following table provides the resulting kW savings (per motor)

| Evaporator Fan Motor Rating (of ECM) | Peak kW Savings/motor |
|---|---|
| 16W | 0.047 |
| 1/15 - 1/20HP | 0.121 |
| 1/5HP | 0.161 |
| 1/3HP | 0.228 |
| 1/2HP | 0.292 |
| 3/4HP | 0.318 |

**NATURAL GAS ENERGY SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-RFG-ECMF-V02-180101**

**REVIEW DEADLINE: 1/1/2022**

## 4.6.5 ENERGY STAR Refrigerated Beverage Vending Machine

### Description

ENERGY STAR qualified new and rebuilt vending machines incorporate more efficient compressors, fan motors, and lighting systems as well as low power mode option that allows the machine to be placed in low-energy lighting and/or low-energy refrigeration states during times of inactivity.

This measure was developed to be applicable to the following program types: TOS, NC .

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

The refrigerated vending machine can be new or rebuilt but must meet the ENERGY STAR specifications which include low power mode.

### Definition of Baseline Equipment

The baseline vending machine is a standard unit

### Deemed Lifetime of Efficient Equipment

The deemed lifetime of this measure is 14 years[848]

### Deemed Measure Cost

The incremental cost of this measure is $500[849]

### Loadshape

Loadshape C22 - Commercial Refrigeration

### Coincidence Factor

It is assumed that controls are only effective during off-peak hours and so have no peak-kW savings.

**Algorithm**

### Calculation of Savings

Beverage machine savings are taken from the ENERGY STAR savings calculator and summarized in the following table. ENERGY STAR provides savings numbers for machines with and without control software. The average savings are calculated here.

### Electric Energy Savings

ENERGY STAR Vending Machine Savings[850]

| Vending Machine Capacity (cans) | kWh Savings Per Machine w/o software | kWh Savings Per Machine w/ software |
|---|---|---|
| <500 | 1,099 | 1,659 |
| 500 - 599 | 1,754 | 2,231 |
| 600 - 699 | 1,242 | 1,751 |

[848] ENERGY STAR
[849] ENERGY STAR
[850] Savings from ENERGY STAR Vending Machine Calculator

| Vending Machine Capacity (cans) | kWh Savings Per Machine w/o software | kWh Savings Per Machine w/ software |
|---|---|---|
| 700 - 799 | 1,741 | 2,283 |
| 800+ | 713 | 1,288 |
| Average | 1,310 | 1,842 |

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

N/A

**NATURAL GAS ENERGY SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-RFG-ESVE-V03-190101**

**REVIEW DEADLINE: 1/1/2022**

## 4.6.6 Evaporator Fan Control for Electrically Commutated Motors

### Description

This measure is for the installation of controls for Electronically Commutated Motors in existing medium temperature walk-in coolers. The controller reduces airflow of the evaporator fans when there is no refrigerant flow.

This measure achieves savings by controlling the motor(s) to run at lower speeds (or shut off entirely) when there is no refrigerant flow, the result of which produces less waste heat that the cooling system must reject.

If eligible, this measure may be claimed in combination with 4.6.4 Electronically Commutated Motors (ECM) for Walk-in and Reach-in Coolers / Freezers.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

The measure must control a minimum of 1/20 HP where fans operate continuously at full speed. The measure also must reduce fan motor power by at least 75% during the off cycle. This measure is not applicable if any of the following conditions apply:

- The compressor runs more than 4380 hours annually
- The evaporator fan does not run at full speed all the time
- The evaporator fan motor runs on poly-phase power
- Evaporator does not use off-cycle or time-off defrost.

### Definition of Baseline Equipment

In order for this characterization to apply, the existing condition must be a reach-in or walk-in freezer or cooler with continuously running evaporator fans driven by Electrically Commutated Motors

### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 13 years[851]

### Deemed Measure Cost

The measure cost is assumed to be $291[852]

### Loadshape

Loadshape C46 - Evaporator Fan Control

### Coincidence Factor

The measure has deemed kW savings therefore a coincidence factor does not apply.

**Algorithm**

### Calculation of Savings

Savings are based on a measure created by Energy & Resource Solutions for the California Municipal Utilities Association[853] and supported by a PGE workpaper. Note that climate differences across all California climate zones result in negligible savings differences, which indicates that the average savings for the California study should apply

[851] As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.
[852] Source: DEER
[853] See 'EC_motor_with_controller_182014.xlsx'.

equally as well to Illinois. Savings found in the aforementioned source are presented in combination with savings from an ECM upgrade, however for the purposes of this measure only those associated with the controller are considered.

## ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \text{Savings per motor} * \text{motors}$$

Where:

Savings per motor = based on the motor rating of the ECM motor:

| Evaporator Fan Motor Rating (of ECM) | Annual kWh Savings/motor |
|---|---|
| 16W | 212 |
| 1/15 - 1/20HP | 315 |
| 1/5HP | 920 |
| 1/3HP | 1,524 |
| 1/2HP | 2,283 |
| 3/4HP | 3,444 |

motors = number of fan motors controlled

## SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \text{Peak kW savings per motor (as listed in the table below)} * \text{motors (as defined above)}$$

| Evaporator Fan Motor Rating (of ECM) | Peak kW Savings/motor |
|---|---|
| 16W | 0.024 |
| 1/15 - 1/20HP | 0.036 |
| 1/5HP | 0.105 |
| 1/3HP | 0.174 |
| 1/2HP | 0.261 |
| 3/4HP | 0.393 |

## NATURAL GAS ENERGY SAVINGS

N/A

## WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

## DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

## MEASURE CODE: CI-RFG-EVPF-V04-190101

## REVIEW DEADLINE: 1/1/2024

## 4.6.7 Strip Curtain for Walk-in Coolers and Freezers

### Description

This commercial measure pertains to the installation of infiltration barriers (strip curtains) on walk-in coolers or freezers. Strip curtains impede heat transfer from adjacent warm and humid spaces into walk-ins when the main door is opened, thereby reducing the cooling load. As a result, compressor run time and energy consumption are reduced. The engineering assumption is that the walk-in door is open for varying durations per day based on facility type, and the strip curtain covers the entire door frame. All assumptions are based on values that were determined by direct measurement and monitoring of over 100 walk-in units in the 2006-2008 evaluation for the CA Public Utility Commission.[854]

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

The efficient equipment is a strip curtain at least 0.06 inches thick[855] added to a walk-in cooler or freezer. The new strip curtain must cover the entire area of the doorway when the door is opened.

### Definition of Baseline Equipment

The baseline assumption is a walk-in cooler or freezer that previously had either no strip curtain installed or an old, ineffective strip curtain installed.

### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 4 years[856].

### Deemed Measure Cost

The incremental capital cost for this measure is $10.22/sq ft of door opening [857]

### Loadshape

Loadshape C22 - Commercial Refrigeration

### Coincidence Factor

The summer peak coincidence factor for this measure is 100%[858].

---

[854] The scale factors have been determined with tracer gas measurements on over 100 walk-in refrigeration units during the California Public Utility Commission's (CPUC) evaluation of the 2006-2008 CA investor owned utility energy efficiency programs. The door-open and close times, and temperatures of the infiltrating and refrigerated airs are taken from shortterm monitoring of over 100 walk-in units. "Commercial Facilities Contract Group 2006-2008 Direct Impact Evaluation", CPUC, February 2010.

[855] Pennsylvania Public Utility Commission TRM, chapter 3.5.9 Strip Curtains for Walk-in Freezers and Coolers.

[856] DEER 2014 Effective Useful Life.

[857] The reference for incremental cost is $10.22 per square foot of door opening (includes material and labor). 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Cost Values and Summary Documentation", California Public Utilities Commission, December 16, 2008.

[858] The summer coincident peak demand reduction is assumed as the total annual savings divided by the total number of hours per year, effectively assuming the average demand reduction is realized during the peak period. This is a reasonable assumption for refrigeration savings.

**Algorithm**

## Calculation of Savings

### Electric Energy Savings[859]

ΔkWh = ΔkWh/sq ft * A

Where:

ΔkWh/sq ft = Average annual kWh savings per square foot of infiltration barrier. Values can be found in Table 4.6.7 - 1.

A = Doorway area. If the actual doorway area in square feet is unknown, then use the values found in Table 4.6.7 - 2.

Table 4.6.7 - 1: Default Energy Savings and for Strip Curtains[860]

| Type | Pre-Existing Curtains | Energy Savings ΔkWh/sq ft |
|---|---|---|
| Supermarket - Cooler | Yes | 37 |
| Supermarket - Cooler | No | 108 |
| Supermarket - Freezer | Yes | 119 |
| Supermarket - Freezer | No | 349 |
| Convenience Store - Cooler | Yes | 5 |
| Convenience Store - Cooler | No | 20 |
| Convenience Store - Freezer | Yes | 8 |
| Convenience Store - Freezer | No | 27 |
| Restaurant - Cooler | Yes | 8 |
| Restaurant - Cooler | No | 30 |
| Restaurant - Freezer | Yes | 34 |
| Restaurant - Freezer | No | 119 |
| Refrigerated Warehouse | Yes | 254 |
| Refrigerated Warehouse | No | 729 |

Table 4.6.7 - 2: Default Doorway Area by Facility Type[861]

| Facility Type | Doorway Area (sq ft) |
|---|---|
| Supermarket - Cooler | 35 |
| Supermarket - Freezer | 35 |
| Convenience Store - Cooler | 21 |
| Convenience Store - Freezer | 21 |
| Restaurant - Cooler | 21 |
| Restaurant - Freezer | 21 |
| Refrigerated Warehouse | 80 |

[859] The source algorithm from which the savings per square foot values are determined is based on Tamm's equation (an application of Bernoulli's equation) [Kalterveluste durch kuhlraumoffnungen. Tamm W,.Kaltetechnik-Klimatisierung 1966;18;142-144;] and the ASHRAE handbook [American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE). 2010. ASHRAE Handbook, Refrigeration: 13.4, 13.6].

[860] Table 3-114 Default Energy Savings and Demand Reductions for Strip Curtains in Pennsylvania Public Utility Commission TRM, chapter 3.5.9 Strip Curtains for Walk-in Freezers and Coolers.

[861] Assumed Doorway area for four different facility types including supermarket, convenience store, restaurant and refrigerated warehouse. Pennsylvania Public Utility Commission 2016 TRM, chapter 3.5.9 Strip Curtains for Walk-in Frezzers and Coolers.

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$\Delta kW = \Delta kWh / 8766 * CF$

Where:

8766 = hours per year

CF = Summer Peak Coincidence Factor for the measure

= 1.0

**NATURAL GAS ENERGY SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-RFG-CRTN-V04-180101**

**REVIEW DEADLINE: 1/1/2022**

## 4.6.8 Refrigeration Economizers

### DESCRIPTION

This measure applies to commercial walk in refrigeration systems and includes two components, outside air economizers and evaporator fan controllers. Economizers save energy by bringing in outside air when weather conditions allow, rather than operating the compressor. Walk-in refrigeration systems evaporator fans run almost all the time; 24 hrs/day, 365 days/yr. This is because they must run constantly to provide cooling when the compressor is running, and to provide air circulation when the compressor is not running. However, evaporator fans are a very inefficient method of providing air circulation. Installing an evaporator fan control system will turn off evaporator fans while the compressor is not running, and instead turn on an energy-efficient 35 watt fan to provide air circulation, resulting in significant energy savings. This measure allows for economizer systems with evaporator fan controls plus a circulation fan and without a circulation fan.

### DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure an economizer is installed on a walk in refrigeration system.

### DEFINITION OF BASELINE EQUIPMENT

The baseline condition is a walk-in refrigeration system without an economizer

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The estimated life of this measure is 15 years[862].

### DEEMED MEASURE COST

The installation cost for an economizer is $2,558.[863]

### LOADSHAPE

Loadshape C22 - Commercial Refrigeration

### COINCIDENCE FACTOR

The summer peak coincidence factor for this measure is assumed to be 0%[864].

## Algorithm

### CALCULATION OF ENERGY SAVINGS

### ELECTRIC ENERGY SAVINGS

Electric energy savings is calculated based on whether evaporator fans run all

With Fan Control Installed

ΔkWh = [HP * kWhCond] + [((kWEvap * nFans) – kWCirc) * Hours * DCComp * BF] – [kWEcon * DCEcon * Hours]

Without Fan Control Installed

ΔkWh = [HP * kWhCond] – [kWEcon * DCEcon * Hours]

[862] Estimated life from Efficiency Vermont TRM
[863] Based on average of costs from Freeaire, Natural Cool, and Cooltrol economizer systems.
[864] Based on the assumption that humidity levels will most likely be relatively high during the peak period, reducing the likelihood of demand savings.

Where:

HP = Horsepower of Compressor

= actual installed

kWhCond = Condensing unit savings, per hp. (value from savings table) [865]

| | Hermetic / Semi-Hermetic | Scroll | Discus |
|---|---|---|---|
| kWh/HP | 1,256 | 1,108 | 1,051 |

Hours = Number of annual hours that economizer operates [866].

| Region (city) | Hours |
|---|---|
| 1 (Rockford) | 2,376 |
| 2 (Chicago/O'Hare) | 1,968 |
| 3 (Springfield) | 1,728 |
| 4 (Belleview) | 1,488 |
| 5 (Marion) | 1,224 |

DCComp = Duty cycle of the compressor

= 50% [867]

kWEvap = Connected load kW of each evaporator fan,

= If known, actual installed. Otherwise assume 0.123 kW[868]

kWCirc = Connected load kW of the circulating fan

= If known, actual installed. Otherwise assume 0.035 kW[869]

nFans = Number of evaporator fans

= actual number of evaporator fans

DCEcon = Duty cycle of the economizer fan on days that are cool enough for the economizer to be working

= If known, actual installed. Otherwise assume 63%[870]

BF = Bonus factor for reduced cooling load from running the evaporator fan less or (1.3)[871]

kWEcon = Connected load kW of the economizer fan

---

[865] Savings table uses Economizer Calc.xls. Assume 5HP compressor size used to develop kWh/Hp value. No floating head pressure controls and compressor is located outdoors

[866] In the source TRM (VT) this value was 2,996 hrs based on 38° F cooler setpoint, Burlington VT weather data, and 5 degree economizer deadband. The IL numbers were calculated by using weather bin data for each location (number of hours < 38F at each location is the Hours value).

[867] A 50% duty cycle is assumed based on examination of duty cycle assumptions from Richard Travers (35%-65%), Cooltrol (35%-65%), Natural Cool (70%), Pacific Gas & Electric (58%). Also, manufacturers typically size equipment with a built-in 67% duty factor and contractors typically add another 25% safety factor, which results in a 50% overall duty factor. (as referenced by the Efficiency Vermont, Technical Reference User Manual)

[868] Based on an a weighted average of 80% shaded pole motors at 132 watts and 20% PSC motors at 88 watts

[869] Wattage of fan used by Freeaire and Cooltrol. This fan is used to circulate air in the cooler when the evaporator fan is turned off. As such, it is not used when fan control is not present

[870] Average of two manufacturer estimates of 50% and 75%.

[871] Bonus factor (1+ 1/3.5) assumes COP of 3.5, based on the average of standard reciprocating and discus compressor efficiencies with a Saturated Suction Temperature of 20°F and a condensing temperature of 90°F

= If known, actual installed. Otherwise assume 0.227 kW.[872]

**EXAMPLE**

For example, adding an outdoor air economizer and fan controls in Rockford to a 5 hp walk in refrigeration unit with 3 evaporator fans would save:

ΔkWh = [HP * kWhCond] + [((kWEvap * nFans) – kWCirc) * Hours * DCComp * BF] – [kWEcon * DCEcon * Hours]

= [5 * 1256] + [((0.123 * 3) – 0.035) * 2376 *0.5 * 1.3] – [0.227 * 0.63 * 2376]

= 6456 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$$\Delta kW = \Delta kWh / Hours$$

**NATURAL GAS SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-RFG-ECON-V05-150601**

**REVIEW DEADLINE: 1/1/2020**

[872] The 227 watts for an economizer is calculated from the average of three manufacturers: Freeaire (186 Watts), Cooltrol (285 Watts), and Natural Cool (218 Watts).

## 4.6.9 Night Covers for Open Refrigerated Display Cases

### DESCRIPTION

This measure is the installation of fitted covers on existing open-type refrigerated and freezer display cases that are deployed during the facility unoccupied hours. Night covers are designed to reduce refrigeration energy consumption by reducing the work done by the compressor. Night covers reduce the heat and moisture entry into the refrigerated space through various heat transfer mechanisms. By fully or partially covering the case opening, night covers reduce the convective heat transfer into the case through reduced air infiltration. Additionally, they provide a measure of insulation, reducing conduction into the case, and also decrease radiation into the case by blocking radiated heat from entering the refrigerated space.

### DEFINITION OF EFFICIENT EQUIPMENT

Curtains or covers on top of open refrigerated or freezer display cases that are applied at least six hours (during off-hours) in a 24-hour period.

### DEFINITION OF BASELINE EQUIPMENT

Refrigerated and freezer, open-type display case in vertical, semi-vertical, and horizontal displays, with no night cover.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is 5 years, based on DEER 2014.[873]

### DEEMED MEASURE COST

The incremental capital cost for this measure is $42 per linear foot of cover installed including material and labor.[874]

### LOADSHAPE

Loadshape 22: Commercial Refrigeration

### COINCIDENCE FACTOR

N/A – savings occur at night only.

**Algorithm**

### CALCULATION OF ENERGY SAVINGS

### ELECTRIC ENERGY SAVINGS

$$\Delta kWh = ES * L$$

Where:

ES = the energy savings (ΔkWh/ft) found in table below:

[873] 2014 Database for Energy-Efficiency Resources (DEER), Version 2014, “Cost Values and Summary Documentation”, California Public Utilities Commission, January, 2014.

[874] 2014 Database for Energy-Efficiency Resources (DEER), Version 2014, “Cost Values and Summary Documentation”, California Public Utilities Commission, January, 2014.

| Display Case Description | Case Temperature Range (°F) | Annual Electricity Use kWh/ft[875] | ES ΔkWh/ft reduction (= 9% reduction of electricity use[876,877]) |
|---|---|---|---|
| Vertical Open, Remote Condensing, Medium Temperature | 35°F to 55°F | 1453 | 131 |
| Vertical Open, Remote Condensing, Low Temperature | 0°F to 30°F | 3292 | 296 |
| Vertical Open, Self-Contained Medium Temperature | 35°F to 55°F | 2800 | 252 |
| Horizontal Open, Remote Condensing, Medium Temperature | 35°F to 55°F | 439 | 40 |
| Horizontal Open, Remote Condensing, Low Temperature | 0°F to 30°F | 1007 | 91 |
| Horizontal Open, Self-Contained, Medium Temperature | 35°F to 55°F | 1350 | 121 |
| Horizontal Open, Self-Contained, Low Temperature | 0°F to 30°F | 2749 | 247 |

L = the length of the refrigerated case in linear feet

= Actual

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

Peak savings are null because savings occur at night only.

**NATURAL GAS SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

---

875 Energy Conservation Standards for Commercial Refrigeration Equipment: Technical Support Document, U.S. Department of Energy, September 2013. The information required to estimate annual energy savings for refrigerated display cases is taken from the 2013-2014 U.S. Department of Energy (DOE) energy conservation standard rulemaking for Commercial Refrigerated Equipment. During the rulemaking process, DOE estimates the energy savings specific to night covers through extensive simulation and energy models that are validated by both manufacturers of night covers and refrigerated cases. The information is also referenced from a study done by Southern California Edison and testing by Technischer Uberwachungs-Verein Rheinland, which are used by DOE for the rulemaking process.

876 Southern California Edison Refrigeration Technology and Test Center. Effects of the Low Emissivity Shields on Performance and Power Use of a Refrigerated Display Case. 1997. Southern California Edison, Rancho Cucamonga, CA.

877 Technischer Uberwachungs-Verein Rheinland E.V. Laboratory test results for energy savings on refrigerated dairy case, conducted for Econofrost.

**MEASURE CODE: CI-RFG-NCOV-V01-150601**

**REVIEW DEADLINE: 1/1/2024**

## 4.6.10 High Speed Rollup Doors

### Description

This measure entails the installation of High Speed Doors in refrigerated warehouses. High speed doors can save energy by lowering infiltration through a reduction in time that cooled spaces are exposed to ambient outdoor conditions. This in turn can lower the demand on refrigeration systems.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

To qualify for this measure the installed equipment must be a High Speed Door installed on the loading dock doorway of a refrigerated space. The high speed door is assumed to act as a primary door. It should be noted that for high-traffic applications (about 45 door passages per hour, using the defaults for this measure) a custom analysis is necessary to ensure that high-speed rollup doors will provide savings, because strip curtains may outperform the high speed door, if no other open-door protection device is installed.

### Definition of Baseline Equipment

The baseline equipment is existing strip curtains on doorways to a loading dock. During times of traffic, primary doors are left open, leaving just the strip curtains as open-doorway protection.

### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 16 years.[878]

### Deemed Measure Cost

The incremental measure cost is $150/sq.ft.[879]

### Loadshape

Loadshape C22 - Commercial Refrigeration

### Coincidence Factor

The coincidence factor is assumed to be 1.00.

**Algorithm**

### Calculation of Savings

### Electric Energy Savings

Electric savings consider the change in loading on the refrigeration system as well as the consumption of the drive on the high speed door. The following algorithms are based heavily on those derived and described in chapter 24 Refrigerated-Facility Loads of the ASHRAE Refrigeration Handbook.

$$\Delta kWh = \left(0.00008333 * q * D_f * \eta * [D_{tB}(1 - E_B) - D_{tE}(1 - E_E)] - D_{tM}\mathrm{M}\right) * t$$

Where:

0.00008333 = conversion from Btu/h to tons

[878] As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.
[879] Rite Hite – Industrial High Speed Doors

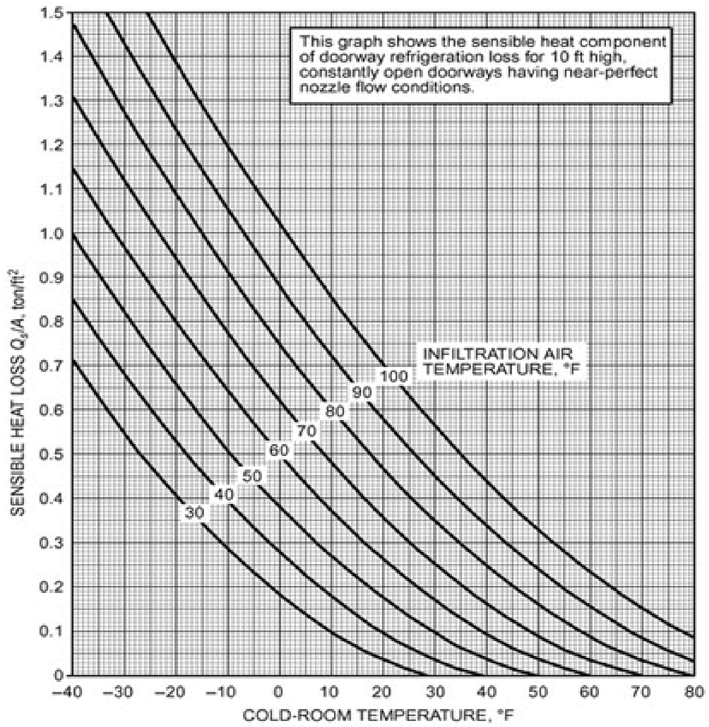
*q* = sensible and latent refrigeration load for fully established flow, Btu/h

$$= 3790 * W * H^{1.5} * \left(\frac{Q_s}{A}\right) * \left(\frac{1}{R_s}\right)$$

W = width of doorway, in feet. Custom input.

H = height of doorway, in feet. Custom input.

$\frac{Q_S}{A}$ = Sensible heat load of infiltration air per square foot of door way opening, as read from the following figure and dependent on infiltration air temperature and cooled space temperature. If unknown, infiltration temperature can be assumed to be 50° F[880], cooler temperature 35°F and freezer temperature -10°F[881], resulting in values of 0.06 for a cooler and 0.5 for a freezer.




$R_s$ = Sensible heat ratio of the infiltration air heat gain, as read or interpolated from the chart below or from a psychometric chart, dependent on temperature and relative humidity of infiltration air and cooled space temperature. If unknown, use the same assumptions as previously with a warm space relative humidity value of 70%[882], resulting in values of 0.685 (interpolated) for coolers and 0.73 (interpolated) for freezers.

[880] Taken to represent the overall annual average temperature in Illinois. TMY3 data for the five weather regions defined by the TRM indicate averages that fall within the range of 47.6 (Rockford) to 55.9 (Marion).

[881] Refrigerated Warehouse, 2013 California Building Energy Standards, CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE), March 2011

[882] Taken to represent the overall annual average in Illinois. TMY3 data for the five weather regions defined by the TRM indicate averages that fall within the range of 69.1 (Springfield) to 72.1 (Rockford).

| Warm Space | | Cold Space at 90% rh Dry-Bulb Temperature, °F | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp. °F | rh, % | –40 | –30 | –20 | –10 | 0 | 10 | 20 | 30 | 40 | 50 |
| 70 | 100 | 0.60 | 0.58 | 0.56 | 0.53 | 0.50 | 0.47 | 0.44 | 0.41 | 0.37 | 0.34 |
| | 80 | 0.66 | 0.64 | 0.61 | 0.59 | 0.56 | 0.53 | 0.50 | 0.48 | 0.46 | 0.44 |
| | 60 | 0.72 | 0.70 | 0.68 | 0.66 | 0.63 | 0.61 | 0.59 | 0.58 | 0.59 | 0.64 |
| | 40 | 0.79 | 0.78 | 0.76 | 0.75 | 0.73 | 0.72 | 0.71 | 0.73 | 0.80 | — |
| 60 | 100 | 0.66 | 0.64 | 0.62 | 0.59 | 0.56 | 0.52 | 0.49 | 0.45 | 0.41 | 0.35 |
| | 80 | 0.71 | 0.69 | 0.67 | 0.64 | 0.62 | 0.59 | 0.56 | 0.53 | 0.52 | 0.53 |
| | 60 | 0.77 | 0.75 | 0.73 | 0.71 | 0.69 | 0.67 | 0.65 | 0.65 | 0.70 | — |
| | 40 | 0.83 | 0.82 | 0.81 | 0.79 | 0.78 | 0.77 | 0.78 | 0.83 | — | — |
| 50 | 100 | 0.72 | 0.70 | 0.67 | 0.64 | 0.61 | 0.57 | 0.53 | 0.49 | 0.43 | — |
| | 80 | 0.76 | 0.74 | 0.72 | 0.70 | 0.67 | 0.64 | 0.61 | 0.59 | 0.62 | — |
| | 60 | 0.81 | 0.80 | 0.78 | 0.76 | 0.74 | 0.72 | 0.71 | 0.75 | — | — |
| | 40 | 0.87 | 0.86 | 0.84 | 0.83 | 0.82 | 0.82 | 0.85 | — | — | — |
| 40 | 100 | 0.77 | 0.75 | 0.72 | 0.69 | 0.66 | 0.62 | 0.57 | 0.51 | — | — |
| | 80 | 0.81 | 0.79 | 0.77 | 0.74 | 0.72 | 0.69 | 0.66 | 0.67 | — | — |
| | 60 | 0.85 | 0.84 | 0.82 | 0.80 | 0.78 | 0.77 | 0.79 | 0.99 | — | — |
| | 40 | 0.90 | 0.89 | 0.88 | 0.87 | 0.86 | 0.88 | 0.97 | — | — | — |
| 30 | 100 | 0.82 | 0.80 | 0.77 | 0.74 | 0.70 | 0.66 | 0.59 | — | — | — |
| | 80 | 0.85 | 0.83 | 0.81 | 0.79 | 0.76 | 0.73 | 0.73 | — | — | — |
| | 60 | 0.88 | 0.87 | 0.86 | 0.84 | 0.83 | 0.83 | 0.94 | — | — | — |
| | 40 | 0.92 | 0.91 | 0.90 | 0.90 | 0.91 | 0.96 | — | — | — | — |
| 20 | 100 | 0.86 | 0.84 | 0.82 | 0.79 | 0.75 | 0.69 | — | — | — | — |
| | 80 | 0.89 | 0.87 | 0.85 | 0.83 | 0.81 | 0.80 | — | — | — | — |
| | 60 | 0.91 | 0.90 | 0.89 | 0.88 | 0.88 | 0.95 | — | — | — | — |
| | 40 | 0.94 | 0.94 | 0.93 | 0.94 | 0.97 | — | — | — | — | — |
| 10 | 100 | 0.90 | 0.88 | 0.86 | 0.83 | 0.78 | — | — | — | — | — |
| | 80 | 0.92 | 0.90 | 0.89 | 0.87 | 0.86 | — | — | — | — | — |
| | 60 | 0.94 | 0.93 | 0.92 | 0.92 | 0.96 | — | — | — | — | — |
| | 40 | 0.96 | 0.96 | 0.96 | 0.98 | — | — | — | — | — | — |
| 0 | 100 | 0.92 | 0.91 | 0.89 | 0.85 | — | — | — | — | — | — |
| | 80 | 0.94 | 0.93 | 0.92 | 0.91 | — | — | — | — | — | — |
| | 60 | 0.96 | 0.95 | 0.95 | 0.97 | — | — | — | — | — | — |
| | 40 | 0.97 | 0.97 | 0.98 | — | — | — | — | — | — | — |

$D_f$ = doorway flow factor. Equal to 0.8 for a doorway between a freezer and a dock and 1.1 for a doorway between a cooler and a dock[883].

η = Efficiency of refrigeration system (kW/ton). Custom input, if unknown assume 1.6 kW/ton for coolers and 2.4 kW/ton[884] for freezers.

$D_{tB}$ = decimal portion of time doorway is open in the baseline condition. If during facility operating hours, the primary doors are left open, leaving only open-doorway protective devices (e.g., strip curtains) as a barrier, this is considered 1.0. If primary doors are actively operated and do not remain open for the entire time the facility is in operation, refer to the following calculation.

$$D_{tB} = \frac{(P\ \theta_{pB}\ +\ 60\ \theta_{oB})}{3600\ \theta_d}$$

P = Number of passages through doorway per hour.

$\Theta_{pB}$ = Door open to close time in seconds.

$\Theta_{oB}$ = Time door remains open in minutes.

$\Theta_d$ = Period of time considered in hours, 1 hr.

$D_{tE}$ = decimal portion of time doorway is open in the efficient condition.

$$D_{tE} = \frac{(P\ \theta_{pE}\ +\ 60\ \theta_{oE})}{3600\ \theta_d}$$

883 ASHRAE, "Refrigerated –Facility Loads", in Refrigeration Handbook 2014: ASHRAE, 2014, 24.7
884 Professional judgement, in alignment with typical freezer and cooler performance found in the Michigan Energy Measures Database (MEMD).

$P$ = Number of passages through doorway per hour. Custom input, assume 5.9[885] if unknown.

$\Theta_{pE}$ = Door open to close time in seconds. Custom input, assume 7.5 seconds[886] if unknown.

$\Theta_{oE}$ = Time door remains open in minutes. Custom input, assume 3 minutes[887] if unknown.

$\Theta_d$ = Period of time considered in hours, 1 hr.

$D_{tM}$ = decimal portion of time high speed door motor is operational.

$$D_{tM} = \frac{P\ \theta_{pE}}{3600\ \theta_d}$$

Variables defined above.

$E_B$ = effectiveness of baseline open-doorway protective device (strip curtains). Equal to 0.85[888].

$E_E$ = effectiveness of efficient open-doorway protective device. Equal to 0, unless an additional protective device exists to limit infiltration during times when the high-speed door is open.

M = operating input power of the high speed door motor, in kW.

= Custom input, assume 1.49kW[889] if unknown.

t = hours per year when primary doors to the cooled space are open.

= Custom input, assume 2,959 hrs/yr[890] if unknown.

## SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = (ΔkWh / t) * CF

Where

CF = Summer peak coincidence factor for this measure

= 1.0

All other variables as defined above.

## NATURAL GAS ENERGY SAVINGS

N/A

## WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

---

885 ASHRAE, "Refrigerated –Facility Loads", in Refrigeration Handbook 2014: ASHRAE, 2014, 24.11
886 ASHRAE, "Refrigerated –Facility Loads", in Refrigeration Handbook 2014: ASHRAE, 2014, 24.6
887 Professional judgement
888 ASHRAE, "Refrigerated –Facility Loads", in Refrigeration Handbook 2014: ASHRAE, 2014, 24.7
889 Rite Hite – Industrial High Speed Doors, product line commonly uses 2HP drives.
890 Based on a ComEd survey that obtained the number of hours per week certain building types operate. Warehouses had an average response of 55.6 and industrials had 58.2. Calculated by taking the simple average of the two and multiplying by 52 weeks/yr.

### DEEMED O&M COST ADJUSTMENT CALCULATION

Manufacturers suggest annual inspection and maintenance (such as patching tears) of high speed doors. At a minimum, greasing of fittings and oil top-off should be carried out annually. This is estimated at a cost of $150 per year[891].

**MEASURE CODE: CI-RFG-HSRD-V02-190101**

**REVIEW DEADLINE: 1/1/2022**

[891] Assumes approximately 1 hour of maintenance, based on manufacturer product spec sheets.

## 4.6.11 Q-Sync Motors for Reach-in Coolers/Freezers

### DESCRIPTION

This measure is applicable to replacement of an existing, uncontrolled, and continuously operating standard-efficiency shaded-pole and electronically commutated (EC) evaporator fan motors in reach-in refrigerated display cases.

This measure achieves energy savings by installing a more efficient Q-Sync motor in these scenarios (accompanied with replacement fan assembly as necessary). In addition to motor energy savings, the measure also results in less waste heat for the refrigeration equipment to reject and improves the power factor of the equipment.

This measure is limited to a typical reach-in refrigerated display case with the evaporator fan power of 9-12 Watts. In addition to the motor, replacement of the evaporator fan may be necessary to ensure matching airflow is provided (because the fan's speed has been modified). Care must be taken by the installer to ensure airflows remain within the specified range, otherwise fan performance could suffer, causing reliability issues. Q-Sync motors are commonly purchased as a kit, which includes replacement fan blades and shrouds when replacement is necessary.

This measure was developed to be applicable to the following program types: RF, NC[892].

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

The replacement unit must be a Q-Sync motor with a minimum of 73% motor efficiency (as listed by manufacturer).

### DEFINITION OF BASELINE EQUIPMENT

Depending on existing conditions, one of three baselines is chosen:

Baseline 1 is the existing shaded-pole motor(s) with no fan control operating 8760 hours continuously in a refrigerated reach-in display case.

Baseline 2 is an EC motor with no fan control operating 8760 hours continuously in a refrigerated reach-in display case.

Baseline 3 is a blended baseline, consisting of a mix of shaded-pole motors and EC motors that are assumed to be present in retrofit project where accurate counts are unknown or difficult to determine. It is assumed that existing motors have no fan control and operate 8760 hours continuously in refrigerated reach-in display cases.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The deemed measure life is ten years.[893]

### DEEMED MEASURE COST

Actual measure costs should be used if available. If costs are not available, the following deemed measure cost can be used[894].

| Measure | Material Unit (Each) | Material Cost / Unit | Labor Unit (Hours) | Labor Rate / Unit | Total Cost / Unit |
|---|---|---|---|---|---|
| 9-12-watt Q-Sync motor (including replacement fan kit) | 1 | $52 | 0.25 | $120 | $82 |

[892] Customers should be encouraged to check with the manufacturer to determine any impact on warranty of new equipment due to installing Q-sync fan/motor assemblies.
[893] Based on communication with QM Power representative, April 16, 2018. See reference document "4.16.2018 Email.msg"
[894] Based on communication with QM Power representative, April 24, 2018. See reference document "4.24.2018 Email.msg"

Note: the unit cost is based on a large-scale retrofit project.

**LOADSHAPE**

Loadshape C53 - Flat

**COINCIDENCE FACTOR**

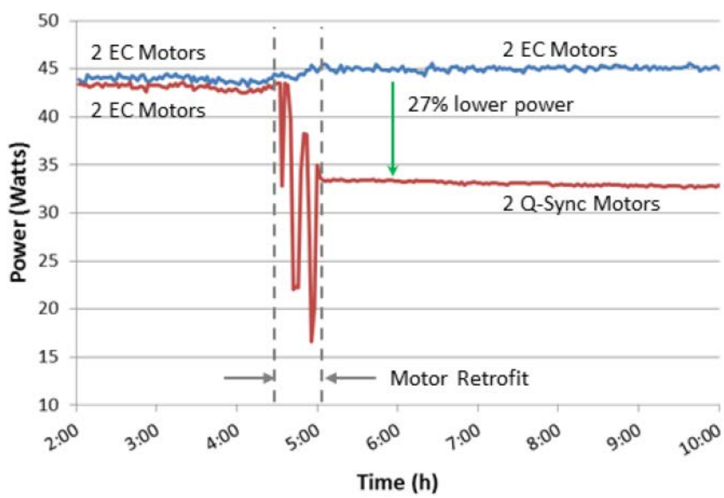
The peak kW coincidence factor is 100%

**Algorithm**

**CALCULATION OF ENERGY SAVINGS**

To determine the savings associated with the Q-Sync motor measure we utilized the field study results provided by Oak Ridge National Laboratory (ORNL)[895] and Alternative Energy Systems Consulting (AESC)[896].

In 2015, ORNL conducted a side-by-side comparison of Q-Sync motors with EC motors in a 16 ft medium-temperature vertical multi-deck refrigerated display case at an Hy-Vee Supermarket in the Kansas City metropolitan area. A retrofit was done on the display case that contained four 12 W EC evaporator fan motors, two in each 8 ft section. Two existing EC motors in one of the 8 ft sections were replaced with two 12 W Q-Sync motors. The initial results show that Q-Sync motors consumed approximately 16.4 watts per motor, and EC motors consumed approximately 22.6 watts per motor[897].




In comparison, the 2011 study by Navigant and PNNL determined that a 12 w shade-pole motor 's actual power is 60.0 watts for use in commercial refrigration equipment at design condition[898], even though some manufacturers also pointed out that "there could be significant variations in efficiency between motors of the same type but different models." In the AESC study, the field test showed that the average input power for each of the 13 shaded

[895] Brian A. Fricke and Bryan R. Becker, "Q-Sync Motors in Commercial Refrigeration: Preliminary Test Results and Projected Benefits," Oak Ridge National Laboratory, September 2015.
[896] M M. Valmiki and Antonio Corradini, "Energy Savings of Permanent Magnet Synchronous Fan Motor Assembly Refrigerated Case Evaporators," Alternative Energy Systems Consulting, August 2016.
[897] Brian A. Fricke and Bryan R. Becker, "Q-Sync Motors in Commercial Refrigeration: Preliminary Test Results and Projected Benefits," Oak Ridge National Laboratory, September 2015.
[898] NCI (Navigant Consulting Inc.) and PNNL (Pacific Northwest National Laboratory), "Preliminary Technical Support Document (TSD): Energy Conservation Program for Certain Commercial and Industrial Equipment: Commercial Refrigeration Equipment," Appliances and Commercial Equipment Standards, Building Technologies Program, Office of Energy Efficiency and Renewable Energy, US Department of Energy, Washington, D.C., 2011.

pole motors retrofitted is 41.6 watts. As a compromise between the two studies, we use 50.0 watts as a representative number for shaded pole motors in our calculation.

The electrical energy savings for replacing a shaded-pole motor with a Q-Sync motor in a retrofit project is calculated by the difference of the two motors demonstrated power draw multiplied by the annual operating hours. For med-temperature cases, T is 8,760 hours. For low-temp freezer cases, T is 8,578 hours considering daily 30-minute defrost cycles during which fans are not powered[899].

Motor energy savings (Baseline 1, med-temp, per motor) = (50 w – 16.4 w) x 8760 hours / 1000 = 294.336 kWh

Motor energy savings (Baseline 1, low-temp, per motor) = (50 w – 16.4 w) x 8578 hours /1000 = 288.221 kWh

The electrical energy savings for replacing an EC motor with a Q-Sync motor in a retrofit project is calculated by the difference of the two motors demonstrated power draw multiplied by the annual operating hours (8760 hours):

Motor energy savings (Baseline 2, med-temp, per motor) = (22.6 w – 16.4 w) x 8760 hours / 1000 = 54.312 kWh

Motor energy savings (Baseline 2, low-temp, per motor) = (22.6 w – 16.4 w) x 8578 hours / 1000 = 53.184 kWh

The reduced motor power will also reduce refrigeration load. Assuming the power to drive the evaporator fan is converted to heat inside the display cases at 100% rate, the reduction in refrigeration system compressor power can be calculated using the following equation:

$$\Delta kWh_{refrigeration} = \frac{\Delta kWh_{motor}}{COP},$$

where COP is the Coefficient of Performance of refrigeration systems in the supermarket display cases. For med-temperature cases, the average COP is 2.5[900]. For low-temp freezer cases, the average COP is 1.3[901].

The refrigeration energy savings can be calculated based on above numbers:

Refrigeration energy savings (Baseline 1, med-temp, per motor) = 117.734 kWh

Refrigeration energy savings (Baseline 1, low-temp, per motor) = 221.708 kWh

Refrigeration energy savings (Baseline 2, med-temp, per motor) = 21.724 kWh

Refrigeration energy savings (Baseline 2, low-temp, per motor) = 40.910 kWh

The overall energy savings are the sums of the motor energy savings and the refrigeration energy savings:

Overall energy savings (Baseline 1, med-temp, per motor) = 412.070 kWh

Overall energy savings (Baseline 1, low-temp, per motor) = 509.929 kWh

Overall energy savings (Baseline 2, med-temp, per motor) = 76.036 kWh

Overall energy savings (Baseline 2, low-temp, per motor) = 94.094 kWh

### ELECTRIC ENERGY SAVINGS

If the numbers of existing shaded-pole motors and EC motors to be retrofitted are known (Baseline 1 & 2):

ΔkWh = Overall annual savings per motor * Motors

Where overall energy savings per motor can is as speficied in the following table:

---

[899] M M. Valmiki and Antonio Corradini, “Energy Savings of Permanent Magnet Synchronous Fan Motor Assembly Refrigerated Case Evaporators,” Alternative Energy Systems Consulting, August 2016.

[900] Michael Deru, et al, “U.S. Department of Energy Commercial Reference Building Models of National Building Stock,” NREL Report TP-5500-46861, February 2011.

[901] Michael Deru, et al, “U.S. Department of Energy Commercial Reference Building Models of National Building Stock,” NREL Report TP-5500-46861, February 2011.

| Evaporator Fan Motor Rating (of Q-Sync motor) | Baseline | Annual kWh Savings/motor |
|---|---|---|
| 9-12W | shaded-pole motor, med-temp | 412.1 |
| 9-12W | shaded-pole motor, low-temp | 509.9 |
| 9-12W | EC motor, med-temp | 76.0 |
| 9-12W | EC motor, low-temp | 94.1 |

Motors = number of fan motors replaced

If the numbers of existing shaded-pole motors and EC motors are unknown in a retrofit project (Baseline 3):

$\Delta kWh = [W_{med\text{-}temp} (W_{SPM} \times S_{SPM\text{-}med} + W_{ECM} \times S_{ECM\text{-}med}) + W_{low\text{-}temp} (W_{SPM} \times S_{SPM\text{-}low} + W_{ECM} \times S_{ECM\text{-}low})] * Motors$

Motors = number of fan motors replaced

S = annual energy savings per motor, by type. Savings for each different type ($S_{SPM\text{-}med}$, $S_{SPM\text{-}low}$, $S_{ECM\text{-}med}$, $S_{ECM\text{-}low}$) can be looked up from the table above.

W = weighting factors. The weights for the medium-temperature and low-temperature applications ($W_{med\text{-}temp}$ and $W_{low\text{-}temp}$) should be calculated based on the actural numbers of motors in a retrofit project, and the sum of the two weights should equal to 1. If these weights cannot be accurately obtained, the estimated weights ($W_{med\text{-}temp}$* and $W_{low\text{-}temp}$*)[902] from the table below can be used (the $W_{SPM}$ and $W_{ECM}$ numbers are slightly adjusted by +/-5% based on national averages in the 2015 ORNL study, reflecting some shaded pole motors may have been replaced with EC motors in the past few years)[903].

| Application | WSPM | WECM | Wmed-temp* | Wlow-temp* |
|---|---|---|---|---|
| Supermarkets | 0.6 | 0.4 | 0.68 | 0.32 |
| Other Food Retail Formats | 0.8 | 0.2 | 0.68 | 0.32 |
| Other Retail Categories | 0.7 | 0.3 | 0.68 | 0.32 |
| Resturants and Bars | 0.85 | 0.15 | 0.68 | 0.32 |
| Beverage Vending Machines | 0.85 | 0.15 | 0.68 | 0.32 |

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$\Delta kW = \Delta kWh / Hours * CF * motors$

Where:

ΔkWh = Gross customer annual kWh savings for the measure, as listed above

Hours = Full Load hours per year

= 8,766 (med-temp); 8,578 (low-temp)

CF = Summer Peak Coincident Factor

= 1.0

Other variables as defined above.

The following table provides the resulting kW savings (per motor):

[902] ASHRAE, "ASHRAE Handbook – Refrigration," ASHRAE, 2018.

[903] NCI (Navigant Consulting Inc.) and PNNL (Pacific Northwest National Laboratory), "Preliminary Technical Support Document (TSD): Energy Conservation Program for Certain Commercial and Industrial Equipment: Commercial Refrigeration Equipment," Appliances and Commercial Equipment Standards, Building Technologies Program, Office of Energy Efficiency and Renewable Energy, US Department of Energy, Washington, D.C., 2011.

| Evaporator Fan Motor Rating (of Q-Sync motor) | Baseline | kW Savings/motor |
|---|---|---|
| 9-12W | shaded-pole motor, med-temp | 0.047 |
| 9-12W | shaded-pole motor, low-temp | 0.059 |
| 9-12W | EC motor, med-temp | 0.009 |
| 9-12W | EC motor, low-temp | 0.011 |

**NATURAL GAS SAVINGS**

N/A

**WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

There is no O&M cost adjustment for replacing shaded pole or EC motors with Q-Sync motors in reach-in refrigerated display case applications. From the 2015 ORNL study[904], the 2016 AESC study[905], and the manufacturer[906], there is no expected degradation in equipment performance after the retrofits, and therefore no O&M cost differences are expected between baseline and efficient measures.

**MEASURE CODE: CI-RFG-QMF-V01-190101**

**REVIEW DEADLINE: 1/1/2022**

904 Brian A. Fricke and Bryan R. Becker, "Q-Sync Motors in Commercial Refrigeration: Preliminary Test Results and Projected Benefits," Oak Ridge National Laboratory, September 2015.
905 M M. Valmiki and Antonio Corradini, "Energy Savings of Permanent Magnet Synchronous Fan Motor Assembly Refrigerated Case Evaporators," Alternative Energy Systems Consulting, August 2016.
906 Based on communication with QM Power representative, August 22, 2018. See reference document "8.22.2018 Email.msg"

## 4.6.12 Variable Frequency Drive for Condenser Fans

### DESCRIPTION

This measure is applicable to VFDs installed on condenser fan motors operating in supermarket refrigeration systems.

Where baseline condenser motor load operates at a fixed-speed, VFDs generate energy and cost savings by modulating frequency and voltage to match the load on the condensers [3]. Savings result from this resulting fan speed variation.

This measure is applicable to motors between 0.5 horsepower and 1.5 horsepower.

This measure was developed to be applicable to the following program types: RF, TOS.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

This measure applies to retrofitted installation of condenser fan motors in supermarkets where no ability to modulate frequency and voltage for fan-speed variation exits. Savings are based on the application of VFDs to baseline load conditions defined as pre-installation load compared to post-installation load.

### DEFINITION OF BASELINE EQUIPMENT

The time-of-sale baseline is a new motor installed without a VFD or other methods of control. Retrofit baseline is an existing motor operating as is.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for VFD condenser fan applications is 15 years.[907]

### DEEMED MEASURE COST

Customer costs will be used when available. For motor sizes 0.5 to 1.5 HP the default measure cost is $1,113/HP. Custom costs must be gathered for other motor sizes.

### LOADSHAPE

C22-commercial refrigeration.

### COINCIDENCE FACTOR

The demand savings factor (DSF) is already based upon coincident savings, and thus there is no additional coincidence factor for this characterization.

**Algorithm**

### CALCULATION OF ENERGY SAVINGS

Energy savings is based on a pre- and post-treatment test. The pre-treatment period being nearly three months in duration with post-treatment of a similar period. Both periods include significant average outdoor temperature (OAT) changes. Measurement of energy savings relies on regression of condenser fan energy use against ambient temperature. These estimates were made on each condenser using both pre- and post-VFD installation; comparison of the two yields savings.[908]

---

[907] Efficiency Vermont TRM 3/16/2015 pp 19 for motor end use-variable frequency drives.

[908] Pre- and post-VFD retrofit kWh consumption were derived from measurement of 14 condensers at 4 supermarkets in Rockford, Il. Annual savings in each Zone is the product of the number of hours in each 5-degree F Typical Meteorological Year

**ELECTRIC ENERGY SAVINGS**

Annual $\Delta kWh_{condenser}$ = No. fans * HP/fan * kWh savings/HP/Zone

| Zone | kWh savings/HP |
|---|---|
| 1 (Rockford) | 1,484 |
| 2 (Chicago) | 1,511 |
| 3 (Springfield) | 1,448 |
| 4 (Belleville) | 1,495 |
| 5 (Marion) | 1,449 |

For example, for a condenser with 5 fans, each rated at 1.5 HP in Chicago (Zone 2):

Annual $\Delta kWh_{condenser}$ = 5 * 1.5 * 1,511

= 11,333 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

N/A

**NATURAL GAS SAVINGS**

N/A

**WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

Variable frequency drives, anecdotally, increase motor life because they allow for soft-start and soft shutdown. This would lead to O&M savings from replacing motors. Unfortunately there is currently insufficient evidence to quantify this savings, so no deemed O&M savings can be claimed at this time.

**MEASURE CODE: CI-RFG-VSC-V01-190101**

**REVIEW DEADLINE: 1/1/2020**

temperature bin multiplied by the mean savings across the 14 condensers measured in the study. Detailed methods, assumptions, and calculations are found in "Variable Frequency Drive Energy Savings in Supermarkets Report. Seventhwave September, 30 2018" [pending report publication by ComEd.] Once published, the report will be made available to Illinois TRM Stakeholders for reference.

# 4.7 Compressed Air

## 4.7.1 VSD Air Compressor

### DESCRIPTION

This measure relates to the installation of an air compressor with a variable frequency drive, load/no load controls or variable displacement control. Baseline compressors choke off the inlet air to modulate the compressor output, which is not efficient. Efficient compressors use a variable speed drive on the motor to match output to the load. Savings are calculated using representative baseline and efficient demand numbers for compressor capacities according to the facility's load shape, and the number of hours the compressor runs at that capacity. Demand curves are as per DOE data for a Variable Speed compressor versus a Modulating compressor. This measure applies only to an individual compressor ≤ 40 hp. Only one compressor per compressed air distribution system is eligible.

This measure was developed to be applicable to the following program types: TOS.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

The high efficiency equipment is a compressor ≤ 40 hp with variable speed control.

### DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is either a modulating compressor with blow down ≤ 40 hp or an oil-free compressor with load/no load controls ≤ 40 hp.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

13 years[909].

### DEEMED MEASURE COST

$$IncrementalCost (\$) = (127 \times hp_{compressor}) + 1446$$

Where:

127 and 1446[910] = compressor motor nominal hp to incremental cost conversion factor and offset

$hp_{compressor}$ = compressor motor nominal

### DEEMED O&M COST ADJUSTMENTS

N/A

### LOADSHAPE

Loadshape C35 - Industrial Process

### COINCIDENCE FACTOR

The summer peak coincidence factor for this measure is dependent on the industrial shift and corresponding hours of operation. Values are provided for each shift type in the variable definition section.

[909] Department of Energy Technical Support Document.

[910] Conversion factor and offset based on a linear regression analysis of the relationship between air compressor motor nominal horsepower and incremental cost, as sourced from the Efficiency Vermont Technical Reference Manual (TRM). Several Vermont vendors were surveyed to determine the cost of equipment.

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

$$\Delta kWh = 0.9 \times hp_{compressor} \times HOURS \times (CF_b - CF_e)$$

Where:

$\Delta$kWh = gross customer annual kWh savings for the measure

$hp_{compressor}$ = compressor motor nominal hp

0.9[911] = compressor motor nominal hp to full load kW conversion factor

HOURS = compressor total hours of operation below depending on shift

| Shift | Hours |
|---|---|
| Single shift (8/5) | 1976 hours<br>7 AM – 3 PM, weekdays, minus some holidays and scheduled down time |
| 2-shift (16/5) | 3952 hours<br>7AM – 11 PM, weekdays, minus some holidays and scheduled down time |
| 3-shift (24/5) | 5928 hours<br>24 hours per day, weekdays, minus some holidays and scheduled down time |
| 4-shift (24/7) | 8320 hours<br>24 hours per day, 7 days a week minus some holidays and scheduled down time |

$CF_b$ = baseline compressor factor[912]

| Baseline Compressor | Compressor Factor |
|---|---|
| Modulating w/ Blowdown | 0.890 |
| Load/No Load w/ 1 Gallon/CFM | 0.909 |
| Load/No Load w/ 3 Gallon/CFM | 0.831 |
| Load/No Load w/ 5 Gallon/CFM | 0.806 |

$CF_e$ = efficient compressor [913]

=0.705

**EXAMPLE**

For example a VFD compressor with 10 HP operating in a 1 shift facility would save

$\Delta$kWh = 0.9 x 10 x 1976 x (0.890 – 0.705)

= 3290 kWh

[911] Conversion factor based on a linear regression analysis of the relationship between air compressor motor nominal horsepower and full load kW from power measurements of 72 compressors at 50 facilities on Long Island, as developed by DOE through a part load compressor analysis and sourced in the Efficiency Vermont TRM.

[912] Compressor factors were developed using DOE part load data for different compressor control types as well as load profiles from 50 facilities employing air compressors less than or equal to 40 hp, as sourced from the Efficiency Vermont TRM.(The "variable speed drive" compressor factor has been adjusted up from the 0.675 presented in the analysis to 0.705 to account for the additional power draw of the VSD).

[913] Ibid.

### Summer Coincident Peak Demand Savings

$\Delta$kW = $\Delta$kWh / HOURS * CF

Where:

CF = Summer peak coincidence factor for this measure

| Shift | Coincidence Factor |
|---|---|
| Single shift (8/5) | 0.59 |
| 2-shift (16/5) | 0.95 |
| 3-shift (24/5) | 0.95 |
| 4-shift (24/7) | 0.95 |

**EXAMPLE**

For example a VFD compressor with 10 HP operating in a 1 shift facility would save

$\Delta$kW = 3290/1976*0.59

= 0.98 kW

### Natural Gas Energy Savings

N/A

### Water Impact Descriptions and Calculation

N/A

### Deemed O&M Cost Adjustment Calculation

N/A

**Measure Code: CI-CPA-VSDA-V02-190101**

**Review Deadline: 1/1/2022**

## 4.7.2 Compressed Air Low Pressure Drop Filters

**DESCRIPTION**

Low pressure drop filters remove solids and aerosols from compressed air systems with a longer life and lower pressure drop than standard coalescing filters, resulting in better efficiencies.

This measure was developed to be applicable to the following program types: RF. If applied to other program types, the measure savings should be verified

**DEFINITION OF EFFICIENT EQUIPMENT**

The efficient condition is a low pressure drop filter with pressure drop not exceeding 1 psid when new and 3 psid at element change.

**DEFINITION OF BASELINE EQUIPMENT**

The baseline condition is a standard coalescing filter with a pressure drop of 3 psid when new and 5 or more at element change

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

10 years [914].

**DEEMED MEASURE COST**

The incremental cost for this measure is estimated to be $1000 Incremental cost per filter[915]

**LOADSHAPE**

Loadshape C35 - Industrial Process

**COINCIDENCE FACTOR**

The summer peak coincidence factor for this measure is dependent on the industrial shift and corresponding hours of operation. Values are provided for each shift type in the variable definition section.

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

$$\Delta kWh = (kW_{typical} \times \Delta P \times SF \times Hours / HP_{typical}) \times HP_{real}$$

Where:

$kW_{typical}$ = Adjusted compressor power (kW) based on typical compressor loading and operating profile. Use Use actual compressor control type if known:

[914] Based on survey of manufacturer claims (Zeks, Van Air, Quincy), as recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.

[915] Incremental cost research found in LPDF Costs. xlsx

Compressor $kW_{typical}$

| Control Type | $kW_{typical}$ [916] |
|---|---|
| Reciprocating - On/off Control | 70.2 |
| Reciprocating - Load/Unload | 74.8 |
| Screw - Load/Unload | 82.3 |
| Screw - Inlet Modulation | 82.5 |
| Screw - Inlet Modulation w/ Unloading | 82.5 |
| Screw - Variable Displacement | 73.2 |
| Screw - VFD | 70.8 |

= If the actual compressor control type is not known, then use a weighted average based on the following market assumptions:

| Control Type | Share % | $kW_{typical}$ [917] |
|---|---|---|
| Market share estimation for load/unload control compressors | 40% | 74.8 |
| Market share estimation for modulation w/unloading control compressors | 40% | 82.5 |
| Market share estimation for variable displacement control compressors | 20% | 73.2 |
| | Weighted Average | 77.6 |

ΔP = Reduced filter loss (psi)

=2 psi[918]

SF =1% reduction in power per 2 psi reduction in system pressure is equal to 0.5% reduction per 1 psi, or a Savings Factor of 0.005[919]

Hours = compressor total hours of operation below depending on shift

| Shift | Hours |
|---|---|
| Single shift (8/5) | 1976 hours<br>7 AM – 3 PM, weekdays, minus some holidays and scheduled down time |
| 2-shift (16/5) | 3952 hours<br>7AM – 11 PM, weekdays, minus some holidays and scheduled down time |
| 3-shift (24/5) | 5928 hours<br>24 hours per day, weekdays, minus some holidays and scheduled down time |
| 4-shift (24/7) | 8320 hours<br>24 hours per day, 7 days a week minus some holidays and scheduled down time |

$HP_{typical}$ = Nominal HP for typical compressor = 100 hp[920]

$HP_{real}$ = Total HP of real compressors distibuting air through filter. This should include the total horsepower of the compressors that normally run through the filter, but not backup compressors

916 See “Industrial System Standard Deemed Saving Analysis.xls”
917 See “Industrial System Standard Deemed Saving Analysis.xls”
918 Assumed pressure will be reduced from a roughly 3 psi pressure drop through a filter to less than 1 psi, for a 2 psi savings
919 “Optimizing Pneumatic Systems for Extra Savings,” Compressed Air Best Practices, DOE Compressed Air Challenge, 2010.

920 Industrial System Standard Deemed Saving Analysis.xls

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$$\Delta kW = \Delta kWh / HOURS * CF$$

Where:

CF = Summer peak coincidence factor for this measure

| Shift | Coincidence Factor |
|---|---|
| Single shift (8/5) | 0.59 |
| 2-shift (16/5) | 0.95 |
| 3-shift (24/5) | 0.95 |
| 4-shift (24/7) | 0.95 |

**NATURAL GAS ENERGY SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-CPA-LPDF-V02-190101**

**REVIEW DEADLINE: 1/1/2022**

## 4.7.3 Compressed Air No-Loss Condensate Drains

**DESCRIPTION**

No-loss condensate drains remove condensate as needed without venting compressed air, resulting in less air demand and consequently better efficiency. Replacement or upgrades of existing no-loss drains are not eligible for the incentive.

This measure was developed to be applicable to the following program types: RF. If applied to other program types, the measure savings should be verified

**DEFINITION OF EFFICIENT EQUIPMENT**

The efficient condition is installation of no-loss condensate drains.

**DEFINITION OF BASELINE EQUIPMENT**

The baseline condition is installation of standard condensate drains (open valve, timer, or both)

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

10 years

**DEEMED MEASURE COST**

$700 per drain [921]

**LOADSHAPE**

Loadshape C35 - Industrial Process

**COINCIDENCE FACTOR**

The coincidence factor equals 0.95[922]

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

$$\Delta kWh = CFM_{reduced} \times kW_{CFM} \times Hours$$

Where:

$CFM_{reduced}$ = Reduced air consumption (CFM) per drain

= 3 CFM[923]

$kW_{CFM}$ = System power reduction per reduced air demand (kw/CFM) depending on the type of compressor control:

System Power Reduction per Reduced Air Demand[924]

---

[921] Based on empirical project data from ComEd Comprehensive Compressed Air Study program and VEIC review of pricing data found in CAS Cost Data.xls

[922] Efficiency Vermont Technical Reference Manual (TRM) Measure Savings Algorithms and Cost Assumptions, August 10, 2016

[923] Reduced CFM consumption is based on a timer drain opening for 10 seconds every 300 seconds as the baseline. See "Industrial System Standard Deemed Saving Analysis.xls"

[924] Calculated based on the type of compressor control. This assumes the compressor will be between 40% and 100% capacity before and after the changes to the system demand. See "Industrial System Standard Deemed Saving Analysis.xls"

| Control Type | kW / CFM |
|---|---|
| Reciprocating - On/off Control | 0.184 |
| Reciprocating - Load/Unload | 0.136 |
| Screw - Load/Unload | 0.152 |
| Screw - Inlet Modulation | 0.055 |
| Screw - Inlet Modulation w/ Unloading | 0.055 |
| Screw - Variable Displacement | 0.153 |
| Screw - VFD | 0.178 |

Or if compressor control type is unknow, then a weighted average based on market share can be used:

| Control Type | Share % | kW / CFM |
|---|---|---|
| Market share estimation for load/unload control compressors | 40% | 0.136 |
| Market share estimation for modulation w/unloading control compressors | 40% | 0.055 |
| Market share estimation for variable displacement control compressors | 20% | 0.153 |
| Weighted Average | | 0.107 |

Hours = Compressed air system pressurized hours

=6136 hours[925]

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = ΔkWh / HOURS * CF

Where:

CF = Summer peak coincidence factor for this measure

= 0.95

**NATURAL GAS ENERGY SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-CPA-NCLD-V02-190101**

**REVIEW DEADLINE: 1/1/2020**

[925] US DOE, Evaluation of the Compressed Air Challenge® Training Program, Page 19

## 4.7.4 Efficient Compressed Air Nozzles

**DESCRIPTION**

This measure is for the replacement of standard air nozzle with high-efficiency air nozzle used in a compressed air system. High-efficiency air nozzles reduce the amount of air required to blow off parts or for drying. These nozzles utilize the Coandă effect to pull in free air to accomplish tasks with significantly less compressed air. High-efficiency nozzles often replace simple copper tubes. These nozzles have the added benefits of noise reduction and improved safety in systems with greater than 30 psig.

**DEFINITION OF EFFICIENT EQUIPMENT**

The high-efficiency air nozzle must meet the following specifications:

1. High-efficiency air nozzle must replace continuous open blow-offs
2. High-efficiency air nozzle must meet SCFM rating at 80psig less than or equal to: 1/8” 11 SCFM, 1/4" 29 SCFM, 5/16” 56 SCFM, 1/2" 140 SCFM.
3. Manufacturer’s specification sheet of the high-efficiency air nozzle must be provided along with the make and model

**DEFINITION OF BASELINE EQUIPMENT**

The baseline condition is a standArd air nozzle

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The measure life is 15 years[926]

**DEEMED MEASURE COST**

The estimated incremental measure costs are presented in the following table[927]

| Nozzle Diameter | 1/8” | 1/4" | 5/16” | 1/2" |
|---|---|---|---|---|
| Average IMC | $42 | $57 | $87 | $121 |

**LOADSHAPE**

Loadshape C35 - Industrial Process

**COINCIDENCE FACTOR**

The summer peak coincidence factor for this measure is dependent on the industrial shift and corresponding hours of operation. Values are provided for each shift type in the variable definition section.

**Algorithm**

**CALCULATION OF ENERGY SAVINGS**

**ELECTRIC ENERGY SAVINGS**

$$\Delta kWh = (SCFM * SCFM\%Reduced) * kW/CFM * \%USE * HOURS$$

[926] PA Consulting Group (2009). Business Programs: Measure Life Study. Prepared for State of Wisconsin Public Service Commission.

[927] Costs are from EXAIR’s website and are an average of nozzles that meet the flow requirements. Models include Atto Super, Pico Super, Nano Super, Micro Super, Mini Super, Super and Large Super nozzles. Accessed March 20, 2014

Where:

SCFM = Air flow through standard nozzle. Use actual rated flow at 80 psi if known. If unknown, the table below includes the CFM by orifice diameter[928, 929].

| Orifice Diameter | SCFM |
|---|---|
| 1/8” | 21 |
| 1/4” | 58 |
| 5/16” | 113 |
| 1/2" | 280 |

SCFM%Reduced = Percent in reduction of air loss per nozzle. Estimated at 50%[930]

kW/CFM = System power reduction per air demand (kW/CFM) depending on the type of air compressor found in table below[931]

| Air Compressor Type | ΔkW/CFM |
|---|---|
| Reciprocating – On/off Control | 0.18 |
| Reciprocating – Load/Unload | 0.14 |
| Screw – Load/Unload | 0.15 |
| Screw – Inlet Modulation | 0.06 |
| Screw – Inlet Modulation w/ Unloading | 0.06 |
| Screw – Variable Displacement | 0.15 |
| Screw - VFD | 0.18 |

%USE = percent of the compressor total operating hours that the nozzle is in use

= Custom, if unknown assume 5%[932]

Hours = Compressed air system pressurized hours.

= Use actual hours if known, otherwise assume values in table below:

| Shift | Hours |
|---|---|
| Single Shift | 1976 |
| Two Shifts | 3952 |
| Three Shifts | 5928 |
| Four Shifts or Continual Operation | 8320 |
| Unknown / Weighted average[933] | 5702 |

928 Review of manufacturer’s information

929 Technical Reference Manual (TRM) for Ohio Senate Bill 221”Energy Efficiency and Conservation Program” and 09-512-GE-UNC, October 15, 2009. Pages 170-171

930 Conservative estimate based on average values provided by the Compressed Air Challenge Training Program, Machinery’s Handbook 25th
Edition, and manufacturers’ catalog.

931 Calculated based on the type of compressor control. This assumes the compressor will be between 40% and 100% capacity before and after the changes to the system demand. See “Industrial System Standard Deemed Saving Analysis.xls”

932 Assumes 50% handheld air guns and 50% stationary air nozzles. Manual air guns tend to be used less than stationary air nozzles, and a conservative estimate of 1 second of blow-off per minute of compressor run time is assumed. Stationary air nozzles are commonly more wasteful as they are often mounted on machine tools and can be manually operated resulting in the possibility of a long term open blow situation. An assumption of 5 seconds of blow-off per minute of compressor run time is used.

933 Weighting of 16% single shift, 23% two shift, 25% three shift and 36% continual based on DOE evaluation of the Compressed Air Challenge, section 2.1.5 Facility Operating Schedules

## SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \Delta kWh/HOURS * CF$$

Where:

ΔkWh = As calculated above

CF = summer peak coincidence factor

| Shift | Coincidence Factor |
|---|---|
| Single Shift | 0.59 |
| Two Shifts | 0.95 |
| Three Shifts | 0.95 |
| Four Shifts or Continual Operation | 0.95 |
| Unknown / Weighted average[934] | 0.89 |

## NATURAL GAS SAVINGS

N/A

## WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

## DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

## MEASURE CODE CI-CPA-CNOZ-V02-190101

## REVIEW DEADLINE: 1/1/2023

[934] Ibid

## 4.7.5 Efficient Refrigerated Compressed Air Dryer

**DESCRIPTION**

An air dryer is an essential component in a compressed air system that prevents condensate from being deposited in the compressed air supply lines of a facility. If the warm, saturated compressed air is supplied directly into the plant, excess condensate will form in the compressed air supply lines. Uncontrolled condensate can damage demand-side tools and process equipment. Secondly, in an oil-flooded rotary screw compressor, the residual oil from compression can be carried along the supply lines potentially damaging process equipment. Industries that use compressed air for processes make use of various types of dryers including refrigerated dryers (both cycling and non-cycling). For this measure, three types of refrigerated air dryers will be considered: thermal mass, variable speed and digital scroll. All of these technologies offer better part load performance compared to non-cycling refrigerated dryers, thereby offering energy savings during periods when the dryer is not operating at peak capacity.

This measure was developed to be applicable to the following program types: TOS.

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

A new, high efficiency thermal mass dryer, variable speed dryer, or digital scroll dryer.

**DEFINITION OF BASELINE EQUIPMENT**

A standard non-cycling refrigerated compressed air dryer of comparable capacity.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The measure life is 13 years.[935]

**DEEMED MEASURE COST**

The incremental capital cost for this measure is $6 per CFM.[936]

**LOADSHAPE**

Loadshape C35 – Industrial Process

**COINCIDENCE FACTOR**

The summer peak coincidence factor for this measure is dependent on the industrial shift and corresponding hours of operation. Values are provided for each shift type in the variable definition section.

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

$$\Delta kWh = P_s \times (EC50_{baseline} - EC50_{efficient}) \times HOURS \times CFM$$

Where:

$P_s$ = Full flow specific power of the dryer

[935] As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.

[936] Analysis of material cost between cycling and non-cycling dryers according to online prices from Grainger. Cost provided is the average incremental cost when comparing non-cycling and cycling dryers of the same CFM capacity.

= 0.007 kW/CFM[937] (for both baseline and efficient equipment)

$EC50_{baseline}$ = Energy consumption ratio of baseline dryer at 50%[938] inlet load capacity as compared to fully loaded operating conditions.[939]

= 0.843

$ECF50_{efficient}$ = Energy consumption ratio of efficient dryer at 50% inlet load capacity as compared to fully loaded operating conditions.

= Dependent on efficient dryer type, refer to the following table[940]:

| Dryer Type | $EC50_{efficient}$ |
|---|---|
| Thermal-Mass | 0.729 |
| VSD | 0.501 |
| Digital Scroll | 0.551 |

HOURS = Compressed air system pressurized hours, depending on shift. If unknown, use weighted average. This value is the weighted average of facility owner responses from the DOE evaluation of the Compressed Air Challenge. Facility owners with compressed air systems were surveyed detailing the number of shifts their facilities operated.

| Shift | Hours | Distribution of Facilities by Hours of Operation[941] | Weighted Hours |
|---|---|---|---|
| Single Shift<br>7 AM – 3 PM, weekdays, minus some holidays and scheduled down time | 1,976 | 16% | 316 |
| Two Shifts<br>7AM – 11 PM, weekdays, minus some holidays and scheduled down time | 3,952 | 23% | 909 |
| Three Shifts<br>24 hours per day, weekdays, minus some holidays and scheduled down time | 5,928 | 25% | 1,482 |
| Four Shifts or Continual Operation<br>24 hours per day, 7 days a week minus some holidays and scheduled down time | 8,320 | 36% | 2,995 |
| | | Total weighted average | 5,702 |

CFM = Cubic feet per minute, rated capacity of refrigerated dryer

= Assume 100% of actual rated capacity.

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$$\Delta kW = \Delta kWh / HOURS * CF$$

Where:

[937] Compressed Air Challenge: Compressed Air Best Practice; "Cycling Air Dryers – Are Savings Significant?" Fox, Timothy J. and Marshall, Ron.
[938] Engineering judgement, based on the assumption that on average, compressed air systems will operate at 50% capacity.
[939] Compressed Air Challenge: Compressed Air Best Practice; "Cycling Air Dryers – Are Savings Significant?" Fox, Timothy J. and Marshall, Ron.
[940] Ibid.
[941] DOE evaluation of the Compressed Air Challenge, section 2.1.5 Facility Operating Schedules.

CF = Summer peak coincidence factor, depending on shift. If unknown, use weighted average.

| Shift | Coincidence Factor |
|---|---|
| Single Shift | 0.59 |
| Two Shifts | 0.95 |
| Three Shifts | 0.95 |
| Four Shifts or Continual Operation | 0.95 |
| Unknown / Weighted average[933] | 0.89 |

**NATURAL GAS ENERGY SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-CPA-CADR-V02-190101**

**REVIEW DEADLINE: 1/1/2024**

# 4.8 Miscellaneous End Use

## 4.8.1 Pump Optimization

### Description

Pump improvements can be done to optimize the design and control of centrifugal water pumping systems, including water solutions with freeze protection up to 15% concentration by volume. Other fluid and gas pumps cannot use this measure calculation. The measurement of energy and demand savings for commercial and industrial applications will vary with the type of pumping technology, operating hours, efficiency, and existing and proposed controls. Depending on the specific application slowing the pump, trimming or replacing the impeller may be suitable options for improving pumping efficiency. Pumps up to 40 HP are allowed to use this energy savings calculation. Larger motors should use a custom calculation (which may result in larger savings that this measure would claim).

### Definition of Efficient Equipment

In order for this characterization to apply, the efficient equipment is proven to be an optimized centrifugal pumping system meeting the applicable program efficiency requirements:

- Pump balancing valves no more than 15% throttled
- Balancing valves on at least one load 100% open.

### Definition of Baseline Equipment

In order for this characterization to apply, the baseline equipment is assumed to be the existing pumping system including existing controls and sequence of operations.

### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 8 years[942]

### Deemed Measure Cost

The incremental capital cost for this measure can vary considerably depending upon the strategy employed to achieve the required efficiency levels and should be determined on a site-specific basis.

### Deemed O&M Cost Adjustments

N/A

### Coincidence Factor

The summer peak coincidence factor for this measure is assumed to be 38%[943]

**Algorithm**

### Calculation of Savings

### Electric Energy Savings

$$\Delta kWh = (HP_{motor} * 0.746 * LF / \eta_{motor}) * HOURS * ESF$$

[942] SCE Pump Test Final Report (2009), Summit Blue Consulting, LLC. This value is a weighted average of estimates provided by program participants.
[943] Summer Peak Coincidence Factor has been preserved from the “Technical Reference Manual” (TRM) for Ohio Senate Bill 221 Energy Efficiency and Conservation Program and 09-512-GE-UNC,” October 15, 2009. This is likely a conservative estimate, but is recommended for further study (as stated in the OH State TRM, page 269)

Where:

$HP_{motor}$ = Installed nameplate motor horsepower

= Actual

0.746 = Conversion factor from horse-power to kW (kW/hp)

$LF / \eta_{motor}$ = Combined as a single factor since efficiency is a function of load

= 0.65 [944]

Where:

LF = Load Factor; Ratio of the peak running load to the nameplate rating of the motor

$\eta_{motor}$ = Motor efficiency at pump operating conditions

HOURS = Annual operating hours of the pump

= Actual

ESF = Energy Savings Factor; assume a value of 15%[945].

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$$\Delta kW = (HP_{motor} * 0.746 *( LF / \eta_{motor})) * (ESF) * CF$$

Where:

CF = Summer Coincident Peak Factor for measure

**NATURAL GAS ENERGY SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-MSC-PMPO-V02-190101**

**REVIEW DEADLINE: 1/1/2022**

944 "Measured Loading of Energy Efficient Motors - the Missing Link in Engineering Estimates of Savings," ACEEE 1994 Summer Study Conference, Asilomar, CA.

945 Published estimates of typical pumping efficiency improvements range from 5 to 40%. For analysis purposes, assume 15%. United States Industrial Electric Motor Systems Market Opportunities Assessment December 2002, Table E-7, Page 18.

## 4.8.2 Roof Insulation for C&I Facilities

### DESCRIPTION

Energy and demand saving are realized through reductions in the building cooling and heating loads. This measure was developed to be applicable to the following program types: RF and NC.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

The efficient condition is above code and should be determined by the program.

### DEFINITION OF BASELINE EQUIPMENT

The retrofit baseline condition is adopted from Ohio Energy Technical Reference Manual and expanded to cover all type of commercial buildings in the state of Illinois as follows.

For retrofits, the R-value for the entire assembly:

| Building Type | Retrofit Assembly R-Value |
|---|---|
| Assembly | 13.5 |
| Assisted Living | 13.5 |
| College | 13.5 |
| Convenience Store | 13.5 |
| Elementary School | 13.5 |
| Garage | 13.5 |
| Grocery | 13.5 |
| Healthcare Clinic | 13.5 |
| High School | 13.5 |
| Hospital | 13.5 |
| Hotel/Motel | 13.5 |
| Manufacturing Facility | 12 |
| MF - High Rise | 13.5 |
| MF - Mid Rise | 13.5 |
| Movie Theater | 13.5 |
| Office - High Rise | 13.5 |
| Office - Low Rise | 13.5 |
| Office - Mid Rise | 13.5 |
| Religious Building | 13.5 |
| Restaurant | 13.5 |
| Retail - Department Store | 13.5 |
| Retail - Strip Mall | 13.5 |
| Warehouse | 12 |
| Unknown | 13.5 |

For new construction use R-value from IECC 2012 or ASHRAE – 90.1 – 2010, or use IECCC 2015 or ASHRAE – 90.1 – 2013, depending on the IECC in effect on the date of the building permit (if unknown assume IECC 2015).

Note IECC 2018 (based on ASHRAE 90.1-2016) is scheduled to become effective March 1, 2019 and will become baseline for all New Construction permits from that date.

<u>R-Values: ASHRAE – 90.1 – 2010</u>

| | IL TRM Zones 1, 2, & 3 [ASHRAE/IECC Climate Zone 5 (A, B, C)] | | | |
|---|---|---|---|---|
| | Nonresidential | | Semiheated | |
| | Assembly Maximum | Insulation Min. R-Value | Assembly Maximum | Insulation Min. R-Value |
| Insulation Entirely Above Deck | 0.048 | R-20 c.i. | U-0.119 | R-7.6 c.i. |
| Metal Building (Roof) | 0.055 | R-13.0 + R-13.0 | U-0.083 | R-13.0 |
| Attic and Other | 0.027 | R-38.0 | U-0.053 | R-19.0 |

| | IL TRM Zones 4 & 5 [ASHRAE/IECC Climate Zone 4 (A, B, C)] | | | |
|---|---|---|---|---|
| | Nonresidential | | Semiheated | |
| | Assembly Maximum | Insulation Min. R-Value | Assembly Maximum | Insulation Min. R-Value |
| Insulation Entirely Above Deck | 0.048 | R-20.0 c.i. | 0.173 | R-5.0 c.i. |
| Metal Building (Roof) | 0.055 | R-13.0 + R-13.0 | 0.097 | R-10.0 |
| Attic and Other | 0.027 | R-38.0 | 0.053 | R-19.0 |

Table Notes
c.i. = continuous insulation

R-Values: ASHRAE – 90.1 – 2013 and 2016

| | IL TRM Zones 1, 2, & 3 [ASHRAE/IECC Climate Zone 5 (A, B, C)] | | | |
|---|---|---|---|---|
| | Nonresidential | | Semiheated | |
| | Assembly Maximum | Insulation Min. R-Value | Assembly Maximum | Insulation Min. R-Value |
| Insulation Entirely Above Deck | 0.032 | R-30.0 c.i. | 0.063 | R-15 c.i. |
| Metal Building (Roof) | 0.037 | R-19 + R-11 Ls or R-25 + R-8 Ls | 0.082 | R-19 |
| Attic and Other | 0.021 | R-49 | 0.034 | R-30 |

| | IL TRM Zones 4 & 5 [ASHRAE/IECC Climate Zone 4 (A, B, C)] | | | |
|---|---|---|---|---|
| | Nonresidential | | Semiheated | |
| | Assembly Maximum | Insulation Min. R-Value | Assembly Maximum | Insulation Min. R-Value |
| Insulation Entirely Above Deck | 0.032 | R-30.0 c.i. | 0.093 | R-10 c.i. |
| Metal Building (Roof) | 0.037 | R-19 + R-11 Ls or R-25 + R-8 Ls | 0.082 | R-19 |
| Attic and Other | 0.021 | R-49 | 0.034 | R-30 |

Table Notes
c.i. = continuous insulation

Ls = linear system, a continuous vapor barrier liner installed below the purlins and uninterrupted by framing members

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure expected useful life (EUL) is assumed to be 20 years per DEER 2008. This is consistent with SDG&E's 9th Year Measure Retrofit Study (1996 & 1997 Residential Weatherization Programs), CPUC's Energy Efficiency Policy Manual v.2, and GDS's Measure Life Report Residential and Commercial/Industrial Lighting and HVAC Measures (June 2007).

### DEEMED MEASURE COST

Per the W017 Itron California Measure Cost Study[946], the material cost for R-30 insulation is $0.59 per square foot. The installation cost is $0.81 per square foot. The total measure cost, therefore, is $1.40 per square foot of insulation installed. However, the actual cost should be used when available.

### LOADSHAPE

Loadshape C03: Commercial Cooling

### COINCIDENCE FACTOR

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [947]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [948]

## Algorithm

### CALCULATION OF ENERGY SAVINGS

### ELECTRIC ENERGY SAVINGS

Electric energy savings is calculated as the sum of energy saved when cooling the building and energy saved when heating the building

$$\Delta kWh = \Delta kWh\_cooling + \Delta kWh\_heating$$

If central cooling, the electric energy saved in annual cooling due to the added insulation is

$$\Delta kWh\_cooling = ((1/R\_existing) - (1/R\_new)) * Area * EFLH_{cooling} * \Delta T_{AVG,cooling} / 1{,}000 / \eta\_cooling$$

Where:

R_existing = Roof heat loss coefficient with existing insulation [(hr-$^oF$-ft$^2$)/Btu]

R_new = Roof heat loss coefficienty with new insulation [(hr-$^oF$-ft$^2$)/Btu]

Area = Area of the roof surface in square feet. Assume 1000 sq ft for planning.

$EFLH_{cooling}$ = Equivalent Full Load Hours for Cooling [hr] are provided in Section 4.4, HVAC end use

$\Delta T_{AVG,cooling}$ = Average temperature difference [$^oF$] during cooling season between outdoor air temperature and assumed 75$^oF$ indoor air temperature

| Climate Zone (City based upon) | $OA_{AVG,cooling}$ [°F][949] | $\Delta T_{AVG,cooling}$ [°F] |
|---|---|---|
| 1 (Rockford) | 81 | 6 |
| 2 (Chicago) | 81 | 6 |
| 3 (Springfield) | 81 | 6 |
| 4 (Belleville) | 82 | 7 |

[946] Measure costs are from the "2010-2012 WO017 Ex Ante Measure Cost Study", Itron, California Public Utilities Commission, May 2014. The data is provided in a file named "MCS Results Matrix – Volume I".
[947] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility's peak hour is divided by the maximum AC load during the year.
[948] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year
[949] National Solar Radiation Data Base -- 1991- 2005 Update: Typical Meteorological Year 3

| Climate Zone (City based upon) | $OA_{AVG,cooling}$ [°F][949] | $\Delta T_{AVG,cooling}$ [°F] |
|---|---|---|
| 5 (Marion) | 82 | 7 |

1,000 = Conversion from Btu to kBtu

η_cooling = Seasonal energy efficiency ratio (SEER) of cooling system (kBtu/kWh). Use actual if possible, if unknown and for planning purposes assume the following:

| Year Equipment was Installed | SEER estimate |
|---|---|
| Before 2006 | 10 |
| After 2006 | 13 |

If the building is heated with electric heat (resistance or heat pump), the electric energy saved in annual heating due to the added insulation is

$$\Delta kWh\_heating = [(1/R\_existing) - (1/R\_new)] * Area * EFLH_{heating} * \Delta T_{AVG,heating} / 3,412 / \eta\_heating$$

Where:

$EFLH_{heating}$ = Equivalent Full Load Hours for Heating [hr] are provided in Section 4.4, HVAC end use

$\Delta T_{AVG,heating}$ = Average temperature difference [$^oF$] during heating season between outdoor air temperature and assumed 55$^o$F heating base temperature

| Climate Zone (City based upon) | $OA_{AVG,heating}$ [°F][950] | $\Delta T_{AVG,heating}$ [°F] |
|---|---|---|
| 1 (Rockford) | 32 | 23 |
| 2 (Chicago) | 34 | 21 |
| 3 (Springfield) | 35 | 20 |
| 4 (Belleville) | 36 | 19 |
| 5 (Marion) | 39 | 16 |

3,142 = Conversion from Btu to kWh.

η_heating = Efficiency of heating system. Use actual efficiency. If not available refer to default table below.

| System Type | Age of Equipment | HSPF Estimate | ηHeat (Effective COP Estimate) (HSPF/3.413)*0.85 |
|---|---|---|---|
| Heat Pump | Before 2006 | 6.8 | 1.7 |
| | After 2006 | 7.7 | 1.92 |
| Resistance | N/A | N/A | 1 |

If the building is heated with a gas furnace, there will be some electric savings in heating the building attributed to extra insulation since the furnace fans will run less.

$$\Delta kWh\_heating = \Delta Therms * Fe * 29.3$$

Where:

ΔTherms = Gas savings calculated with equation below.

Fe = Percentage of heating energy consumed by fans, assume 3.14%

[950] National Solar Radiation Data Base -- 1991- 2005 Update: Typical Meteorological Year 3

29.3 = Conversion from therms to kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$$\Delta kW = (\Delta kWh\_cooling / EFLH\_cooling) * CF$$

Where:

$EFLH_{cooling}$ = Equivalent full load hours of air conditioning are provided in Section 4.4, HVAC end use

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [951]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8% [952]

**NATURAL GAS SAVINGS**

If building uses a gas furnace, the savings resulting from the insulation is calculated with the following formula.

$$\Delta Therms = ((1/R\_existing) - (1/R\_new)) * Area * EFLH_{heating} * \Delta T_{AVG,heating} / 100{,}000 / \eta\_heat$$

Where:

R_existing = Roof heat loss coefficient with existing insulation [(hr-$^{o}$F-ft$^{2}$)/Btu]

R_new = Roof heat loss coefficienty with new insulation [(hr-$^{o}$F-ft$^{2}$)/Btu]

Area = Area of the roof surface in square feet. Assume 1000 sq ft for planning.

$EFLH_{heating}$ = Equivalent Full Load Hours for Heating are provided in Section 4.4, HVAC end use

$\Delta T_{AVG,heating}$ = Average temperature difference [$^{o}$F] during heating season (see above)

100,000 = Conversion from BTUs to Therms

η_heat = Efficiency of existing furnace. Assume 0.78 for planning purposes.

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-MSC-RINS-V03-190101**

**REVIEW DEADLINE: 1/1/2021**

[951] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility's peak hour is divided by the maximum AC load during the year.

[952] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year

## 4.8.3 Computer Power Management Software

**DESCRIPTION**

Computer power management software is installed on a network of computers. This is software which monitors and records computer and monitor usage, as well as allows centralized control of computer power management settings.

**DEFINITION OF EFFICIENT EQUIPMENT**

The efficient equipment is defined by the requirements listed below:

- Allow centralized control and override of computer power management settings of workstations which include both a computer monitor and CPU (i.e. a desktop or laptop computer on a distributed network)
- Be able to control on/off/sleep states on both the CPU and monitor according to the Network Administrator-defined schedules and apply power management policies to network groups
- Have capability to allow networked workstations to be remotely wakened from power-saving mode (e.g. for system maintenance or power/setting adjustments)
- Have capability to detect and monitor power management performance and generate energy savings reports
- Have capability to produce system reports to confirm the inventory and performance of equipment on which the software is installed.

This measure was developed to be applicable to the following program types: Retrofit. If applied to other program types, the measure savings should be verified.

**DEFINITION OF BASELINE EQUIPMENT**

Baseline is defined as a computer network without software enforcing the power management capabilities in existing computers and monitors.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected measure life is five years.[953]

**DEEMED MEASURE COST**

The deemed measure cost is $29 per networked computer, including labor.[954]

**LOADSHAPE**

Loadshape C21: Commercial Office Equipment.

**COINCIDENCE FACTOR**

N/A

[953] The following reference uses 10 years, however, given the rapid changes in the technology industry, there is quite a lot of uncertainty about the measure life and a more conservative value was used (i.e. half the published measure life): Table VI.1: Dimetrosky, S., Luedtke, J. S., & Seiden, K. (2005). Surveyor Network Energy Manager: Market Progress Evaluation Report, No. 2 (Northwest Energy Efficiency Alliance report #E05-136). Portland, OR: Quantec, LLC).

[954] Work Paper WPSCNROE0003 Revision 1, Power Management Software for Networked Computers. Southern California Edison

**Algorithm**

## CALCULATION OF ENERGY SAVINGS

### ELECTRIC ENERGY SAVINGS

$$\Delta kWh = Wsavings * W$$

Where:

Wsavings = annual energy savings per workstation

= 200 kWh[955] for desktops, 50 kWh for laptops[956]

= If unknown assume 161 kWh (based on 74% desktop and 26% laptop[957])

W = number of desktop or laptop workstations controlled by the power management software

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

NA

### NATURAL GAS SAVING

NA

### WATER IMPACT DESCRIPTIONS AND CALCULATION

NA

### DEEMED O&M COST ADJUSTMENT CALCULATION

Assumed to be $2/unit [958]

**MEASURE CODE: CI-MSC-CPMS-V01-150601**

**REVIEW DEADLINE: 1/1/2020**

---

[955] Based on average energy savings/computer from the following sources:
South California Edison, Work Paper WPSCNROE0003 (200k Wh)
Surveyor Network Energy Manager Evaluation Report , NEEA (68, 100, and 128kWh)
Regional Technical Forum, UES Measures, Non-Res Network Computer Management (200 kWh)
EnergySTAR Computer Power Management Savings Calculator (~190 kWh for a mix of laptop/desktop and assuming 30% are already turned off at night) Power Management for Networked Computers: A Review of Utility Incentive Programs J. Michael Walker, Beacon Consultants Network Inc., 2009 ACEEE Summer Study on Energy Efficiency in Industry (330 kWh)

[956] Power Management for Networked Computers: A Review of Utility Incentive Programs J. Michael Walker, Beacon Consultants Network Inc., 2009 ACEEE Summer Study on Energy Efficiency in Industry

[957] Based on PY6 ComEd Computer Software Program data showing a split of 74% desktop to 26% laptop.

[958] Based on Dimetrosky, S., Luedtke, J. S., & Seiden, K. (2005). Surveyor Network Energy Manager: Market Progress Evaluation Report, No. 2 (Northwest Energy Efficiency Alliance report #E05-136). Portland, OR: Quantec LLC and review of CLEARResult document providing Qualifying Software Providers for ComEd program and their licensing fees; “Qualifying Vendor Software Comparison.pdf”.

## 4.8.4 Modulating Commercial Gas Clothes Dryer

### Description

This measure relates to the installation of a two-stage modulating gas valve retrofit kit on a standard commercial non-modulating gas dryer. Commercial gas clothes dryers found in coin-operated laundromats or on-premise laundromats (hospitals, hotels, health clubs, etc.) traditionally have a single firing rate which is sized properly for highest heat required in initial drying stages but is oversized for later drying stages requiring lesser heat. This causes the burner to cycle on/off frequently, resulting in less efficient drying and wasted gas. Replacing the single stage gas valve with a two-stage gas valve allows the firing rate to adjust to the changing heat demand, thereby reducing overall gas consumption.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

A 30 to 250 pound capacity commercial gas dryer retrofitted with a two-stage modulating gas valve kit.

### Definition of Baseline Equipment

A 30 to 250 pound capacity commercial gas dryer with no modulating capabilities.

### Deemed Lifetime of Efficient Equipment

The deemed measure life for the retrofit kit is 14 years, assumed to be equal to that of a commercial gas dryer[959].

### Deemed Measure Cost

The full retrofit cost is assumed to be $700, including the material cost for the basic modulating gas valve retrofit kit ($600) and the associated of labor for installation ($100)[960].

### Loadshape

N/A

### Coincidence Factor

N/A

**Algorithm**

### Calculation of Savings

### Electric Energy Savings

N/A

### Summer Coincident Peak Demand Savings

N/A

[959] Zhang, Yanda, and Julianna Wei. *Commerical Clothes Dryers, CASE Initiative for PY2013: Title 20 Standards Development.* California Public Utilities Commission, 2013.

[960] Engineering judgement, based on observed costs during Nicor Gas pilot study. "Nicor Gas Emerging Technology Program, 1036: Commercial Dryer Modulation Retrofit Public Project Report." 2014.

## NATURAL GAS ENERGY SAVINGS

*Note: Accurately estimating dryer energy consumption is complicated and challenging due to a variety of factors that influence cycle times and characteristics and ultimately drying energy requirements. Clothing loads can vary by weight, volume, fiber composition, physical structure, and initial water content, meaning that for any given cycle drying energy requirements can differ. Additionally, dryer settings selected by the user as well as interactions with the site's HVAC systems are known to influence dryer performance. As better information becomes available, this characterization can be modified to allow for a more site-specific estimation of savings.*

$\Delta Therms = N_{Cycles} * SF$

Where:

$N_{Cycles}$ = Number of dryer cycles per year. Refer to the table below if this value is not directly available.

| Application | Cycles per Year |
|---|---|
| Coin- Operated Laundromats[961] | 1,483 |
| Multi-family Dryers[962] | 1,074 |
| On-Premise Laundromats[963] | 3,607 |

SF = Savings factor

= 0.18 therms/cycle[964]

If using default cycles the savings are as follows:

| Application | ΔTherms |
|---|---|
| Coin- Operated Laundromats[965] | 267 |
| Multi-family Dryers[966] | 193 |
| On-Premise Laundromats[967] | 649 |

## WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

## DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

## MEASURE CODE: CI-MSC-MODD-V01-160601

## REVIEW DEADLINE: 1/1/2023

961 From DOE's Federal Register Notices, Energy Conservation Program: Energy Conservation Standards for Commercial Clothes Dryers, Office of Energy Efficiency & Renewable Energy

962 Ibid.

963 Average value for dryer cycles in healthcare facility, hotels, drycleaners and laundromats from tests conducted in Nicor Gas Emerging Technology Program's Commercial Dryer Modulation Retrofit Public Project Report.

964 Based on Illinois weather data, and average dryer performance for laundromat (30 to 45lb) and hotel (75 to 170 lb) dryers. See GTI Analysis.xlsx for complete derivation.

965 From DOE's Federal Register Notices, Energy Conservation Program: Energy Conservation Standards for Commercial Clothes Dryers, Office of Energy Efficiency & Renewable Energy

966 Ibid.

967 Average value for dryer cycles in healthcare facility, hotels, drycleaners and laundromats from tests conducted in Nicor Gas Emerging Technology Program's Commercial Dryer Modulation Retrofit Public Project Report.

## 4.8.5 High Speed Clothes Washer

### Description

This measure applies to the installation of clothes washers with extraction speeds of 200 g or greater, which is significantly higher than traditional hard-mount washers. Standard washer extractors in laundromats operate at speeds of 70-80[968] g. The high-speed extraction process in the wash cycle removes more water from each compared to standard washers, reducing operating time and gas consumption of clothes dryers. Heat exposure and mechanical action are also reduced, resulting in less linen wear.

This measure was developed to be applicable to the following program types: TOS, NC, EREP. If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

The efficient equipment is assumed to be a clothes washer with an extraction speed of 200 g or greater, installed in a commercial laundromat.

### Definition of Baseline Equipment

The baseline equipment is assumed to be a clothes washer with an extraction speed of 100 g or less, installed in a commercial laundromat.

### Deemed Lifetime of Efficient Equipment

The measure lifetime is assumed to be the typical lifetime of a commercial clothes washer: 7 years[969].

For early replacement measures it is assumed the existing unit would last another 2.3 years[970]

### Deemed Measure Cost[971]

The incremental cost for time of sale is $9.70/lb capacity.

The full cost of the high speed washer for early replacement applications is $164.89/lb capacity. The deferred replacement cost of the baseline unit is $155.19/lb capacity. This future cost should be discounted to present value using the real discount rate:

### Loadshape

N/A

### Coincidence Factor

N/A

**Algorithm**

### Calculation of Savings

### Electric Energy Savings

N/A

[968] "The Real Size of a Front Load Washer", Laundromat123
[969] "Assessment of Water Savings for Commercial Washers: Report on the Monitoring and Assessment of Water Savings from the Coin-Operated Multi-Load Clothes Washers Voucher Initiative Program." San Diego County Water Authority October 2016.
[970] Third of expected measure life.
[971] Measure costs are based on data from a quote provided by a commercial washer distributor to Franklin Energy Services.

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

#### NATURAL GAS SAVINGS

$$\Delta Therms = (Ncycles * Days * Capacity * RMC * h_e / \eta_{dryer} /100{,}000) * DryerUse * LF$$

Where:

Ncycles = Average number of washer cycles per day

= Use values from table below, depending on application

| Application | Ncycles |
|---|---|
| Coin-operated Laundromats | 4.3[972] |
| Multi-family | 3.4[973] |
| Hotel/Motel/Hospital | 10.4[974] |

Days = Days per year of commercial laundromat operation

= Actual, or if unknown, assume 360 days[975]

Capacity = Clothes washer rated capacity (lb/cycle)[976]

= Actual

RMC = Retained Moisture Content (%)[977] reduction from replacing a low extraction speed washer

= Assume 25%[978]

[972]"2014-2015 State of the Self-Service Laundry Industry Report." Carlo Calma, April 13, 2015.

[973] "Assessment of Water Savings for Commercial Washers: Report on the Monitoring and Assessment of Water Savings from the Coin-Operated Multi-Load Clothes Washers Voucher Initiative Program." San Diego County Water Authority October 2016.

[974] "Laundry Planning Guide." EDRO, January 2015.

[975] Based on professional judgement, assuming closed on holidays.

[976] Clothes washer capacity is based on weight of dry clothing.

[977] The EDRO "Laundry Planning Guide" describes moisture retention as "the ratio of retained moisture weight to clean dry textile weight." The pounds of water retained by clothing at the end of a wash cycle is calculated by multiplying Capacity (lbs of dry clothing per cycle) by RMC.

[978] Using chart provided (Figure 1) and assuming a 100% nominal cotton load, the retained moisture drops from approximately 90% to 65% when a 100 g washer is replaced with a 200 g washer. Chart from "Laundry Planning Guide." EDRO, January 2015.

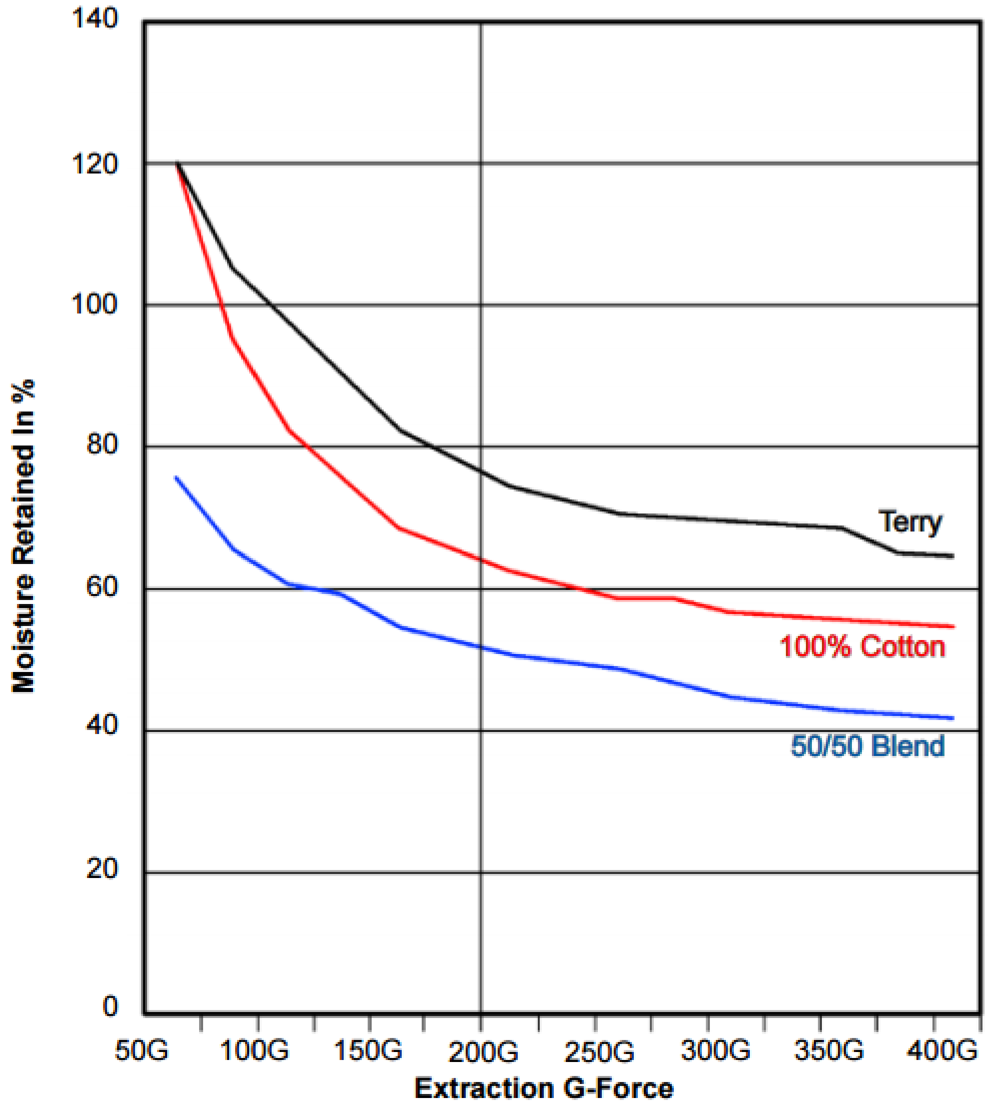



**Figure 1**

$h_e$ = Heat required by a dryer to evaporate 1 lb of water

= Assume 1,200 Btu/lb[979]

$\eta_{dryer}$ = Efficiency of the clothes dryer

= Actual, or if unknown, assume 60%[980]

100,000 = Converts Btus to therms

DryerUse = % of washer loads dried in the field

= Assume 91%[981]

LF = Load Factor (%) to account for the pounds per washer load, as a percentage of rated capacity

---

979 "Laundry Planning Guide." EDRO, January 2015.

980 ACEEE (2010), "Are We Missing Energy Savings in Clothes Dryers?" Paul Bendt (Ecos), 2010

981 "Dryer Field Study." Northwest Energy Efficiency Alliance, November 20, 2014.

= Assume 66%[982]

**EXAMPLE**

For example, a clothes washer with a 14 lb/cycle capacity and installed at a coin-operated laundromat, using default assumptions, would save:

ΔTherms = (Ncycles * Days * Capacity * RMC * $h_e$ / $\eta_{dryer}$ /100,000) * DryerUse * LF

= (4.3 * 360 * 14 * 0.25 * 1,200 / 0.60 /100,000) * 0.91 * 0.66

= 65 therms

**WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-MSC-HSCW-V01-180101**

**REVIEW DEADLINE: 1/1/2021**

[982]"Assessment of Water Savings for Commercial Washers: Report on the Monitoring and Assessment of Water Savings from the Coin-Operated Multi-Load Clothes Washers Voucher Initiative Program." San Diego County Water Authority October 2016.

## 4.8.6 ENERGY STAR Computers

### DESCRIPTION

This measure estimates savings for a desktop computer with ENERGY STAR (ES) Version 6.0 rating, ES 6.0 +20%, ES 6.0 with 80 PLUS Gold PSUs, and ES 6.0 with 80 PLUS Platinum PSUs.

This measure was developed to be applicable to the following program types: TOS. If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

The efficient product is a desktop with a rating of ENERGY STAR Version 6.0 rating, ES 6.0 +20%, ES 6.0 with 80 PLUS Gold PSUs, or ES 6.0 with 80 PLUS Platinum PSUs.

### DEFINITION OF BASELINE EQUIPMENT

Non ENERGY STAR qualified equipment with standard efficiency power supply

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The life of this measure is 4 years.[983]

### DEEMED MEASURE COST[984]

The incremental cost for an 80 Plus Desktop PSU is $5.
The incremental cost for an ENERGY STAR desktop PSU is $20.

### LOADSHAPE

C21 Commercial Office Equipment

### COINCIDENCE FACTOR

N/A

**Algorithm**

### CALCULATION OF ENERGY SAVINGS

### ELECTRIC ENERGY SAVINGS[985]

$$\Delta kWh = 8760/1000 * (((Watts_{Base,Off} * \%Time_{Off}) + (Watts_{Base,Sleep} * \%Time_{Sleep}) + (Watts_{Base,Long} * \%Time_{Long}) + (Watts_{Base,Short} * \%Time_{Short})) - ((Watts_{Eff,Off} * \%Time_{Off}) + (Watts_{Eff,Sleep} * \%Time_{Sleep}) + (Watts_{Eff,Long} * \%Time_{Long}) + (Watts_{Eff,Short} * \%Time_{Short})))$$

Where (see assumptions in table below):

8760/1000 = Converts W to kWh

$Watts_{Base,Off}$ = baseline equipment power in off mode

$\%Time_{Off}$ = typical percent of time a desktop, integrated desktop or notebook is in off mode during the year

$Watts_{Base,Sleep}$ = baseline equipment power in sleep mode

983 Codes and Standards Enhancement (CASE) Initiative For PY 2013: Title 20 Standards Development, August 6, 2013. Page 6.
984 Research Into Action, 80 PLUS Market Progress Evaluation Report #5, November 26, 2013. Page 24.
985 Algorithm comes from ENERGY STAR Version 6.0 Guide

$\%Time_{Sleep}$ = typical percent time in sleep mode

$Watts_{Base,Long}$ = baseline equipment power in long idle mode

$\%Time_{Long}$ = typical percent time in long idle mode

$Watts_{Base,Short}$ = baseline equipment power in short idle mode

$\%Time_{Short}$ = typical percent time in short idle mode

$Watts_{Eff,Off}$ = efficient equipment power in off mode

$Watts_{Eff,Sleep}$ = efficient equipment power in sleep mode

$Watts_{Eff,Long}$ = efficient equipment power in long idle mode

$Watts_{Eff,Short}$ = efficient equipment power in short idle mode

| Measure Annual Mode Time (%) | Off | Sleep | Long Idle | Short Idle |
|---|---|---|---|---|
| Duty cycle - Commercial[986] | 45% | 5% | 15% | 35% |

| Measure Watt Draw in Mode (Watts) | Off | Sleep | Long Idle | Short Idle |
|---|---|---|---|---|
| Baseline[987] | 0.88 | 2.1 | 26.5 | 27.9 |
| ES 6.0 Desktops[988] | 0.55 | 1.23 | 24.66 | 26.04 |
| ES 6.0 +20% Desktops[989] | 0.52 | 1.63 | 21.33 | 22.58 |
| ES 6.0 Desktops w/ 80 PLUS Gold PSUs[990] | 0.50 | 1.50 | 23.08 | 24.38 |
| ES 6.0 Desktops w/ 80 PLUS Platinum PSUs[991] | 0.50 | 1.50 | 22.19 | 23.44 |

Calculated energy consumption in each mode, and savings provided below:

| Measure TEC by Mode (kWh) Commercial | Off | Sleep | Long Idle | Short Idle | TEC (kWh/yr) | Savings (kWh/yr) |
|---|---|---|---|---|---|---|
| Baseline | 3.5 | 0.9 | 34.8 | 85.5 | 124.8 | N/A |
| ES 6.0 Desktops | 2.2 | 0.5 | 32.4 | 79.9 | 115.0 | 9.8 |
| ES 6.0 +20% Desktops | 2.0 | 0.7 | 28.0 | 69.2 | 100.0 | 24.7 |
| ES 6.0 Desktops w/ 80 PLUS Gold PSUs | 2.0 | 0.7 | 30.3 | 74.7 | 107.7 | 17.1 |
| ES 6.0 Desktops w/ 80 PLUS Platinum PSUs | 2.0 | 0.7 | 29.2 | 71.9 | 103.7 | 21.1 |

Savings calculations can be referenced in "ENERGY STAR Desktop Analysis.xlsx"

986 ECMA 283, Appendix B, Majority Profile Study; ENERGY STAR v6.0 duty cycle. For more information, see the ENERGY STAR Program Requirements Product Specification for Computers, version 6.1, effective June 2, 2014

987 Codes and Standards Enhancement (CASE) Initiative For PY 2013: Title 20 Standards Development, August 6, 2013

988 Analysis of current DT I2 category desktops in ENERGY STAR version 6.0 Qualified Products List (QPL).

989 Analysis of current DT I2 category desktops in ENERGY STAR version 6.0 Qualified Products List (QPL), passing with > 20% margin.

990 80 PLUS program savings calculator, additional 6.4% savings over ES v6.0 Bronze PSU levels. Based on program measurements from 80 PLUS Certified Power Supplies and Management.

991 80 PLUS program savings calculator, additional 10% savings over ES v6.0 Bronze PSU levels.

### SUMMER COINCIDENT PEAK DEMAND SAVINGS[992]

$\Delta kW = (Watts_{Base} - Watts_{Eff})/1000 * CF$

Where:

$Watts_{Base}$ = Assumed average baseline wattage during peak period (see table below)

$Watts_{Eff}$ = Assumed average efficient wattage during peak period (see table below)

CF = Summer Peak Coincidence Factor

= 1.0

Calculated average demand during peak period, and savings provided below:

| Measure TEC by Mode (kWh) Commercial | TEC (watts) | Demand Savings |
|---|---|---|
| Baseline | 25.2 | N/A |
| ES 6.0 Desktops | 23.4 | 0.0018 |
| ES 6.0 +20% Desktops | 20.3 | 0.0048 |
| ES 6.0 Desktops w/ 80 PLUS Gold PSUs | 21.9 | 0.0032 |
| ES 6.0 Desktops w/ 80 PLUS Platinum PSUs | 21.1 | 0.0041 |

Savings calculations can be referenced in “ENERGY STAR Desktop Analysis.xlsx”

### NATURAL GAS SAVINGS

N/A

### WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION

N/A

### DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

### MEASURE CODE: CI-MSC-COMP-V01-180101

### REVIEW DEADLINE: 1/1/2020

[992] It assumed that computers will not be off during peak period, and that the weighting of sleep, long idle and short idle during peak hours is consistent with the whole year. Wattage assumptions are weighted accordingly and coincidence factor is thus assumed to be 1.0 – see “ENERGY STAR Desktop Analysis.xlsx” for calculation.

## 4.8.7 Advanced Power Strip – Tier 1 Commercial

### DESCRIPTION

This measure relates to Advanced Power Strips – Tier 1 which are multi-plug power strips with the ability to automatically disconnect specific connected loads depending upon the power draw of a control load, also plugged into the strip. Power is disconnected from the switched (controlled) outlets when the control load power draw is reduced below a certain adjustable threshold, thus turning off the appliances plugged into the switched outlets. By disconnecting, the standby load of the controlled devices, the overall load of a centralized group of equipment (e.g. a desk workstation) can be reduced. In a commercial office space, savings generally occur during off-hours, when connected equipment continues to consume electricity while in standby mode or when off. Uncontrolled outlets are also provided that are not affected by the control device and so are always providing power to any device plugged into it.

This measure was developed to be applicable to the following program types: DI.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

The efficient case is an advanced power strip with a load-sensing master plug and at least two controlled plugs.

### DEFINITION OF BASELINE EQUIPMENT

The assumed baseline is a standard power strip with surge protection that does not control connected loads.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The assumed lifetime of the advanced power strip is 7 years.[993]

### DEEMED MEASURE COST

For direct install the actual full install cost (including labor) and for kits the full equipment cost should be used.

### LOADSHAPE

Loadshape C47 – Standby Losses – Commercial Office[994]

### COINCIDENCE FACTOR

N/A due to no savings attributable to standby losses between 1 and 5 PM.

---

[993] This is a consistent assumption with 5.2.2 Advanced Power Strip – Tier 2.

[994] Loadshapes were calculated from empirical studies and compared to the existing loadshape in Volume 1, Table 3.5. The studies were:
Acker, Brad *et. al,* "Office Space Plug Load Profiles and Energy Saving Interventions," 2012 ACEEE Summer Study on Energy Efficiency in Buildings.
Sheppy, M. *et al*, "Reducing Plug Loads in Office Spaces" Hawaii and Guam Energy Improvement Technology Demonstration Project, NREL/NAVFAC (January 2014).

**Algorithm**

### CALCULATION OF ENERGY SAVINGS

### ELECTRIC ENERGY SAVINGS

$\Delta kWh$[995] = $((kW_{wkday} * (hrs_{wkday} - hrs_{wkday\text{-}open})) + (kW_{wkend} * (hrs_{wkend} - hrs_{wkend\text{-}open}))) * weeks/year * ISR$

Where:

$W_{wkday}$ = Standby power consumption of connected electronics on weekday off-hours. If unknown, assume 0.0315 kW.

$kW_{wkend}$ = Standby power consumption of connected electronics on weekend off-hours. If unknown, assume 0.00617 kW.

$hrs_{wkday}$ = total hours during the work week (Monday 7:30 AM to Friday 5:30 PM)

= 106

$hrs_{wkend}$ = total hours during the weekend (Friday 5:30 PM to Monday 7:30 AM)

= 62

$hrs_{wkday\text{-}open}$ = hours the office is open during the work week. If unknown, assume 50 hours.

$hrs_{wkend\text{-}open}$ = hours the office is open during the weekend. If unknown, assume 0 hours.

weeks/year = number of weeks per year

= 52.2

ISR = In Service Rate

= Assume 0.969 for commercial Direct Install application[996]

For example, an office open 9 hours per day (45 hours per week) on weekdays and 4 hours on Saturday:

$\Delta kWh$ = ((0.0315 * (106 - 45)) + (0.00617 * (62 - 4))) * 52.2 * 0.969

= 115 kWh

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A due to no savings attributable to standby losses between 1 and 5 PM.

### NATURAL GAS SAVINGS

N/A

### WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION

N/A

[995] Savings algorithm reconstructed from weekday and weekend savings information in Sheppy *et. al*, and verified against savings in Acker *et. al* and savings in: BPA, "Smart Power Strip Energy Savings Evaluation: Ross Complex," (2011). Office stations are assumed to have zero or minimal standy losses during normal operating hours. Method shown in "Commercial Tier 1 APS Calculations – IL TRM.xlsx".

[996] Based upon review of the PY2 and PY3 ComEd Direct Install Residential program surveys. This value could be modified based upon commercial application evaluation.

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-MSC-APSC-V02-190101**

**REVIEW DEADLINE: 1/1/2020**

## 4.8.8 High Efficiency Transformer

### DESCRIPTION

Distribution transformers are used in commercial and industrial applications to step down power from distribution voltage to be used in HVAC or process loads (220V or 480V) or to serve plug loads (120V).
Distribution transformers that are more efficient than the required minimum federal standard efficiency qualify for this measure. If there is no specific standard efficiency requirement, the transformer does not qualify (because we cannot define a reasonable baseline). For example, although the federal standards increased the minimum required efficiency in 2016, most transformers with a NEMA premium or CEE Tier 2 rating will still achieve energy conservation. Standards are defined for low-voltage dry-type distribution transformers (up to 333kVA single-phase and 1000kVA 3-phase), liquid-immersed distribution transformers (up to 833kVA single-phase and 2500kVA 3-phase), and medium-voltage dry-type distribution transformers (up to 833kVA single-phase and 2500kVA 3-phase).

This measure was developed to be applicable to the following program types: TOS, NC.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

Any transformer that is more efficient than the federal minimum standard. This includes CEE Tier II (single or three phase) and most NEMA premium efficiency rated products.

### DEFINITION OF BASELINE EQUIPMENT

A transformer that meets the minimum federal efficiency requirement should be used as the baseline to calculate savings. Standards are developed by the Department of Energy and published in the Federal Register 10CFR 431[997].

**(a)** ***Low-Voltage Dry-Type Distribution Transformers.***

**(2)** The efficiency of a low-voltage dry-type distribution transformer manufactured on or after January 1, 2016, shall be no less than that required for their kVA rating in the table below. Low-voltage dry-type distribution transformers with kVA ratings not appearing in the table shall have their minimum efficiency level determined by linear interpolation of the kVA and efficiency values immediately above and below that kVA rating.

| Single-phase | | Three-phase | |
|---|---|---|---|
| kVA | Efficiency (%) | kVA | Efficiency (%) |
| 15 | 97.70 | 15 | 97.89 |
| 25 | 98.00 | 30 | 98.23 |
| 37.5 | 98.20 | 45 | 98.40 |
| 50 | 98.30 | 75 | 98.60 |
| 75 | 98.50 | 112.5 | 98.74 |
| 100 | 98.60 | 150 | 98.83 |
| 167 | 98.70 | 225 | 98.94 |
| 250 | 98.80 | 300 | 99.02 |
| 333 | 98.90 | 500 | 99.14 |
| | | 750 | 99.23 |
| | | 1000 | 99.28 |

**(b)** ***Liquid-Immersed Distribution Transformers.***

[997] US Department of Energy, "Energy Conservation Program: Energy Conservation Standards for Distribution Transformers; Final Rule", 10 CFR Part 431, Published April 18, 2013, Compliance effective as of January 1, 2016.

**(2)** The efficiency of a liquid-immersed distribution transformer manufactured on or after January 1, 2016, shall be no less than that required for their kVA rating in the table below. Liquid-immersed distribution transformers with kVA ratings not appearing in the table shall have their minimum efficiency level determined by linear interpolation of the kVA and efficiency values immediately above and below that kVA rating.

| Single-phase | | Three-phase | |
|---|---|---|---|
| kVA | Efficiency (%) | kVA | Efficiency (%) |
| 10 | 98.70 | 15 | 98.65 |
| 15 | 98.82 | 30 | 98.83 |
| 25 | 98.95 | 45 | 98.92 |
| 37.5 | 99.05 | 75 | 99.03 |
| 50 | 99.11 | 112.5 | 99.11 |
| 75 | 99.19 | 150 | 99.16 |
| 100 | 99.25 | 225 | 99.23 |
| 167 | 99.33 | 300 | 99.27 |
| 250 | 99.39 | 500 | 99.35 |
| 333 | 99.43 | 750 | 99.40 |
| 500 | 99.49 | 1000 | 99.43 |
| 667 | 99.52 | 1500 | 99.48 |
| 833 | 99.55 | 2000 | 99.51 |
| | | 2500 | 99.53 |

**(c)** ***Medium-Voltage Dry-Type Distribution Transformers.***

**(2)** The efficiency of a medium- voltage dry-type distribution transformer manufactured on or after January 1, 2016, shall be no less than that required for their kVA and BIL rating in the table below. Medium-voltage dry-type distribution transformers with kVA ratings not appearing in the table shall have their minimum efficiency level determined by linear interpolation of the kVA and efficiency values immediately above and below that kVA rating.

| 1 | | | | Three-phase | | | |
|---|---|---|---|---|---|---|---|
| kVA | BIL* | | | kVA | BIL | | |
| | 20-45 kV | 46-95 kV | ≥96 kV | | 20-45 kV | 46-95 kV | ≥96 kV |
| | Efficiency (%) | Efficiency (%) | Efficiency (%) | | Efficiency (%) | Efficiency (%) | Efficiency (%) |
| 15 | 98.10 | 97.86 | | 15 | 97.50 | 97.18 | |
| 25 | 98.33 | 98.12 | | 30 | 97.90 | 97.63 | |
| 37.5 | 98.49 | 98.30 | | 45 | 98.10 | 97.86 | |
| 50 | 98.60 | 98.42 | | 75 | 98.33 | 98.13 | |
| 75 | 98.73 | 98.57 | 98.53 | 112.5 | 98.52 | 98.36 | |
| 100 | 98.82 | 98.67 | 98.63 | 150 | 98.65 | 98.51 | |
| 167 | 98.96 | 98.83 | 98.80 | 225 | 98.82 | 98.69 | 98.57 |
| 250 | 99.07 | 98.95 | 98.91 | 300 | 98.93 | 98.81 | 98.69 |
| 333 | 99.14 | 99.03 | 98.99 | 500 | 99.09 | 98.99 | 98.89 |
| 500 | 99.22 | 99.12 | 99.09 | 750 | 99.21 | 99.12 | 99.02 |
| 667 | 99.27 | 99.18 | 99.15 | 1000 | 99.28 | 99.20 | 99.11 |
| 833 | 99.31 | 99.23 | 99.20 | 1500 | 99.37 | 99.30 | 99.21 |
| | | | | 2000 | 99.43 | 99.36 | 99.28 |
| | | | | 2500 | 99.47 | 99.41 | 99.33 |

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

30 years[998]

### DEEMED MEASURE COST

Actual incremental costs should be used.

### LOADSHAPE

Use custom loadshape based on application; default loadshape is Loadshape C53 – Flat.

### COINCIDENCE FACTOR

Coincidence Factor for distribution transformers is 1.0 by definition. By including the load factor in the demand savings calculation, the load profile is accounted for.

## Algorithm

### CALCULATION OF ENERGY SAVINGS

Savings are determined by metering equipment

### ELECTRIC ENERGY SAVINGS

$$\Delta kWh = Losses_{base} - Losses_{EE}$$

Where:

$$Losses_{base} = \text{PowerRating} * \text{LF} * \text{PF} * \left(\frac{1}{EFF_{base}} - 1\right) * 8766$$

$$Losses_{EE} = \text{PowerRating} * \text{LF} * \text{PF} * \left(\frac{1}{EFF_{EE}} - 1\right) * 8766$$

PowerRating = kVA rating of the transformer (in units of kVA)

$EFF_{base}$ = baseline total efficiency rating of federal minimum standard transformer (refer to baseline tables above based on kVA, voltage, and type of transformer)

$EFF_{EE}$ = actual total efficiency rating of the transformer as calculated by the appropriate DOE test method[999]

LF = Load Factor for the transformer. Ratio of average transformer load to peak load rating over a period of one year. Use actual load factor for the network segment served based on historical data. If unknown, use 22% for commercial load and 45% for industrial load.[1000]

PF = Power Factor for the load being served by the transformer. Ratio of real power to apparent power supplied to the transformer. Use actual power factor for the network segment served. If unknown, use 1.0 (unity) by default.[1001]

---

[998] US DOE lists lifetime at 32 years. For consistency with efficiency measure evaluated lifetimes, 30 years is the recommended maximum deemed lifetime. US Department of Energy, "Energy Conservation Program: Energy Conservation Standards for Distribution Transformers; Final Rule", 10 CFR Part 431, Published April 18, 2013, Effective as of January 1, 2016.

[999] Energy Conservation Program: Test Procedures for Distribution Transformers; Final Rule. Effective May 30, 2006.

[1000] Guidelines on The Calculation and Use of Loss Factors, Electric Authority, Te Mana Hiko, February 14, 2013

[1001] Unity power factor for used as default value, as used in the test procedures provided by US DOE. Energy Conservation Program: Test Procedures for Distribution Transformers; Final Rule. Effective May 30, 2006.

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$$\Delta kW = PowerRating * \ LF * PF * \left(\frac{1}{Eff_{base}} - \frac{1}{Eff_{EE}}\right)$$

Variables as provided above.

**NATURAL GAS SAVINGS**

N/A

**WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-MSC-TRNS-V01-180101**

**REVIEW DEADLINE: 1/1/2021**

## 4.8.9 High Frequency Battery Chargers

### Description

This measure applies to industrial high frequency battery chargers, used for industrial equipment such as fork lifts, replacing existing SCR (silicon controlled rectifier) or ferroresonant charging technology. High frequency battery chargers have a greater system efficiency.

This measure was developed to be applicable to the following program types: TOS, NC. If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

High frequency battery charger systems with minimum Power Conversion Efficiency of 90% and a minimum 8-hour shift operation five days per week.

### Definition of Baseline Equipment

SCR or ferroresonant battery charger systems with minimum 8-hour shift operation five days per week.

### Deemed Lifetime of Efficient Equipment

15 years[1002]

### Deemed Measure Cost

The deemed incremental measure cost is $400[1003]

### Loadshape

Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights)
Loadshape C15 - Indust. 2-shift (16/5) (e.g., comp. air, lights)
Loadshape C16 - Indust. 3-shift (24/5) (e.g., comp. air, lights)
Loadshape C17 - Indust. 4-shift (24/7) (e.g., comp. air, lights)

### Coincidence Factor

The coincidence factor is assumed to be 0.0 for 1 and 2-shift operation and 1.0 for 3 and 4-shift operation. [1004]

---

**Algorithm**

---

### Electric Energy Savings

$$\Delta kWh = (CAP * DOD) * CHG * (CR_B / PC_B - CR_{EE} / PC_{EE})$$

Where:

CAP = Capacity of Battery

= Use actual battery capacity, otherwise use a default value of 35 kWh[1005]

DOD = Depth of Discharge

---

[1002] Suzanne Foster Porter et al., "Analysis of Standards Options for Battery Charger Systems", (PG&E, 2010), 45
[1003] Suzanne Foster Porter et al., "Analysis of Standards Options for Battery Charger Systems", (PG&E, 2010), 42
[1004] Emerging Technologies Program Application Assessment Report #0808, Industrial Battery Charger Energy Savings Opportunities, Pacific Gas & Electric. May 29, 2009.
[1005] Jacob V. Renquist, Brian Dickman, and Thomas H. Bradley, :"Economic Comparison of fuel cell powered forklifts to battery powered forklifts", International Journal of Hydrogen Energy Volume 37, Issue 17, (2012): 2

= Use actual depth of discharge, otherwise use a default value of 80%.[1006]

CHG = Number of Charges per year

= Use actual number of annual charges, if unknown use values below based on the type of operations[1007]

| Standard Operations | Number of Charges per year |
|---|---|
| 1-shift (8 hrs/day – 5 days/week) | 520 |
| 2-shift (16 hrs/day – 5 days/week) | 1040 |
| 3-shift (24 hrs/day – 5 days/week) | 1560 |
| 4-shift (24 hrs/day – 7 days/week) | 2184 |

$CR_B$ = Baseline Charge Return Factor

= 1.2485[1008]

$PC_B$ = Baseline Power Conversion Efficiency

= 0.84[1009]

$CR_{EE}$ = Efficient Charge Return Factor

= 1.107[1010]

$PC_{EE}$ = Efficient Power Conversion Efficiency

= 0.89[1011]

Default savings using defaults provided above are provided below:

| Standard Operations | ΔkWh |
|---|---|
| 1-shift (8 hrs/day – 5 days/week) | 3,531 |
| 2-shift (16 hrs/day – 5 days/week) | 7,061 |
| 3-shift (24 hrs/day – 5 days/week) | 10,592 |
| 4-shift (24 hrs/day – 7 days/week) | 14,829 |

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$$\Delta kW = (PF_B/PC_B - PF_{EE}/PC_{EE}) * Volts_{DC} * Amps_{DC} / 1000 * CF$$

Where:

$PF_B$ = Power factor of baseline charger

= 0.9095[1012]

[1006] Ryan Matley, “Measuring Energy Efficiency Improvements in Industrial Battery Chargers”, (ESL-IE-09-05-32, Energy Technology Conference, New Orleans, LA, May 12-15, 2009), 4

[1007] Number of charges is derived from the following reference and adjusted to the hours and days of the different types of shift operations. These values are based on an estimated 2-charge per 8-hour workday. See reference file Ryan Matley, “Measuring Energy Efficiency Improvements in Industrial Battery Chargers”, (ESL-IE-09-05-32, Energy Technology Conference, New Orleans, LA, May 12-15, 2009), 4

[1008] Ryan Matley, “Measuring Energy Efficiency Improvements in Industrial Battery Chargers”, (ESL-IE-09-05-32, Energy Technology Conference, New Orleans, LA, May 12-15, 2009), 4 (average of SCR and Ferroresonant)

[1009] Ibid.

[1010] Ibid.

[1011] Ibid.

[1012] Ibid.

$PF_{EE}$ = Power factor of high frequency charger

= 0.9370[1013]

$Volts_{DC}$ = Actual DC rated voltage of charger (assumed baseline charger is replaced with same rated high frequency unit)

= Use actual battery DC voltage rating, otherwise use a default value of 48 volts.[1014]

$Amps_{DC}$ = Actual DC rated amperage of charger (assumed baseline charger is replaced with same rated high frequency unit)

= Use actual battery DC ampere rating, otherwise use a default value of 81 amps.[1015]

1,000 = watt to kilowatt conversion factor

CF = Summer Coincident Peak Factor for this measure

= 0.0 (for 1 and 2-shift operation)[1016]

= 1.0 (for 3 and 4-shift operation)[1017]

Other variables as provided above.

Default savings using defaults provided above are provided below:

| Standard Operations | ΔkW |
|---|---|
| 1-shift (8 hrs/day – 5 days/week) | 0 |
| 2-shift (16 hrs/day – 5 days/week) | 0 |
| 3-shift (24 hrs/day – 5 days/week) | 0.1165 |
| 4-shift (24 hrs/day – 7 days/week) | 0.1165 |

**NATURAL GAS SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-MSC-BACH-V01-180101**

**REVIEW DEADLINE: 1/1/2021**

1013 Ibid.

1014 Voltage rating based on the assumption of 35kWh battery with a normalized average amp-hour capacity of 760 Ah charged over a 7.5 hour charge cycle. Pacific Gas & Electric, "Emerging Technologies Program Application Assessment Report #0808", Industrial Battery Charger Energy Savings Opportunities. May 29, 2009. Page 8, Table 3.

1015 Ampere rating based on the assumption of 35kWh battery with a normalized average amp-hour capacity of 760 Ah charged over a 7.5 hour charge cycle. Pacific Gas & Electric, "Emerging Technologies Program Application Assessment Report #0808", Industrial Battery Charger Energy Savings Opportunities. May 29, 2009. Page 8, Table 3.

1016 Emerging Technologies Program Application Assessment Report #0808, Industrial Battery Charger Energy Savings Opportunities, Pacific Gas & Electric. May 29, 2009.

1017 Ibid.

## 4.8.10 Commercial Clothes Dryer Moisture Sensor

### Description

This measure applies to moisture sensing controllers installed on new or existing commercial natural gas clothes dryers controlled electronically. Moisture controllers detect when the load is dry, which will stop the cycle from consuming additional energy. Some new commercial dryers utilize moisture sensors, but the majority of older dryers, as well as many new models, still do not utilize moisture sensors. In a commercial dyer, when a load is drying, the heat will run completely on in the early stages. Then, it begins to cycle on and off more frequently as the load becomes drier. Traditional moisture sensors use a conductivity strip in the dryer drum. The wet load will contact the strip that completes the circuit. When the load is dry, the circuit is shorted that completes the drying cycle. Instead, this technology is a "plug and play" retrofit controller that uses patent-pending software to determine when the load is dry. When the load is dry, it overrides the existing controls to end the cycle, which shuts the drying cycle. This measure does not apply to mechanical timer dryers or to dryers with modulating valves installed.

Natural gas energy savings will be achieved by reduced drying times and correspondingly reduced natural gas consumption. Electric savings will also be achieved by reduced operating times.

This measure was developed to be applicable to following facility types:

- Hotel/Motel
- Miscellaneous - Fitness and Recreational Sports Centers
- Hospital
- Assisted Living Facilities
- Miscellaneous - Dry cleaning
- Multifamily

Moisture sensing controller retrofits could create significant energy savings opportunities at other larger facility types with on-premise laundry operations (such as correctional facilities, universities, and staff laundries); however, the results included in this analysis are based heavily on past project data for the applicable facility types listed above and may not apply to facilities outside of this list due to variances in number of loads and average pound (lbs.) capacity per project site. Projects at these facilities should continue to be evaluated through custom programs and the applicable facility types and the resulting analysis should be updated based on new information.

This measure was developed to be applicable to the following program types: RF. If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

A retrofit moisture controlling technology is added to new or existing commercial natural gas clothes dryers. Existing facilities must be able to confirm that they do not have moisture sensors (conductive strip type) or modulating gas valves installed on clothes dryers already before proceeding with the installation of this technology.

### Definition of Baseline Equipment

The baseline equipment is a conventional natural gas clothes dryer without a moisture sensor or a modulating gas valve installed.

### Deemed Lifetime of Efficient Equipment

The equipment effective useful life (EUL) is 14 years based on manufacturer claims, assumed to be equal to that of a commercial dryer.[1018]

[1018] Zhang, Yanda, and Julianna Wei. *Commerical Clothes Dryers, CASE Initiative for PY2013: Title 20 Standards Development.* California Public Utilities Commission, 2013.

### DEEMED MEASURE COST

The full retrofit cost is assumed to be $600, including the material cost for the basic moisture control retrofit ($500) and the associated labor for installation ($100).[1019]

### LOADSHAPE

Loadshape C55; Commercial Clothes Washer

### COINCIDENCE FACTOR

The coincidence factor for this measure is dependent on the application:

| Application | Coincidence Factor[1020] |
|---|---|
| Multi-family Dryers | 0.15 |
| On-Premise Laundromats | 0.52 |

## Algorithm

### CALCULATION OF ENERGY SAVINGS

### ELECTRIC ENERGY SAVINGS

Electric energy savings are per retrofitted dryer.

$\Delta kWh = N_{Cycles} * SF$

Where:

$N_{Cycles}$ = Number of dryer cycles per year. Refer to the table below if this value is not directly available from the facility.

| Application | Cycles per Dryer Per Year |
|---|---|
| Multi-family Dryers[1021] | 1,074 |
| On-Premise Laundromats[1022] | 3,607 |

SF = Savings factor

= 0.16 kWh/cycle[1023]

If using default cycles the savings are as follows:

| Application | ΔkWh per Dryer |
|---|---|
| Multi-family Dryers | 171.8 |
| On-Premise Laundromats | 577.1 |

[1019] Based on Gas Technology Institute's analysis of cost data from "Nicor Gas Emerging Technology Program, 1069: Moisture Sensor Retrofit, Comprehensive Pilot Assessment Report," May 1, 2017.

[1020] In the absence of loadshape information for commercial applications, this is estimated by adjusting the residential coincidence factor proportionately by the relative number of loads (264 for residential and as described in this measure for commercial applications).

[1021] From DOE's Federal Register Notices - found here: http://energy.gov/eere/buildings/recent-federal-register-notices

[1022] Average value for dryer cycles in healthcare facility, hotels, drycleaners and laundromats from tests conducted in Nicor Gas Emerging Technology Program's Commercial Dryer Modulation Retrofit Public Project Report.

[1023] Savings factor based on engineering analysis of savings data from "Nicor Gas Emerging Technology Program, 1069: Moisture Sensor Retrofit, Comprehensive Pilot Assessment Report," May 1, 2017 and "Advanced Commercial Clothes Dryer Technologies Field Test," prepared by Gas Technology Institute for the Minnesota Department of Commerce, January 15, 2018.

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$$\Delta kW = \Delta kWh / Hours * CF$$

Where:

Hours = Assumed Run hours of Clothes Dryer[1024]

| Application | Hours |
|---|---|
| Multi-family Dryers | 806 |
| On-Premise Laundromats | 2,705 |

CF = Summer Peak Coincidence Factor for measure.

| Application | Coincidence Factor[1025] |
|---|---|
| Multi-family Dryers | 0.15 |
| On-Premise Laundromats | 0.52 |

If using default cycles the savings are as follows:

| Application | ΔkW per Dryer |
|---|---|
| Multi-family Dryers | 0.0320 |
| On-Premise Laundromats | 0.1109 |

**NATURAL GAS SAVINGS**

Natural gas savings are per retrofitted dryer.

$$\Delta Therms = N_{Cycles} * SF$$

Where:

SF = Savings factor

= 0.15 therms/cycle[1026]

If using default cycles the savings are as follows:

| Application | ΔTherms per Dryer |
|---|---|
| Multi-family Dryers | 161 |
| On-Premise Laundromats | 541 |

**WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-MSC-CDMS-V01-190101**

**REVIEW DEADLINE: 1/1/2023**

[1024] Estimate based on 45 minutes per cycle.

[1025] In the absence of loadshape information for commercial applications, this is estimated by adjusting the residential coincidence factor proportionately by the relative number of loads (264 for residential and as described in this measure for commercial applications).

[1026] Savings factor based on engineering analysis of savings data from "Nicor Gas Emerging Technology Program, 1069: Moisture Sensor Retrofit, Comprehensive Pilot Assessment Report," May 1, 2017 and "Advanced Commercial Clothes Dryer Technologies Field Test," prepared by Gas Technology Institute for the Minnesota Department of Commerce, January 15, 2018.

## 4.8.11 Efficient Thermal Oxidizers

**DESCRIPTION**

Thermal Oxidizers are used to destroy volatile organic compounds (VOCs) from process exhausts, before emitting the treated air to the environment. VOC emissions are precursors to the formation of ground-level ozone pollution, and its control is mandated by the U.S. EPA. Some VOC constituents are individually toxic and require efficient destruction. Some waste streams have high enough concentrations to present an explosion hazard. Other waste streams merely present nuisance odors that need to be mitigated.

A facility may be required to utilize a Thermal Oxidizer by a state regulatory agency air quality permit. Some permits may require a VOC destruction efficiency that must be demonstrated with periodic emissions testing. Other permits merely require maintaining an oxidizer chamber temperature. A facility may also choose to utilize a Thermal Oxidizer for other purposes (nuisance odors), without a regulatory requirement.

The Efficient Thermal Oxidizer measure seeks to evaluate natural gas savings from utilizing more efficient means for VOC destruction with the use of a recuperative or regenerative thermal oxidizer. The heat recovery (either Recuperative or Regenerative) is used to pre-heat the inlet process air stream. This primary heat recovery is used within the thermal oxidizer process and the only heat recovery that is covered in this measure protocol. Natural gas savings will result from reduced burner firing. There is a "secondary" form of heat recovery that recovers heat from the combustion exhaust stack for other purposes like space heating, DHW heating, etc.

**DEFINITION OF EFFICIENT EQUIPMENT**

Two Thermal Oxidizer technologies can be considered as efficient equipment: Recuperative and Regenerative.

Recuperative Thermal Oxidizer

In a Recuperative Thermal Oxidizer, the exhaust air stream is sent through a heat exchanger to indirectly pre-heat the inlet air stream coming from the process. The heat exchanger efficiency[1027] for a recuperator is typically 50-70%. The chamber temperature is typically 1400 $^{o}$F to 1500 $^{o}$F.

Regenerative Thermal Oxidizer

A Regenerative Thermal Oxidizer utilizes a two-chamber ceramic bed as its heat exchanger system. The exhaust air passes through one bed, imparting its heat onto the ceramic media, while the intake air passes through the other bed, capturing the waste heat from the previous cycle. The flow reverses every few minutes so that the intake bed becomes the exhausted bed and vice versa. The heat exchanger efficiency of a regenerative system is much higher than a recuperative system. These efficiencies[1028] can reach 85% to 97%. However, the ceramic media needs to be periodically cleaned or replaced. The chamber temperatures in Regenerative Thermal Oxidizers are typically 1,500 $^{o}$F to 1,600 $^{o}$F (depending on VOC requirements).

**DEFINITION OF BASELINE EQUIPMENT**

Depending on the facility process, there may be two baseline selection options: incinerator or recuperator.

The baseline Thermal Oxidizer with no heat recovery is referred to as an Incinerator. This baseline is recommended for selection if it currently exists on site or in new construction when there is a specific process that cannot practically utilize a recuperator due to VOCs coating or clogging the heat exchanger. This system employs a burner to provide direct fire to a process exhaust air stream. Typical operative temperatures are 1400 $^{o}$F to 2200 $^{o}$F. The advantage of an afterburner is a quick startup and shutdown time that is ready on demand. The equipment cost is lower than the efficient equipment, but the fuel consumption is much higher.

[1027] Presentation on the "Operating Cost Reduction Strategies for Oxidizers", presented by Rich Grzanka, during the Chem Show Technology Exposition on October 31, 2007.
[1028] Ibid.

In all other cases, (existing equipment is recuperative or new construction/ expansion of manufacturing process), a recuperative thermal oxidizer is recommended as the appropriate baseline.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected useful life of any thermal oxidizer system is assumed to 20 years.[1029]

### DEEMED MEASURE COST

The cost[1030] of any thermal oxidizer is dependent on various variables such as air flow capacity, destruction efficiency, heat exchanger efficiency, etc. Shown below is an example of a system for 20,000 CFM.

Recuperative Thermal Oxidizer costs, based on their heat recovery efficiency, is detailed in the table below.

| Heat Recovery Efficiency | Equipment Cost |
|---|---|
| 0% | $106,042 |
| 35% | $174,193 |
| 50% | $203,801 |
| 70% | $253,801 |
| Average | $184,317 |

Regenerative Thermal Oxidizer, at 95% heat recovery, have a deemed cost of $546,000.

Incinerator cost is treated as 0% heat recovery in the Recuperative Cost summary table above, and has a deemed cost of $106,042.

### LOADSHAPE

N/A

### COINCIDENCE FACTOR

N/A

## Algorithm

### CALCULATION OF ENERGY SAVINGS

Energy savings from thermally efficient equipment are entirely natural gas related. There are no electricity savings nor peak demand savings, as the blower fans and valve actuators are assumed to operate the same in all conditions.

### ELECTRIC ENERGY SAVINGS

N/A

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

### NATURAL GAS SAVINGS

ΔTherms = ((Baseline QT Air Pollution Control Device - Proposed QT Air Pollution Control Device) x Hours) / LHV

Where:

[1029] EPA Air Pollution Control Cost Manual, Chapter 2, November 2017. The system capital recovery cost is based on an estimated 20-year equipment life. This estimate of oxidizer equipment life is consistent with information available to EPA and is consistent with statements from large vendors for incinerators and oxidizers.

[1030] U.S. Environmental Protection Agency, Incinerators and Oxidizers, Chapter 2, November 2017

LHV = Latent Heat of Vaporization

= If the post is regenerative thermal oxidizer, LHV = 0.953.

= If the post is recuperative thermal oxidizer, LHV = 1.

Regenerative or Recuperative: A baseline or proposed Regenerative or Recuperative Air Pollution Control Device can each be modeled in the following heat balance equation[1031]:

QT (BTU/hr) = QI + QCC + QRL – QVOC

Incinerator: A baseline incinerator Air Pollution Control Device can be modeled as the following heat balance equation:

QT (BTU/hr) = QI + QCC + QRL

Where:

QT = Total Energy Input

QI = Energy used to raise the temperature of process air (FI) in BTU/hr

QCC = Heat used to raise the temperature of combustion air (FCC)

QRL = Radiation heat loss from RTO (BTU/hr)

QVOC = Heat release provided by VOC combustion

Hours = Annual hours per year that Oxidizer is used

Where:

QI = FI X 1.08 x (TO – TI)

TO = Average stack outlet temperature (°F) (actual trended average or use efficiency equation below to solve for TO under assumed conditions)

TO = TC - (N X (TC - TI) X FI / (FI + FCC)

TC = Combustion chamber temperature (°F), trended or design value provided by the manufacturer

N = Thermal Efficiency of Heat Exchanger

| Thermal Oxidizer | Efficiency |
|---|---|
| Regenerative | 97% |
| Recuperative | 70% |
| Incinerator | 0% |

TI = Inlet air temperature (°F), this is the temperature of the air coming from the process

FI = Process air (CFM), actual loading or use maximum design value

1.08 = Conversion Factor

= 60 (min/hr) x 0.07489 (lb/ft$^3$, density air at standard conditions) x 0.2404 Btu/°F-lb, (specific heat of air), where 0.2404 is average heat capacity of intake air

Where:

QCC = FCC X 1.08 X (TO – TA)

FCC = Additional combustion air CFM at provided FI value

[1031] ICAC Guidance Method for Estimation of Gas Consumption in a Regenerative Thermal Oxidizer (RTO), July 2002.

= If unknown, assume 3% of design value[1032]

TO = Average outlet temperature (°F) (same as above)

TA = Combustion intake air temperature (°F)

= Indoor: Actual, or assume 70 °F year-round

= Outdoor: Actual annual average found near the facility, or assume TMY3 annual averages:

| Region / Area | Average Outdoor Air Temperature |
|---|---|
| Chicago O'Hare | 50.0 °F |
| Chicago Midway | 52.5 °F |
| Rockford Airport | 47.6 °F |

Where:

QRL = SA x BTU/hr radiant loss

SA = Surface Area (provided by the manufacturer or rough measurements taken)

BTU/hr radiant loss = Assume 240 BTU/hr if installed outdoors, otherwise, 0 BTU/hr for indoor installation since the waste heat provides space heating and offset gas-fired space heating equipment

Where:

QVOC = VOC X HC X (% Dest / 100)

VOC = Average lbs/hr from process to oxidizer

HC = Btu/lb, weighted average for the heat of combustion of VOCS

= Site-specific, lookup table

% Destruction = Destruction efficiency of VOCs provided by the manufacturer, or use:

Hours = Annual hours of operation of the air pollution control device, assume customer production schedule or hours of occupancy

LHV = Lower heating value of natural gas

= 983 BTU/CF[1033]

HHV = High heating value of natural gas

= 1,031 BTU/CF[1034]

0.953 = LHV / HHV conversion factor

To calculate the natural gas savings by upgrading from an incinerator to an Efficient Thermal Oxidizer system, the new temperatures must be considered. The addition of heat recovery (either Recuperative or Regenerative) will increase the inlet temperature, TI, above that found in the facility.

The calculation should consider changes in the inlet temperature. First, the key temperature required for 99.99% destruction efficiency of various VOC compounds must be determined. The U.S. EPA’s Innovative Strategies and Economics Group produced some guidance on the key temperatures[1035] for the following compounds:

[1032] Ibid.

[1033] Biomass Energy Data Book, 2011, Appendix A: Lower and Higher Heating Values of Gas, Liquid, and Solid Fuels

[1034] Heat content of natural gas delivered to consumers per the Energy Information Administration, Independent Statistics & Analysis, 2018

[1035] U.S. Environmental Protection Agency, Incinerators and Oxidizers, Chapter 2, November 2017

| VOC Compound | Key Destruction Temperature (°F) |
|---|---|
| Acrylonitrile | 1,344 |
| Allyl chloride | 1,276 |
| Benzene | 1,350 |
| Chlorobenzene | 1,407 |
| 1,2 – dichloromethane | 1,368 |
| Methyl chloride | 1,596 |
| Toluene | 1,341 |
| Vinyl chloride | 1,369 |

For VOC compounds not listed above, the Key Destruction Temperature should be determined through product literature, equipment vendors, Material Data Safety Sheets (MSDS), or some other source.

When employing heat recovery, either Recuperative or Regenerative, the increased outlet temperature is limited to the heat exchanger efficiency. This efficiency, or in other words how much heat can be recovered, is limited to the auto-ignition temperatures of the VOCs in the air stream. Regenerative Thermal Oxidizers offer the advantage of recovering more heat as the combustion can occur within the heat exchanger, whereas with Recuperative Thermal Oxidizers, the heat exchanger efficiency is much lower to prevent premature combustion in the stack of the recuperator.

While the VOCs in the waste air stream have some heating value that contributes to reaching the required chamber temperature, such contributions do not have as high of an impact in the overall energy consumption calculation when compared to the heat exchanger efficiency.

### Water and Other Non-Energy Impact Descriptions and Calculation

Thermal oxidizer operations will have no impact on water or other resources. There may be some safety issues with potential burning hazards from deploying this equipment at high temperatures. There may also be some potential issues with installing outdoor natural gas piping to the location of the Thermal Oxidizers. In terms of physical sizing, regenerative thermal oxidizers are much larger, thus requiring larger physical space at the site of installation.

### Deemed O&M Cost Adjustment Calculation

The ceramic media in the regenerative thermal oxidizer requires regular servicing and may need to be considered as a regular part of facility O&M.

### Measure Code: CI-MSC-ETOX-V01-190101

### Review Deadline: 1/1/2023

# 2019 Illinois Statewide Technical Reference Manual for Energy Efficiency

# Version 7.0

# Volume 3: Residential Measures

## FINAL

## September 28, 2018

## Effective:

## January 1, 2019

[INTENTIONALLY LEFT BLANK]

**VOLUME 4: CROSS-CUTTING MEASURES AND ATTACHMENTS**

# Volume 3: Residential Measures

## 5.1 Appliances End Use

### 5.1.1 ENERGY STAR Air Purifier/Cleaner

**DESCRIPTION**

An air purifier (cleaner) meeting the efficiency specifications of ENERGY STAR is purchased and installed in place of a model meeting the current federal standard.

This measure was developed to be applicable to the following program types: TOS, NC.

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

The efficient equipment is defined as an air purifier meeting the efficiency specifications of ENERGY STAR as provided below.

- Must produce a minimum 50 Clean Air Delivery Rate (CADR) for Dust[1] to be considered under this specification.
- Minimum Performance Requirement: = 2.0 CADR/Watt (Dust)
- Standby Power Requirement: = 2.0 Watts Qualifying models that perform secondary consumer functions (e.g. clock, remote control) must meet the standby power requirement.
- UL Safety Requirement: Models that emit ozone as a byproduct of air cleaning must meet UL Standard 867 (ozone production must not exceed 50ppb)

**DEFINITION OF BASELINE EQUIPMENT**

The baseline equipment is assumed to be a conventional unit[2].

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The measure life is assumed to be 9 years[3].

**DEEMED MEASURE COST**

The incremental cost for this measure is $70.[4]

**LOADSHAPE**

Loadshape C53 - Flat

**COINCIDENCE FACTOR**

The summer peak coincidence factor for this measure is assumed to be 100 % (the unit is assumed to be always on).

[1] Measured according to the latest ANSI/AHAM AC-1 (AC-1) Standard
[2] As defined as the average of non-ENERGY STAR products found in EPA research, 2011, ENERGY STAR Qualified Room Air Cleaner Calculator.
[3] ENERGY STAR Qualified Room Air Cleaner Calculator.
[4] Ibid

## Algorithm

### Calculation of Savings

### Electric Energy Savings

$$\Delta kWh = kWh_{Base} - kWh_{ESTAR}$$

Where:

$kWh_{BASE}$ = Baseline kWh consumption per year[5]

= see table below

$kWh_{ESTAR}$ = ENERGY STAR kWh consumption per year[6]

= see table below

| Clean Air Delivery Rate (CADR) | CADR used in calculation (midpoint) | Baseline Unit Energy Consumption (kWh/year) | ENERGY STAR Unit Energy Consumption (kWh/year) | ΔkWH |
|---|---|---|---|---|
| CADR 51-100 | 75 | 441 | 148 | 293 |
| CADR 101-150 | 125 | 733 | 245 | 488 |
| CADR 151-200 | 175 | 1025 | 342 | 683 |
| CADR 201-250 | 225 | 1317 | 440 | 877 |
| CADR Over 250 | 300 | 1755 | 586 | 1169 |

### Summer Coincident Peak Demand Savings

$$\Delta kW = \Delta kWh/Hours * CF$$

Where:

ΔkWh = Gross customer annual kWh savings for the measure

Hours = Average hours of use per year

= 5844 hours[7]

CF = Summer Peak Coincidence Factor for measure

= 66.7%[8]

| Clean Air Delivery Rate | ΔkW |
|---|---|
| CADR 51-100 | 0.033 |
| CADR 101-150 | 0.056 |
| CADR 151-200 | 0.078 |
| CADR 201-250 | 0.100 |
| CADR Over 250 | 0.133 |

### Natural Gas Savings

N/A

[5] ENERGY STAR Qualified Room Air Cleaner Calculator.
[6] Ibid.
[7] Consistent with ENERGY STAR Qualified Room Air Cleaner Calculator assumption of 16 hours per day (16 * 365.25 = 5844).
[8] Assumes that the purifier usage is evenly spread throughout the year, therefore coincident peak is calculated as 5844/8766 = 66.7%.

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

There are no operation and maintenance cost adjustments for this measure.[9]

**MEASURE CODE: RS-APL-ESAP-V02-160601**

**REVIEW DEADLINE: 1/1/2023**

[9] Some types of room air cleaners require filter replacement or periodic cleaning, but this is likely to be true for both efficient and baseline units and so no difference in cost is assumed.

## 5.1.2 ENERGY STAR Clothes Washers

### DESCRIPTION

This measure relates to the installation of a clothes washer meeting the ENERGY STAR or CEE Tier 2 minimum qualifications. Note if the DHW and dryer fuels of the installations are unknown (for example through a retail program) savings should be based on a weighted blend using RECS data (the resultant values (kWh, therms and gallons of water) are provided). The algorithms can also be used to calculate site specific savings where DHW and dryer fuels are known.

This measure was developed to be applicable to the following program types: TOS, NC.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

Clothes washer must meet the ENERGY STAR or CEE Tier 2 minimum qualifications, as required by the program.

### DEFINITION OF BASELINE EQUIPMENT

The baseline condition is a standard sized clothes washer meeting the minimum federal baseline as of January 2018[10].

| Efficiency Level | Top Loading >2.5 Cu ft | Front Loading >2.5 Cu ft |
|---|---|---|
| Federal Standard | ≥1.57 IMEF, ≤6.5 IWF | ≥1.84 IMEF, ≤4.7 IWF |
| ENERGY STAR | ≥2.06 IMEF, ≤4.3 IWF | ≥2.76 IMEF, ≤3.2 IWF |
| CEE Tier 2 | ≥2.92 IMEF, ≤3.2 IWF | |

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 14 years[11].

### DEEMED MEASURE COST

The incremental cost for an ENERGY STAR unit is assumed to be $84 and for a CEE Tier 2 unit it is $141[12].

### DEEMED O&M COST ADJUSTMENTS

N/A

### LOADSHAPE

Loadshape R01 - Residential Clothes Washer

### COINCIDENCE FACTOR

The coincidence factor for this measure is 3.8%[13].

[10] DOE Energy Conservation Standards for Clothes Washers, Appliance and Equipment Standard, 10 CFR Part 430.32(g)
[11] Based on DOE Life-Cycle Cost and Payback Period Excel-based analytical tool.
[12] Cost estimates are based on Navigant analysis for the Department of Energy (see CW Analysis_05032018.xls). This analysis looked at incremental cost and shipment data from manufacturers and the Association of Home Appliance Manufacturers and attempts to find the costs associated only with the efficiency improvements. The ENERGY STAR level in this analysis was made the baseline (as it is now equivalent), the CEE Tier 2 level was extrapolated based on equal rates. Note these assumptions should be reviewed as qualifying product becomes available.
[13] Calculated from Itron eShapes, 8760 hourly data by end use for Missouri, as provided by Ameren.

## Algorithm

### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

1. Calculate clothes washer savings based on the Integrated Modified Energy Factor (IMEF).

   The Integrated Modified Energy Factor (IMEF) includes unit operation, standby, water heating, and drying energy use: "*IMEF is the quotient of the capacity of the clothes container, C, divided by the total clothes washer energy consumption per cycle, with such energy consumption expressed as the sum of the machine electrical energy consumption, M, the hot water energy consumption, E, the energy required for removal of the remaining moisture in the wash load, D, and the combined low-power mode energy consumption*" [14].

   The hot water and dryer savings calculated here assumes electric DHW and Dryer (this will be separated in Step 2).

IMEFsavings[15] = Capacity * (1/IMEFbase - 1/IMEFeff) * Ncycles

Where

Capacity = Clothes Washer capacity (cubic feet)

= Actual. If capacity is unknown assume 3.50 cubic feet [16]

IMEFbase = Integrated Modified Energy Factor of baseline unit

= 1.75[17]

IMEFeff = Integrated Modified Energy Factor of efficient unit

= Actual. If unknown assume average values provided below.

Ncycles = Number of Cycles per year

= 264[18]

IMEFsavings is provided below based on deemed values[19]:

| Efficiency Level | IMEF | IMEF Savings (kWh) |
|---|---|---|
| Federal Standard | 1.75 | 0.0 |
| ENERGY STAR | 2.23 | 113 |
| CEE Tier 2 | 2.92 | 211 |

[14] Definition provided on the ENERGY STAR website.
[15] IMEFsavings represents total kWh only when water heating and drying are 100% electric.
16 Based on the average clothes washer volume of all units that pass the new Federal Standard on the California Energy Commission (CEC) database of Clothes Washer products accessed on 05/03/2018. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.
[17] Weighted average IMEF of Federal Standard rating for Front Loading and Top Loading units. Weighting is based upon the relative top v front loading percentage of available non-ENERGY STAR product in the CEC database (products accessed on 05/03/2018).
[18] Weighted average of clothes washer cycles per year (based on 2015 Residential Energy Consumption Survey (RECS) national sample survey of housing appliances section, Midwest Census Region, West North Central Census Division.
If utilities have specific evaluation results providing a more appropriate assumption for single-family or Multifamily homes, in a particular market, or geographical area then that should be used.
[19] IMEF values are the weighted average of the new ENERGY STAR specifications. Weighting is based upon the relative top v front loading percentage of available ENERGY STAR and CEE Tier 2 products in the CEC database. See “CW Analysis_05032018.xls” for the calculation.

2. Break out savings calculated in Step 1 for electric DHW and electric dryer

ΔkWh = [Capacity * 1/IMEFbase * Ncycles * (%CWbase + (%DHWbase * %Electric_DHW) + (%Dryerbase * %Electric_Dryer))] - [Capacity * 1/IMEFeff * Ncycles * (%CWeff + (%DHWeff * %Electric_DHW) + (%Dryereff * %Electric_Dryer))]

Where:

%CW = Percentage of total energy consumption for Clothes Washer operation (different for baseline and efficient unit – see table below)

%DHW = Percentage of total energy consumption used for water heating (different for baseline and efficient unit – see table below)

%Dryer = Percentage of total energy consumption for dryer operation (different for baseline and efficient unit – see table below)

| | Percentage of Total Energy Consumption[20] | | |
|---|---|---|---|
| | %CW | %DHW | %Dryer |
| Baseline | 8.1% | 26.5% | 65.4% |
| ENERGY STAR | 5.8% | 31.2% | 63.0% |
| CEE Tier 2 | 13.9% | 9.6% | 76.5% |

%Electric_DHW = Percentage of DHW savings assumed to be electric

| DHW fuel | %Electric_DHW |
|---|---|
| Electric | 100% |
| Natural Gas | 0% |
| Unknown | 32%[21] |

%Electric_Dryer = Percentage of dryer savings assumed to be electric

| Dryer fuel | %Electric_Dryer |
|---|---|
| Electric | 100% |
| Natural Gas | 0% |
| Unknown | 62%[22] |

Using the default assumptions provided above, the prescriptive savings for each configuration are presented below:

[20] The percentage of total energy consumption that is used for the machine, heating the hot water or by the dryer is different depending on the efficiency of the unit. Values are based on a weighted average of top loading and front loading units based on data from DOE Life-Cycle Cost and Payback Period Excel-based analytical tool. See "CW Analysis_05032018.xls" for the calculation.

[21] Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2015 for Midwest Region, East North Central Census Division. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used

[22] Default assumption for unknown is based on percentage of homes with electric dryer from EIA Residential Energy Consumption Survey (RECS) 2015 for Midwest Region, East North Central Census Division. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.

| | ΔkWH | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Electric DHW Electric Dryer | Gas DHW Electric Dryer | Electric DHW Gas Dryer | Gas DHW Gas Dryer | Electric DHW Unknown Dryer | Gas DHW Unknown Dryer | Unknown DHW Electric Dryer | Unknown DHW Gas Dryer | Unknown DHW Unknown Dryer |
| ENERGY STAR | 112.8 | 120.5 | 29.1 | 18.8 | 80.8 | 70.5 | 105.8 | 22.1 | 73.8 |
| CEE Tier 2 | 211 | 101.9 | 108.2 | -0.9 | 171.7 | 62.6 | 137.1 | 34.3 | 97.8 |

<u>Secondary kWh Savings for Water Supply and Wastewater Treatment</u>

The following savings should be included in the total savings for this measure, but should not be included in TRC tests to avoid double counting the economic benefit of water savings.

$$\Delta kWh_{water} = \Delta Water\ (gallons) / 1{,}000{,}000 * E_{water\ total}$$

Where

$E_{water\ total}$ = IL Total Water Energy Factor (kWh/Million Gallons)

=5,010[23]

Using defaults provided:

ENERGY STAR $\Delta kWh_{water}$ = 1159/1,000,000*5,010

= 5.8 kWh

ENERGY STAR Most Efficient $\Delta kWh_{water}$ = 1931/1,000,000*5,010

= 9.7 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$$\Delta kW = \Delta kWh/Hours * CF$$

Where:

ΔkWh = Energy Savings as calculated above Note do not include the secondary savings in this calculation.

Hours = Assumed Run hours of Clothes Washer

= 264 hours[24]

CF = Summer Peak Coincidence Factor for measure.

= 0.038[25]

Using the default assumptions provided above, the prescriptive savings for each configuration are presented below:

[23] This factor include 2571 kWh/MG for water supply based on Illinois energy intensity data from a 2012 ISAWWA study and 2439 kWh/MG for wastewater treatment based on national energy intensity use estimates. For more information please review Elevate Energy's 'IL TRM: Energy per Gallon Factor, May 2018 paper'.

[24] Based on a weighted average of 264 clothes washer cycles per year assuming an average load runs for one hour (2015 Residential Energy Consumption Survey (RECS) national sample survey of housing appliances section, Midwest Census Region, West North Central Census Division)

[25] Calculated from Itron eShapes, 8760 hourly data by end use for Missouri, as provided by Ameren.

| | ΔkW | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Electric DHW Electric Dryer | Gas DHW Electric Dryer | Electric DHW Gas Dryer | Gas DHW Gas Dryer | Electric DHW Unknown Dryer | Gas DHW Unknown Dryer | Unknown DHW Electric Dryer | Unknown DHW Gas Dryer | Unknown DHW Unknown Dryer |
| ENERGY STAR | 0.0162 | 0.0148 | 0.0042 | 0.0027 | 0.0116 | 0.0101 | 0.0152 | 0.0032 | 0.0106 |
| CEE Tier 3 | 0.0304 | 0.0147 | 0.0156 | -0.0001 | 0.0247 | 0.0090 | 0.0197 | 0.0049 | 0.0141 |

**NATURAL GAS SAVINGS**

Break out savings calculated in Step 1 of electric energy savings (MEF savings) and extract Natural Gas DHW and Natural Gas dryer savings from total savings:

ΔTherm = [(Capacity * 1/IMEFbase * Ncycles * ((%DHWbase * %Natural Gas_DHW * R_eff) + (%Dryerbase * %Gas _Dryer))) – (Capacity * 1/IMEFeff * Ncycles * ((%DHWeff * %Natural Gas_DHW * R_eff) + (%Dryereff * %Gas_Dryer)))] * Therm_convert

Where:

Therm_convert = Convertion factor from kWh to Therm

= 0.03412

R_eff = Recovery efficiency factor

= 1.26[26]

%Natural Gas_DHW = Percentage of DHW savings assumed to be Natural Gas

| DHW fuel | %Natural Gas_DHW |
|---|---|
| Electric | 0% |
| Natural Gas | 100% |
| Unknown | 62%[27] |

%Gas_Dryer = Percentage of dryer savings assumed to be Natural Gas

| Dryer fuel | %Gas_Dryer |
|---|---|
| Electric | 0% |
| Natural Gas | 100% |
| Unknown | 36%[28] |

Other factors as defined above

Using the default assumptions provided above, the prescriptive savings for each configuration are presented below:

[26] To account for the different efficiency of electric and Natural Gas hot water heaters (gas water heater: recovery efficiencies ranging from 0.74 to 0.85 (0.78 used), and electric water heater with 0.98 recovery efficiency (see ENERGY STAR Waste Water Recovery Guidelines). Therefore a factor of 0.98/0.78 (1.26) is applied.

[27] Default assumption for unknown fuel is based on percentage of homes with gas dryer from EIA Residential Energy Consumption Survey (RECS) 2015 for Midwest Region, East North Central Census Division If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used

[28] Ibid.

| | ΔTherms | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Electric DHW Electric Dryer | Gas DHW Electric Dryer | Electric DHW Gas Dryer | Gas DHW Gas Dryer | Electric DHW Unknown Dryer | Gas DHW Unknown Dryer | Unknown DHW Electric Dryer | Unknown DHW Gas Dryer | Unknown DHW Unknown Dryer |
| ENERGY STAR | 0.0 | 0.4 | 2.9 | 3.3 | 1.0 | 1.5 | 0.3 | 3.1 | 1.3 |
| CEE Tier 3 | 0.0 | 4.7 | 3.5 | 8.2 | 5.9 | 5.9 | 2.9 | 6.4 | 4.2 |

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

ΔWater (gallons) = Capacity * (IWFbase - IWFeff) * Ncycles

Where

ΔWater (gallons) = Water saved, in gallons

IWFbase = Integrated Water Factor of baseline clothes washer

= 5.29[29]

IWFeff = Water Factor of efficient clothes washer

= Actual. If unknown assume average values provided below.

Using the default assumptions provided above, the prescriptive water savings for each efficiency level are presented below:

| Efficiency Level | IWF[30] | ΔWater (gallons per year) |
|---|---|---|
| Federal Standard | 5.29 | 0.0 |
| ENERGY STAR | 4.04 | 1,159 |
| ENERGY STAR Most Efficient | 3.20 | 1,931 |

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-APL-ESCL-V06-190101**

**REVIEW DEADLINE: 1/1/2020**

[29] Weighted average IWF of Federal Standard rating for Front Loading and Top Loading units. Weighting is based upon the relative top v front loading percentage of available non-ENERGY STAR product in the CEC database (products accessed on 05/03/2018).

[30] IWF values are the weighted average of the new ENERGY STAR specifications. Weighting is based upon the relative top v front loading percentage of available ENERGY STAR and CEE Tier 2 products in the CEC database (products accessed on 05/03/2018). See "CW Analysis_05032018.xls" for the calculation.

## 5.1.3 ENERGY STAR Dehumidifier

### DESCRIPTION

A dehumidifier meeting the minimum qualifying efficiency standard established by the current ENERGY STAR Version 4.0 (effective 10/25/2016) and ENERGY STAR Most Efficient 2018 Criteria (effective 01/01/2018) is purchased and installed in a residential setting in place of a unit that meets the minimum federal standard efficiency.

This measure was developed to be applicable to the following program types: TOS, NC.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the new dehumidifier must meet the ENERGY STAR standards as defined below:

| Capacity (pints/day) | ENERGY STAR Criteria (L/kWh) | ENERGY STAR Most Efficient: Stand Alone (L/kWh) | ENERGY STAR Most Efficient: Whole House (L/kWh) |
|---|---|---|---|
| <75 | ≥2.00 | ≥2.20 | ≥2.30 |
| 75 to ≤185 | ≥2.80 | N/A | N/A |

Qualifying units shall be equipped with an adjustable humidistat control or shall require a remote humidistat control to operate.

### DEFINITION OF BASELINE EQUIPMENT

The baseline for this measure is defined as a new dehumidifier that meets the federal efficiency standards. The Federal Standard for Dehumidifiers as of October 2012 is defined below:

| Capacity (pints/day) | Federal Standard Criteria (L/kWh) |
|---|---|
| Up to 35 | ≥1.35 |
| > 35 to ≤ 45 | ≥1.50 |
| > 45 to ≤ 54 | ≥1.60 |
| > 54 to ≤ 75 | ≥1.70 |
| > 75 to ≤ 185 | ≥2.50 |

Effective June 13, 2019 new federal standards for dehumidifiers become active and are detailed in the table below. This change to baseline will be made effective 1/1/2020 to allow for sell through of product:

| Equipment Specification | Capacity (pints/day) | Federal Standard Criteria (L/kWh) |
|---|---|---|
| Portable dehumidifier | Up to 25 | ≥1.30 |
| | > 25 to ≤ 50 | ≥1.60 |
| | > 50 | ≥2.80 |

| Equipment Specification | Product Case Volume (cubic feet) | Federal Standard Criteria (L/kWh) |
|---|---|---|
| Whole-home dehumidifier | Up to 8 | ≥1.77 |
| | > 8 | ≥2.41 |

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The assumed lifetime of the measure is 12 years[31].

### DEEMED MEASURE COST

The incremental cost for an ENERGY STAR unit is assumed to be $9.52[32] and for an ENERGY STAR Most Efficient unit is $75[33].

### LOADSHAPE

Loadshape R12 - Residential - Dehumidifier

### COINCIDENCE FACTOR

The coincidence factor is assumed to be 37% [34].

## Algorithm

### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

ΔkWh = (((Avg Capacity * 0.473) / 24) * Hours) * (1 / (L/kWh_Base) – 1 / (L/kWh_Eff))

Where:

Avg Capacity = Average capacity of the unit (pints/day)

= Actual, if unknown assume capacity in each capacity range as provided in table below, or if capacity range unknown assume average.

0.473 = Constant to convert Pints to Liters

24 = Constant to convert Liters/day to Liters/hour

Hours = Run hours per year

= 1632 [35]

L/kWh = Liters of water per kWh consumed, as provided in tables above

Annual kWh results for each capacity class are presented below:

[31] EPA Research, 2012; ENERGY STAR Dehumidifier Calculator

[32] Based on incremental costs sourced from the 2016 ENERGY STAR Appliance Calculator and weighted by capacity based on ENERGY STAR qualified products, accessed on July 2016.

[33] DOE Energy Conservation Standards for Residential Dehumidifiers, Appliance and Equipment Standard, 10 CFR Part 430, July 23, 2012, page 73. The sourced table is an analysis on the incremental manufacturer product costs on dehumidifiers with varying incentive levels. Assuming the markup costs between the baseline units and the most efficient units are equal. The incremental cost reproduced is a straight average of all the dehumidifiers, both stand alone and whole house, with an efficiency level meeting or exceeding ENERGY STAR's Most Efficient criteria. Opted to combine the incremental cost into one value because the stand alone and whole house incremental costs were near identical.

[34] Assume usage is evenly distributed day vs. night, weekend vs. weekday and is used between April through the end of September (4392 possible hours). 1632 operating hours from ENERGY STAR Dehumidifier Calculator. Coincidence peak during summer peak is therefore 1632/4392 = 37.2%

[35] ENERGY STAR Dehumidifier Calculator; 24 hour operation over 68 days of the year.

| | | | | | | Annual kWh | | | |
|---|---|---|---|---|---|---|---|---|---|
| Capacity Range | Capacity Used (pints/day) | Federal Standard Criteria | ENERGY STAR Criteria | ENERGY STAR Most Efficient: Stand Alone | ENERGY STAR Most Efficient: Whole House | Federal Standard | ENERGY STAR | ENERGY STAR Most Efficient: Stand Alone | ENERGY STAR Most Efficient: Whole House |
| (pints/day) | | (≥ L/kWh) | (≥ L/kWh) | (≥ L/kWh) | (≥ L/kWh) | | | | |
| ≤25 | 20 | 1.35 | 2.00 | 2.20 | 2.30 | 477 | 322 | 292 | 280 |
| > 25 to ≤35 | 30 | 1.35 | 2.00 | 2.20 | 2.30 | 715 | 482 | 439 | 420 |
| > 35 to ≤45 | 40 | 1.50 | 2.00 | 2.20 | 2.30 | 858 | 643 | 585 | 559 |
| > 45 to ≤ 54 | 50 | 1.60 | 2.00 | 2.20 | 2.30 | 1,005 | 804 | 731 | 699 |
| > 54 to ≤ 75 | 65 | 1.70 | 2.00 | 2.20 | 2.30 | 1,230 | 1,045 | 950 | 909 |
| > 75 to ≤ 185 | 130 | 2.50 | 2.80 | N/A | N/A | 1,673 | 1493 | N/A | N/A |
| Average[36] | 57.6 | 1.60 | 2.00 | 2.20 | 2.30 | 1,155 | 926 | 842 | 805 |

| | | Energy Savings (kWh) | | |
|---|---|---|---|---|
| Capacity Range (pints/day) | Capacity Used (pints/day) | ENERGY STAR | ENERGY STAR Most Efficient: Stand Alone | ENERGY STAR Most Efficient: Whole House |
| ≤25 | 20 | 155 | 184 | 197 |
| > 25 to ≤35 | 30 | 232 | 276 | 295 |
| > 35 to ≤45 | 40 | 214 | 273 | 298 |
| > 45 to ≤ 54 | 50 | 201 | 274 | 306 |
| > 54 to ≤ 75 | 65 | 184 | 280 | 321 |
| > 75 to ≤ 185 | 130 | 179 | N/A | N/A |
| Average | 57.6 | 229 | 313 | 350 |

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$$\Delta kW = \Delta kWh / Hours * CF$$

Where:

Hours = Annual operating hours

= 1632 hours [37]

CF = Summer Peak Coincidence Factor for measure

= 0.37 [38]

Summer coincident peak demand results for each capacity class are presented below:

[36] The relative weighting of each product class is based on number of units on the ENERGY STAR certified list, accessed in July 2016. See "Dehumidifier Calcs_05082018.xls.

[37] Based on 68 days of 24 hour operation; ENERGY STAR Dehumidifier Calculator

[38] Assume usage is evenly distributed day vs. night, weekend vs. weekday and is used between April through the end of September (4392 possible hours). 1632 operating hours from ENERGY STAR Dehumidifier Calculator. Coincidence peak during summer peak is therefore 1632/4392 = 37.2%

| | Annual Summer Peak kW Savings | | |
|---|---|---|---|
| Capacity (pints/day) Range | ENERGY STAR | ENERGY STAR Most Efficient: Stand Alone | ENERGY STAR Most Efficient: Whole House |
| ≤25 | 0.035 | 0.042 | 0.045 |
| > 25 to ≤35 | 0.053 | 0.063 | 0.067 |
| > 35 to ≤45 | 0.049 | 0.062 | 0.068 |
| > 45 to ≤ 54 | 0.046 | 0.062 | 0.069 |
| > 54 to ≤ 75 | 0.042 | 0.063 | 0.073 |
| > 75 to ≤ 185 | 0.041 | N/A | N/A |
| Average | 0.052 | 0.071 | 0.079 |

**NATURAL GAS SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-APL-ESDH-V05-190101**

**REVIEW DEADLINE: 1/1/2020**

## 5.1.4 ENERGY STAR Dishwasher

### Description

A standard or compact residential dishwasher meeting ENERGY STAR standards is installed in place of a model meeting the federal standard.

This measure was developed to be applicable to the following program types: TOS, NC.

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

The efficient equipment is defined as a standard or compact dishwasher meeting the ENERGY STAR standards presented in the table below.

**ENERGY STAR Requirements (Version 3.0, Effective January 29, 2016)**

| Dishwasher Type | Maximum kWh/year | Maximum gallons/cycle |
|---|---|---|
| Standard<br>(≥ 8 place settings + six serving pieces) | 270 | 3.5 |
| Standard with Connected Functionality[39] | 283 | |
| Compact<br>(< 8 place settings + six serving pieces) | 203 | 3.1 |

### Definition of Baseline Equipment

The baseline reflects the minimum federal efficiency standards for dishwashers effective May 30, 2013, as presented in the table below.

| Dishwasher Type | Maximum kWh/year | Maximum gallons/cycle |
|---|---|---|
| Standard | 307 | 5.0 |
| Compact | 222 | 3.5 |

### Deemed Lifetime of Efficient Equipment

The assumed lifetime of the measure is 11 years[40].

### Deemed Measure Cost

The incremental cost[41] for standard and compact dishwashers is provided in the table below.

| Dishwasher Type | Baseline Cost | ENERGY STAR Cost | Incremental Cost |
|---|---|---|---|
| Standard | $255.63 | $331.30 | $75.67 |

[39] The new ENERGY STAR specification "establishes optional connected criteria for dishwashers. ENERGY STAR certified dishwashers with connected functionality offer favorable attributes for demand response programs to consider, since their peak energy consumption is relatively high, driven by water heating. ENERGY STAR certified dishwashers with connected functionality will offer consumers new convenience and energy-saving features, such as alerts for cycle completion and/or recommended maintenance, as well as feedback on the energy use of the product". See 'ENERGY STAR Residential Dishwasher Final Version 6.0 Cover Memo.pdf'. Calculated as per Version 6.0 specification; "ENERGY STAR Residential Dishwasher Version 6.0 Final Program Requirements.pdf". Note that the potential for demand response and additional peak savings from units with Connected Functionality have not been explored. This could be a potential addition in a future version.

[40] Measure lifetime from California DEER. See file California DEER 2014-EUL Table - 2014 Update.xlsx.

[41] Costs are based on data from U.S. DOE, Final Rule Life-Cycle Cost (LCC) Spreadsheet. See file Residential Dishwasher Analysis_Nov2017.xlsx for cost calculation details.

| Dishwasher Type | Baseline Cost | ENERGY STAR Cost | Incremental Cost |
|---|---|---|---|
| Compact | $290.13 | $308.62 | $18.49 |

**LOADSHAPE**

Loadshape R02 - Residential Dish Washer

**COINCIDENCE FACTOR**

The coincidence factor is assumed to be 2.6%[42].

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

$\Delta kWh$[43] = $((kWh_{Base} - kWh_{ESTAR}) * (\%kWh\_op + (\%kWh\_heat * \%Electric\_DHW)))$

Where:

$kWh_{BASE}$ = Baseline kWh consumption per year

| Dishwasher Type | Maximum kWh/year |
|---|---|
| Standard | 307 |
| Compact | 222 |

$kWh_{ESTAR}$ = ENERGY STAR kWh annual consumption

| Dishwasher Type | Maximum kWh/year |
|---|---|
| Standard | 270 |
| Standard with Connected Functionality | 283 |
| Compact | 203 |

%kWh_op = Percentage of dishwasher energy consumption used for unit operation

= 1 - 56%[44]

= 44%

%kWh_heat = Percentage of dishwasher energy consumption used for water heating

= 56%[45]

%Electric_DHW = Percentage of DHW savings assumed to be electric

| DHW fuel | %Electric_DHW |
|---|---|
| Electric | 100% |

[42] Calculated from Itron eShapes, 8760 hourly data by end use for Missouri, as provided by Ameren.
[43] The Federal Standard and ENERGY STAR annual consumption values include electric consumption for both the operation of the machine and for heating the water that is used by the machine.
[44] ENERGY STAR Appliance Calculator.
[45] Ibid.

| DHW fuel | %Electric_DHW |
|---|---|
| Natural Gas | 0% |
| Unknown | 16%[46] |

| Dishwasher Type | ΔkWh | | |
|---|---|---|---|
| | With Electric DHW | With Gas DHW | With Unknown DHW |
| ENERGY STAR Standard | 37.0 | 16.3 | 19.6 |
| ENERGY STAR Standard with Connected Functionality | 24.0 | 10.6 | 12.7 |
| ENERGY STAR Compact | 19.0 | 8.4 | 10.1 |

<u>Secondary kWh Savings for Water Supply and Wastewater Treatment</u>

The following savings should be included in the total savings for this measure, but should not be included in TRC tests to avoid double counting the economic benefit of water savings.

$$\Delta kWh_{water} = \Delta Water\ (gallons) / 1{,}000{,}000 * E_{water\ total}$$

Where

$E_{water\ total}$ = IL Total Water Energy Factor (kWh/Million Gallons)

=5,010[47]

Using defaults provided:

Standard $\Delta kWh_{water}$ = 252/1,000,000*5,010

= 1.3 kWh

Compact $\Delta kWh_{water}$ = 67/1,000,000*5,010

= 0.3 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**[48]

$$\Delta kW = \Delta kWh/Hours * CF$$

Where:

ΔkWh = Annual kWh savings from measure as calculated above. Note do not include the secondary savings in this calculation.

Hours = Annual operating hours[49]

= 353 hours

---

[46] Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IL. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.

[47] This factor include 2571 kWh/MG for water supply based on Illinois energy intensity data from a 2012 ISAWWA study and 2439 kWh/MG for wastewater treatment based on national energy intensity use estimates. For more information please review Elevate Energy's 'IL TRM: Energy per Gallon Factor, May 2018 paper'.

[48] Note that the potential for demand response and additional peak savings from units with Connected Functionality have not been explored. This could be a potential addition in a future version.

[49] Assuming 2.1 hours per cycle and 168 cycles per year therefore 353 operating hours per year. 168 cycles per year is based on a weighted average of dishwasher usage in Illinois derived from the 2009 RECs data.

CF = Summer Peak Coincidence Factor

= 2.6% [50]

| Dishwasher Type | ΔkW | | |
|---|---|---|---|
| | With Electric DHW | With Gas DHW | With Unknown DHW |
| ENERGY STAR Standard | 0.0027 | 0.0012 | 0.0014 |
| ENERGY STAR Standard with Connected Functionality | 0.0018 | 0.0008 | 0.0009 |
| ENERGY STAR Compact | 0.0014 | 0.0006 | 0.0007 |

**NATURAL GAS SAVINGS**

$$\Delta Therm = (kWh_{Base} - kWh_{ESTAR}) * \%kWh\_heat * \%Natural\ Gas\_DHW * R\_eff * 0.03412$$

Where

%kWh_heat = % of dishwasher energy used for water heating

= 56%

%Natural Gas_DHW = Percentage of DHW savings assumed to be Natural Gas

| DHW fuel | %Natural Gas_DHW |
|---|---|
| Electric | 0% |
| Natural Gas | 100% |
| Unknown | 84%[51] |

R_eff = Recovery efficiency factor

= 1.26[52]

0.03412 = factor to convert from kWh to Therm

| Dishwasher Type | ΔTherms | | |
|---|---|---|---|
| | With Electric DHW | With Gas DHW | With Unknown DHW |
| ENERGY STAR Standard | 0.00 | 0.89 | 0.75 |
| ENERGY STAR Standard with Connected Functionality | 0.00 | 0.58 | 0.49 |
| ENERGY STAR Compact | 0.00 | 0.46 | 0.38 |

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

$$\Delta Water\ (gallons) = Water_{Base} - Water_{EFF}$$

Where

$Water_{Base}$ = water consumption of conventional unit

| Dishwasher Type | $Water_{Base}$ (gallons) [53] |
|---|---|
| Standard | 840 |

[50] End use data from Ameren representing the average DW load during peak hours/peak load.

[51] Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IL. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.

[52] To account for the different efficiency of electric and natural gas hot water heaters (gas water heater: recovery efficiencies ranging from 0.74 to 0.85 (0.78 used), and electric water heater with 0.98 recovery efficiency (see ENERGY STAR Waste Water Heat Recovery Guidelines). Therefore a factor of 0.98/0.78 (1.26) is applied.

[53] Assuming maximum allowed from specifications and 168 cycles per year based on a weighted average of dishwasher usage in

| Dishwasher Type | $Water_{Base}$ (gallons) [53] |
|---|---|
| Compact | 588 |

$Water_{EFF}$ = annual water consumption of efficient unit:

| Dishwasher Type | $Water_{EFF}$ (gallons) [54] |
|---|---|
| Standard | 588 |
| Compact | 521 |

| Dishwasher Type | ΔWater (gallons) |
|---|---|
| ENERGY STAR Standard | 252 |
| ENERGY STAR Compact | 67 |

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-APL-ESDI-V04-190101**

**REVIEW DEADLINE: 1/1/2022**

Illinois derived from the 2009 RECs data.

[54] Assuming maximum allowed from specifications and 168 cycles per year based on a weighted average of dishwasher usage in Illinois derived from the 2009 RECs data.

## 5.1.5 ENERGY STAR Freezer

### DESCRIPTION

A freezer meeting the efficiency specifications of ENERGY STAR is installed in place of a model meeting the federal standard (NAECA). Energy usage specifications are defined in the table below (note, AV is the freezer Adjusted Volume and is calculated as 1.73*Total Volume):

| Product Category | Volume (cubic feet) | Assumptions after September 2014 | |
|---|---|---|---|
| | | Federal Baseline Maximum Energy Usage in kWh/year[55] | ENERGY STAR Maximum Energy Usage in kWh/year[56] |
| Upright Freezers with Manual Defrost | 7.75 or greater | 5.57*AV + 193.7 | 5.01*AV + 174.3 |
| Upright Freezers with Automatic Defrost | 7.75 or greater | 8.62*AV + 228.3 | 7.76*AV + 205.5 |
| Chest Freezers and all other Freezers except Compact Freezers | 7.75 or greater | 7.29*AV + 107.8 | 6.56*AV + 97.0 |
| Compact Upright Freezers with Manual Defrost | < 7.75 and 36 inches or less in height | 8.65*AV + 225.7 | 7.79*AV + 203.1 |
| Compact Upright Freezers with Automatic Defrost | < 7.75 and 36 inches or less in height | 10.17*AV + 351.9 | 9.15*AV + 316.7 |
| Compact Chest Freezers | <7.75 and 36 inches or less in height | 9.25*AV + 136.8 | 8.33*AV + 123.1 |

This measure was developed to be applicable to the following program types: TOS, NC.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

The efficient equipment is defined as a freezer meeting the efficiency specifications of ENERGY STAR, as defined below and calculated above:

| Equipment | Volume | Criteria |
|---|---|---|
| Full Size Freezer | 7.75 cubic feet or greater | At least 10% more energy efficient than the minimum federal government standard (NAECA). |
| Compact Freezer | Less than 7.75 cubic feet and 36 inches or less in height | At least 20% more energy efficient than the minimum federal government standard (NAECA). |

### DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is assumed to be a model that meets the federal minimum standard for energy efficiency. The standard varies depending on the size and configuration of the freezer (chest freezer or upright freezer, automatic or manual defrost) and is defined in the table above.

[55] See Department of Energy Federal Standards.
[56] See Version 5.0 ENERGY STAR specification.

### Deemed Lifetime of Efficient Equipment

The measure life is assumed to be 22 years[57].

### Deemed Measure Cost

The incremental cost for this measure is $35[58].

### Loadshape

Loadshape R04 - Residential Freezer

### Coincidence Factor

The summer peak coincidence factor for this measure is assumed to be 95%[59].

## Algorithm

### Calculation of Savings

### Electric Energy Savings:

$$\Delta kWh = kWh_{Base} - kWh_{ESTAR}$$

Where:

$kWh_{BASE}$ = Baseline kWh consumption per year as calculated in algorithm provided in table above.

$kWh_{ESTAR}$ = ENERGY STAR kWh consumption per year as calculated in algorithm provided in table above.

For example for a 7.75 cubic foot Upright Freezers with Manual Defrost purchased after September 2014:

$$\Delta kWh = (5.57*(7.75* 1.73)+193.7) - (5.01*(7.75* 1.73)+174.3)$$
$$= 268.4 - 241.5$$
$$= 26.9 \text{ kWh}$$

If volume is unknown, use the following default values:

| Product Category | Volume Used[60] | Assumptions after September 2014 | | |
|---|---|---|---|---|
| | | $kWh_{BASE}$ | $kWh_{ESTAR}$ | kWh Savings |
| Upright Freezers with Manual Defrost | 27.9 | 349.2 | 314.2 | 35.0 |
| Upright Freezers with Automatic Defrost | 27.9 | 469.0 | 422.2 | 46.8 |
| Chest Freezers and all other Freezers except Compact Freezers | 27.9 | 311.4 | 280.2 | 31.2 |
| Compact Upright Freezers with Manual Defrost | 10.4 | 467.2 | 420.6 | 46.6 |

[57] Based on 2011 DOE Rulemaking Technical Support Document, as recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.
[58] Based on review of data from the Northeast Regional ENERGY STAR Consumer Products Initiative; "2009 ENERGY STAR Appliances Practices Report", submitted by Lockheed Martin, December 2009.
[59] Based on eShapes Residential Freezer load data as provided by Ameren.
[60] Volume is based on ENERGY STAR Calculator assumption of 16.14 $ft^3$ average volume, converted to Adjusted volume by multiplying by 1.73.

| Product Category | Volume Used[60] | Assumptions after September 2014 | | |
|---|---|---|---|---|
| | | $kWh_{BASE}$ | $kWh_{ESTAR}$ | kWh Savings |
| Compact Upright Freezers with Automatic Defrost | 10.4 | 635.9 | 572.2 | 63.7 |
| Compact Chest Freezers | 10.4 | 395.1 | 355.7 | 39.4 |

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$\Delta kW = \Delta kWh / Hours * CF$

Where:

ΔkWh = Gross customer annual kWh savings for the measure

Hours = Full Load hours per year

= 5890[61]

CF = Summer Peak Coincident Factor

= 0.95 [62]

For example for a 7.75 cubic foot Upright Freezers with Manual Defrost:

$\Delta kW = 26.9/5890 * 0.95$

$= 0.0043$ kW

If volume is unknown, use the following default values:

| Product Category | Assumptions after September 2014 |
|---|---|
| | kW Savings |
| Upright Freezers with Manual Defrost | 0.0057 |
| Upright Freezers with Automatic Defrost | 0.0076 |
| Chest Freezers and all other Freezers except Compact Freezers | 0.0050 |
| Compact Upright Freezers with Manual Defrost | 0.0075 |
| Compact Upright Freezers with Automatic Defrost | 0.0103 |
| Compact Chest Freezers | 0.0064 |

**NATURAL GAS SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

[61] Calculated from eShapes Residential Freezer load data as provided by Ameren by dividing total annual load by the maximum kW in any one hour.
[62] Based on eShapes Residential Freezer load data as provided by Ameren.

**MEASURE CODE: RS-APL-ESFR-V03-190101**

**REVIEW DEADLINE: 1/1/2021**

## 5.1.6 ENERGY STAR and CEE Tier 2 Refrigerator

**DESCRIPTION**

This measure relates to:

a) Time of Sale: the purchase and installation of a new refrigerator meeting either ENERGY STAR or CEE TIER 2 specifications.

b) Early Replacement: the early removal of an existing residential inefficient Refrigerator from service, prior to its natural end of life, and replacement with a new ENERGY STAR or CEE Tier 2 qualifying unit. Savings are calculated between existing unit and efficient unit consumption during the remaining life of the existing unit, and between new baseline unit and efficient unit consumption for the remainder of the measure life.

Energy usage specifications are defined in the table below (note, Adjusted Volume is calculated as the fresh volume + (1.63 * Freezer Volume):

| Product Category | Existing Unit | Assumptions after September 2014 | |
|---|---|---|---|
| | Based on Refrigerator Recycling algorithm | Federal Baseline Maximum Energy Usage in kWh/year[63] | ENERGY STAR Maximum Energy Usage in kWh/year[64] |
| 1. Refrigerators and Refrigerator-freezers with manual defrost | Use Algorithm in 5.1.8 Refrigerator and Freezer Recycling measure to estimate existing unit consumption | 6.79AV + 193.6 | 6.11 * AV + 174.2 |
| 2. Refrigerator-Freezer--partial automatic defrost | | 7.99AV + 225.0 | 7.19 * AV + 202.5 |
| 3. Refrigerator-Freezers--automatic defrost with top-mounted freezer without through-the-door ice service and all-refrigerators--automatic defrost | | 8.07AV + 233.7 | 7.26 * AV + 210.3 |
| 4. Refrigerator-Freezers--automatic defrost with side-mounted freezer without through-the-door ice service | | 8.51AV + 297.8 | 7.66 * AV + 268.0 |
| 5. Refrigerator-Freezers--automatic defrost with bottom-mounted freezer without through-the-door ice service | | 8.85AV + 317.0 | 7.97 * AV + 285.3 |
| 5A Refrigerator-freezer—automatic defrost with bottom-mounted freezer with through-the-door ice service | | 9.25AV + 475.4 | 8.33 * AV + 436.3 |
| 6. Refrigerator-Freezers--automatic defrost with top-mounted freezer with through-the-door ice service | | 8.40AV + 385.4 | 7.56 * AV + 355.3 |
| 7. Refrigerator-Freezers--automatic defrost with side-mounted freezer with through-the-door ice service | | 8.54AV + 432.8 | 7.69 * AV + 397.9 |

This measure was developed to be applicable to the following program types: TOS, NC, EREP.

If applied to other program types, the measure savings should be verified.

[63] See Department of Energy Federal Standards.
[64] See Version 5.0 ENERGY STAR specification.

### DEFINITION OF EFFICIENT EQUIPMENT

The efficient equipment is defined as a refrigerator meeting the efficiency specifications of ENERGY STAR or CEE Tier 2 (defined as requiring >= 10% or >= 15% less energy consumption than an equivalent unit meeting federal standard requirements respectively). The ENERGY STAR standard varies according to the size and configuration of the unit, as shown in table above.

### DEFINITION OF BASELINE EQUIPMENT

Time of Sale: baseline is a new refrigerator meeting the minimum federal efficiency standard for refrigerator efficiency. The current federal minimum standard varies according to the size and configuration of the unit, as shown in table above. Note also that this federal standard will be increased for units manufactured after September 1, 2014.

Early Replacement: the baseline is the existing refrigerator for the assumed remaining useful life of the unit and the new baseline as defined above for the remainder of the measure life.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 17 years.[65]

Remaining life of existing equipment is assumed to be 6 years[66]

### DEEMED MEASURE COST

Time of Sale: The incremental cost for this measure is assumed to be $40[67] for an ENERGY STAR unit and $140[68] for a CEE Tier 2 unit.

Early Replacement: The measure cost is the full cost of removing the existing unit and installing a new one. The actual program cost should be used. If unavailable assume $451 for ENERGY STAR unit and $551 for CEE Tier 2 unit[69].

The avoided replacement cost (after 4 years) of a baseline replacement refrigerator is $413[70]. This cost should be discounted to present value using the nominal societal discount rate.

### LOADSHAPE

Loadshape R05 - Residential Refrigerator

### COINCIDENCE FACTOR

A coincidence factor is not used to calculate peak demand savings for this measure, see below.

[65] Based on 2011 DOE Rulemaking Technical Support Document, as recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.
[66] Standard assumption of one third of effective useful life.
[67] From ENERGY STAR calculator linked above.
[68] Based on weighted average of units participating in Efficiency Vermont program and retail cost data provided in Department of Energy, "TECHNICAL REPORT: Analysis of Amended Energy Conservation Standards for Residential Refrigerator-Freezers", October 2005.
[69] ENERGY STAR full cost is based upon IL PHA Efficient Living Program data on sample size of 910 replaced units finding average cost of $430 plus an average recycling/removal cost of $21. The CEE Tier 2 estimate uses the delta from the Time of Sale estimate.
[70] Calculated using incremental cost from Time of Sale measure and applying inflation rate of 1.91%.

## Algorithm

### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS:

Time of Sale: $\Delta kWh = UEC_{BASE} – UEC_{EE}$

Early Replacement:

ΔkWh for remaining life of existing unit (1st 4 years) $= UEC_{EXIST} – UEC_{EE}$

ΔkWh for remaining measure life (next 8 years) $= UEC_{BASE} – UEC_{EE}$

Where:

$UEC_{EXIST}$ = Annual Unit Energy Consumption of existing unit as calculated in algorithm from 5.1.8 Refrigerator and Freezer Recycling measure.

$UEC_{BASE}$ = Annual Unit Energy Consumption of baseline unit as calculated in algorithm provided in table above.

$UEC_{EE}$ = Annual Unit Energy Consumption of ENERGY STAR unit as calculated in algorithm provided in table above.

For CEE Tier 2, unit consumption is calculated as 25% lower than baseline.

If volume is unknown, use the following defaults, based on an assumed Adjusted Volume of 25.8[71]:

Assumptions after standard changes on September 1st, 2014:

| Product Category | Existing Unit $UEC_{EXIST}$ [72] | New Baseline $UEC_{BASE}$ | New Efficient $UEC_{EE}$ | | Early Replacement (1st 4 years) ΔkWh | | Time of Sale and Early Replacement (last 8 years) ΔkWh | |
|---|---|---|---|---|---|---|---|---|
| | | | ENERGY STAR | CEE T2 | ENERGY STAR | CEE T2 | ENERGY STAR | CEE T2 |
| 1. Refrigerators and Refrigerator-freezers with manual defrost | 1027.7 | 368.6 | 331.6 | 276.4 | 696.1 | 751.3 | 36.9 | 92.1 |
| 2. Refrigerator-Freezer--partial automatic defrost | 1027.7 | 430.9 | 387.8 | 323.2 | 640.0 | 704.6 | 43.1 | 107.7 |
| 3. Refrigerator-Freezers--automatic defrost with top-mounted freezer without through-the-door ice service and all-refrigerators--automatic defrost | 814.5 | 441.7 | 397.4 | 331.2 | 417.2 | 483.3 | 44.3 | 110.4 |
| 4. Refrigerator-Freezers--automatic defrost with side-mounted freezer without through-the-door ice service | 1241.0 | 517.1 | 465.4 | 387.8 | 775.6 | 853.1 | 51.7 | 129.3 |

[71] Volume is based on the ENERGY STAR calculator average assumption of 14.75 $ft^3$ fresh volume and 6.76 $ft^3$ freezer volume.
[72] Estimates of existing unit consumption are based on using the 5.1.8 Refrigerator and Freezer Recycling algorithm and the inputs described here: Age = 10 years, Pre-1990 = 0, Size = 21.5 ft3 (from ENERGY STAR calc and consistent with AV of 25.8), Single Door = 0, Side by side = 1 for classifications stating side by side, 0 for classifications stating top/bottom, and 0.5 for classifications that do not distinguish, Primary appliances = 1, unconditioned = 0, Part use factor = 0.

| Product Category | Existing Unit $UEC_{EXIST}$ [72] | New Baseline $UEC_{BASE}$ | New Efficient $UEC_{EE}$ | | Early Replacement (1st 4 years) ΔkWh | | Time of Sale and Early Replacement (last 8 years) ΔkWh | |
|---|---|---|---|---|---|---|---|---|
| | | | ENERGY STAR | CEE T2 | ENERGY STAR | CEE T2 | ENERGY STAR | CEE T2 |
| 5. Refrigerator-Freezers--automatic defrost with bottom-mounted freezer without through-the-door ice service | 814.5 | 545.1 | 490.7 | 408.8 | 323.9 | 405.8 | 54.4 | 136.3 |
| 5A Refrigerator-freezer—automatic defrost with bottom-mounted freezer with through-the-door ice service | 814.5 | 713.8 | 651.0 | 535.3 | 163.6 | 279.2 | 62.8 | 178.4 |
| 6. Refrigerator-Freezers--automatic defrost with top-mounted freezer with through-the-door ice service | 814.5 | 601.9 | 550.1 | 451.4 | 264.4 | 363.2 | 51.7 | 150.5 |
| 7. Refrigerator-Freezers--automatic defrost with side-mounted freezer with through-the-door ice service | 1241.0 | 652.9 | 596.1 | 489.6 | 644.9 | 751.3 | 56.8 | 163.2 |

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = (ΔkWh/8766) * TAF * LSAF

Where:

TAF = Temperature Adjustment Factor

= 1.25[73]

LSAF = Load Shape Adjustment Factor

= 1.057 [74]

If volume is unknown, use the following defaults:

[73] Average temperature adjustment factor (to account for temperature conditions during peak period as compared to year as a whole) based on Blasnik, Michael, "Measurement and Verification of Residential Refrigerator Energy Use, Final Report, 2003-2004 Metering Study", July 29, 2004 (p. 47). It assumes 90 °F average outside temperature during peak period, 71°F average temperature in kitchens and 65°F average temperature in basement, and uses assumption that 66% of homes in Illinois have central cooling (CAC saturation: "Table HC7.9 Air Conditioning in Homes in Midwest Region, Divisions, and States, 2009 from Energy Information Administration", 2009 Residential Energy Consumption Survey).

[74] Daily load shape adjustment factor (average load in peak period /average daily load) also based on Blasnik, Michael, "Measurement and Verification of Residential Refrigerator Energy Use, Final Report, 2003-2004 Metering Study", July 29, 2004 (p. 48, using the average Existing Units Summer Profile for hours 13 through 17)

| Product Category | Assumptions after September 2014 standard change ΔkW | | | |
|---|---|---|---|---|
| | Early Replacement (1st 4 years) | | Time of Sale and Early Replacement (last 8 years) | |
| | ENERGY STAR | CEE T2 | ENERGY STAR | CEE T2 |
| 1. Refrigerators and Refrigerator-freezers with manual defrost | 0.105 | 0.113 | 0.006 | 0.014 |
| 2. Refrigerator-Freezer--partial automatic defrost | 0.096 | 0.106 | 0.006 | 0.016 |
| 3. Refrigerator-Freezers--automatic defrost with top-mounted freezer without through-the-door ice service and all-refrigerators--automatic defrost | 0.063 | 0.073 | 0.007 | 0.017 |
| 4. Refrigerator-Freezers--automatic defrost with side-mounted freezer without through-the-door ice service | 0.117 | 0.129 | 0.008 | 0.019 |
| 5. Refrigerator-Freezers--automatic defrost with bottom-mounted freezer without through-the-door ice service | 0.049 | 0.061 | 0.008 | 0.021 |
| 5A Refrigerator-freezer—automatic defrost with bottom-mounted freezer with through-the-door ice service | 0.025 | 0.042 | 0.009 | 0.027 |
| 6. Refrigerator-Freezers--automatic defrost with top-mounted freezer with through-the-door ice service | 0.040 | 0.055 | 0.008 | 0.023 |
| 7. Refrigerator-Freezers--automatic defrost with side-mounted freezer with through-the-door ice service | 0.097 | 0.113 | 0.009 | 0.025 |

**NATURAL GAS SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-APL-ESRE-V06-190101**

**REVIEW DEADLINE: 1/1/2021**

## 5.1.7 ENERGY STAR Room Air Conditioner

### DESCRIPTION

This measure relates to:

a) Time of Sale the purchase and installation of a room air conditioning unit that meets ENERGY STAR version 4.0 which is effective October 26th 2015), in place of a baseline unit. The baseline is based on the Federal Standard effective June 1st, 2014.

| Product Type and Class (Btu/hr) | | Federal Standard with louvered sides (CEER) [75] | Federal Standard without louvered sides (CEER) | ENERGY STAR v4.0 with louvered sides (CEER) [76] | ENERGY STAR v4.0 without louvered sides (CEER) |
|---|---|---|---|---|---|
| Without Reverse Cycle | < 8,000 | 11.0 | 10.0 | 12.1 | 11.0 |
| | 8,000 to 10,999 | 10.9 | 9.6 | 12.0 | 10.6 |
| | 11,000 to 13,999 | 10.9 | 9.5 | 12.0 | 10.5 |
| | 14,000 to 19,999 | 10.7 | 9.3 | 11.8 | 10.2 |
| | 20,000 to 27,999 | 9.4 | 9.4 | 10.3 | 10.3 |
| | >=28,000 | 9.0 | 9.4 | 9.9 | 10.3 |
| With Reverse Cycle | <14,000 | 9.8 | 9.3 | 10.8 | 10.2 |
| | 14,000 to 19,999 | 9.8 | 8.7 | 10.8 | 9.6 |
| | >=20,000 | 9.3 | 8.7 | 10.2 | 9.6 |
| Casement only | | 9.5 | | 10.5 | |
| Casement-Slider | | 10.4 | | 11.4 | |

Side louvers extend from a room air conditioner model in order to position the unit in a window. A model without louvered sides is placed in a built-in wall sleeve and are commonly referred to as "through-the-wall" or "built-in" models.

Casement-only refers to a room air conditioner designed for mounting in a casement window of a specific size.

Casement-slider refers to a room air conditioner with an encased assembly designed for mounting in a sliding or casement window of a specific size.

Reverse cycle refers to the heating function found in certain room air conditioner models.

b) Early Replacement: the early removal of an existing residential inefficient Room AC unit from service, prior to its natural end of life, and replacement with a new ENERGY STAR qualifying unit. Savings are calculated between existing unit and efficient unit consumption during the remaining life of the existing unit, and between new baseline unit and efficient unit consumption for the remainder of the measure life.

This measure was developed to be applicable to the following program types: TOS, NC, EREP.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the new room air conditioning unit must meet the ENERGY STAR version 4.0 (effective October 26th 2015)[77] efficiency standards presented above.

[75] See DOE's Appliance and Equipment Standards for Room AC;
[76] ENERGY STAR Version 4.0 Room Air Conditioners Program Requirements
[77] ENERGY STAR Version 4.0 Room Air Conditioners Program Requirements

#### DEFINITION OF BASELINE EQUIPMENT

Time of Sale: the baseline assumption is a new room air conditioning unit that meets the Federal Standard (effective June 1st, 2014)[78] efficiency standards as presented above.

Early Replacement: the baseline is the existing Room AC for the assumed remaining useful life of the unit and the new baseline as defined above for the remainder of the measure life.

#### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 12 years[79].

Remaining life of existing equipment is assumed to be 4 years[80]

#### DEEMED MEASURE COST

Time of Sale: The incremental cost for this measure is assumed to be $40 for a ENERGY STAR unit[81].

Early Replacement: The measure cost is the full cost of removing the existing unit and installing a new one. The actual program cost should be used. If unavailable assume $448 for ENERGY STAR unit[82].

The avoided replacement cost (after 4 years) of a baseline replacement unit is $432.[83] This cost should be discounted to present value using the nominal societal discount rate.

#### LOADSHAPE

Loadshape R08 - Residential Cooling

#### COINCIDENCE FACTOR

The coincidence factor for this measure is assumed to be 0.3[84].

**Algorithm**

#### CALCULATION OF SAVINGS

#### ELECTRIC ENERGY SAVINGS

Time of Sale: $\Delta kWh = (FLH_{RoomAC} * Btu/H * (1/CEERbase - 1/CEERee))/1000$

Early Replacment:

$\Delta kWh$ for remaining life of existing unit (1st 4 years) $= (FLH_{RoomAC} * Btu/H * (1/(EERexist/1.01) - 1/CEERee))/1000$

$\Delta kWh$ for remaining measure life (next 8 years) $= (FLH_{RoomAC} * Btu/H * (1/CEERbase - 1/CEERee))/1000$

Where:

$FLH_{RoomAC}$ = Full Load Hours of room air conditioning unit

---

[78] See DOE's Appliance and Equipment Standards for Room AC.
[79] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
[80] Standard assumption of one third of effective useful life.
[81] Incremental cost based on field study conducted by Efficiency Vermont.
[82] Based on IL PHA Efficient Living Program Data for 810 replaced units showing $416 per unit plus $32 average recycling/removal cost.
[83] Estimate based upon Time of Sale incremental costs and applying inflation rate of 1.91%.
[84] Consistent with coincidence factors found in: RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008.

= dependent on location[85]:

| Climate Zone (City based upon) | $FLH_{RoomAC}$ |
|---|---|
| 1 (Rockford) | 220 |
| 2 (Chicago) | 210 |
| 3 (Springfield) | 319 |
| 4 (Belleville) | 428 |
| 5 (Marion) | 374 |
| Weighted Average[86] | 248 |

Btu/H = Size of rebated unit

= Actual. If unknown assume 8500 Btu/hr[87]

EERexist =Efficiency of existing unit

= Actual. If unknown assume 7.7[88]

1.01 = Factor to convert EER to CEER (CEER includes standby and off power consumption)[89].

CEERbase = Combined Energy Efficiency Ratio of baseline unit

= As provided in tables above

CEERee = Combined Energy Efficiency Ratio of ENERGY STAR unit

= Actual. If unknown assume minimum qualifying standard as provided in tables above

Time of Sale:

For example for an 8,500 Btu/H capacity unit, with louvered sides, in an unknown location:

$\Delta kWH_{ENERGY\ STAR}$ = (248 * 8500 * (1/10.9 – 1/12.0)) / 1000

= 17.7 kWh

Early Replacement:

A 7.7EER, 9000Btu/h unit is removed from a home in Springfield and replaced with an ENERGY STAR unit with louvered sides:

ΔkWh for remaining life of existing unit (1st 4 years) = (319 * 9000 * (1/(7.7/1.01) - 1/12.0))/1000

= 137.3 kWh

ΔkWh for remaining measure life (next 8 years) = (319 * 9000 * (1/10.9 - 1/12.0))/1000

= 24.1 kWh

85 Full load hours for room AC is significantly lower than for central AC. The average ratio of FLH for Room AC (provided in RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008) to FLH for Central Cooling for the same location is 31%. This ratio is applied to those IL cities that have FLH for Central Cooling provided in the ENERGY STAR calculator. For other cities this is extrapolated using the FLH assumptions VEIC have developed for Central AC. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

86 Weighted based on number of residential occupied housing units in each zone.

87 Based on maximum capacity average from the RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008

88 Based on Nexus Market Research Inc, RLW Analytics, December 2005; "Impact, Process, and Market Study of the Connecticut Appliance Retirement Program: Overall Report."

89 Since the existing unit will be rated in EER, this factor is used to appropriately compare with the new CEER rating. Version 3.0 of the ENERGY STAR specification provided equivalent EER and CEER ratings and for the most popular size band the EER rating is approximately 1% higher than the CEER. See 'ENERGY STAR Version 3.0 Room Air Conditioners Program Requirements'.

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

Time of Sale: ΔkW = Btu/H * ((1/(CEERbase *1.01) - 1/(CEERee * 1.01)))/1000) * CF

Early Replacement: ΔkW = Btu/H * ((1/EERexist - 1/(CEERee * 1.01)))/1000) * CF

Where:

CF = Summer Peak Coincidence Factor for measure

= 0.3[90]

1.01 = Factor to convert CEER to EER (CEER includes standby and off power consumption)[91].

Other variable as defined above

> Time of Sale:
>
> For example for an 8,500 Btu/H capacity unit, with louvered sides, for an unknown location:
>
> $\Delta kW_{CEE\ TIER\ 1}$ = (8500 * (1/(10.9 * 1.01) – 1/(12.0*1.01))) / 1000 * 0.3
>
> = 0.021 kW
>
> Early Replacement:
>
> A 7.7 EER, 9000Btu/h unit is removed from a home in Springfield and replaced with an ENERGY STAR unit with louvered sides:
>
> ΔkW for remaining life of existing unit (1st 4 years) = (9000 * (1/7.7 - 1/(12.0 * 1.01)))/1000 * 0.3
>
> = 0.128 kW
>
> ΔkW for remaining measure life (next 8 years) = (9000 * (1/(10.9 * 1.01) - 1/(12.0 * 1.01)))/1000 * 0.3
>
> = 0.022 kW

### NATURAL GAS SAVINGS

N/A

### WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

### DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

### MEASURE CODE: RS-APL-ESRA-V07-190101

### REVIEW DEADLINE: 1/1/2022

---

90 Consistent with coincidence factors found in: RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008

91 Since the new CEER rating includes standby and off power consumption, for peak calculations it is more appropriate to apply the EER rating, but it appears as though new units will only be rated with a CEER rating. Version 3.0 of the ENERGY STAR specification provided equivalent EER and CEER ratings and for the most popular size band the EER rating is approximately 1% higher than the CEER. See ‘ENERGY STAR Version 3.0 Room Air Conditioners Program Requirements’.

## 5.1.8 Refrigerator and Freezer Recycling

### DESCRIPTION

This measure describes savings from the retirement and recycling of inefficient but operational refrigerators and freezers. Savings are provided based on a 2013 workpaper provided by Cadmus that used data from a 2012 ComEd metering study and metering data from a Michigan study, to develop a regression equation that uses key inputs describing the retired unit. The savings are equivalent to the Unit Energy Consumption of the retired unit and should be claimed for the assumed remaining useful life of that unit. A part use factor is applied to account for those secondary units that are not in use throughout the entire year. The reader should note that the regression algorithm is designed to provide an accurate portrayal of savings for the population as a whole and includes those parameters that have a significant effect on the consumption. The precision of savings for individual units will vary.

For Net to Gross factor considerations, please refer to section 4.2 Appliance Recycling Protocol of Appendix A: Illinois Statewide Net-to-Gross Methodologies of Volume 4.0 Cross Cutting Measures and Attachments.

This measure was developed to be applicable to the following program types: ERET.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

N/A

### DEFINITION OF BASELINE EQUIPMENT

The existing inefficient unit must be operational and have a capacity of between 10 and 30 cubic feet.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The estimated remaining useful life of the recycling units is 6.5 years [92].

### DEEMED MEASURE COST

Measure cost includes the customer's value placed on their lost amenity, any customer transaction costs, and the cost of pickup and recycling of the refrigerator/freezer and should be based on actual costs of running the program. The payment (bounty) a Program Administrator makes to the customer serves as a proxy for the value the customer places on their lost amenity and any customer transaction costs. If unknown assume $170[93] per unit.

### LOADSHAPE

Loadshape R05 - Residential Refrigerator

### COINCIDENCE FACTOR

The coincidence factor is assumed to be 0.00012.

[92] DOE refrigerator and freezer survival curves are used to calculate RUL for each equipment age and develop a RUL schedule. The RUL of each unit in the ARCA database is calculated and the average RUL of the dataset serves as the final measure RUL. Refrigerator recycling data from ComEd (PY7-PY9) and Ameren (PY6-PY8) were used to determined EUL with the DOE survival curves from the 2009 TSD. A weighted average of the retailer ComEd data and the Ameren data results in an average of 6.5 years. See Navigant 'ComEd Effective Useful Life Research Report', May 2018.

[93] The $170 default assumption is based on $120 cost of pickup and recycling per unit and $50 proxy for customer transaction costs and value customer places on their lost amenity. $120 is cost of pickup and recycling based on similar Efficiency Vermont program. $50 is bounty, based on Ameren and ComEd program offerings as of 7/27/15.

**Algorithm**

## CALCULATION OF SAVINGS

### ENERGY SAVINGS[94]

Refrigerators:

Energy savings for refrigerators are based upon a linear regression model using the following coefficients[95]:

| Independent Variable Description | Estimate Coefficient |
|---|---|
| Intercept | 83.324 |
| Age (years) | 3.678 |
| Pre-1990 (=1 if manufactured pre-1990) | 485.037 |
| Size (cubic feet) | 27.149 |
| Dummy: Side-by-Side (= 1 if side-by-side) | 406.779 |
| Dummy: Primary Usage Type (in absence of the program) (= 1 if primary unit) | 161.857 |
| Interaction: Located in Unconditioned Space x CDD/365.25 | 15.366 |
| Interaction: Located in Unconditioned Space x HDD/365.25 | -11.067 |

ΔkWh = [83.32 + (Age * 3.68) + (Pre-1990 * 485.04) + (Size * 27.15) + (Side-by-side * 406.78) + (Proportion of Primary Appliances * 161.86) + (CDD/365.25 * unconditioned * 15.37) + (HDD/365.25 *unconditioned *-11.07)] * Part Use Factor

Where:

Age = Age of retired unit

Pre-1990 = Pre-1990 dummy (=1 if manufactured pre-1990, else 0)

Size = Capacity (cubic feet) of retired unit

Side-by-side = Side-by-side dummy (= 1 if side-by-side, else 0)

Primary Usage = Primary Usage Type (in absence of the program) dummy

(= 1 if Primary, else 0)

Interaction: Located in Unconditioned Space x CDD/365.25

(=1 * CDD/365.25 if in unconditioned space)

CDD = Cooling Degree Days

= Dependent on location[96]:

| Climate Zone (City based upon) | CDD 65 | CDD/365.25 |
|---|---|---|
| 1 (Rockford) | 820 | 2.25 |

[94] Based on the specified regression, a small number of units may have negative energy and demand consumption. These are a function of the unit size and age, and should comprise a very small fraction of the population. While on an individual basis this result is counterintuitive it is important that these negative results remain such that as a population the average savings is appropriate.

[95] Energy savings are based on an average 30-year TMY temperature of 51.1 degrees. Coefficients provided in July 30, 2014 memo from Cadmus: "Appliance Recycling Update no single door July 30 2014".

[96] National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 65°F.

| Climate Zone (City based upon) | CDD 65 | CDD/365.25 |
|---|---|---|
| 2 (Chicago) | 842 | 2.31 |
| 3 (Springfield) | 1,108 | 3.03 |
| 4 (Belleville) | 1,570 | 4.30 |
| 5 (Marion) | 1,370 | 3.75 |

Interaction: Located in Unconditioned Space x HDD/365.25

(=1 * HDD/365.25 if in unconditioned space)

HDD = Heating Degree Days

= Dependent on location:[97]

| Climate Zone (City based upon) | HDD 65 | HDD/365.25 |
|---|---|---|
| 1 (Rockford) | 6,569 | 17.98 |
| 2 (Chicago) | 6,339 | 17.36 |
| 3 (Springfield) | 5,497 | 15.05 |
| 4 (Belleville) | 4,379 | 11.99 |
| 5 (Marion) | 4,476 | 12.25 |

Part Use Factor = To account for those units that are not running throughout the entire year. The most recent part-use factor participant survey results available at the start of the current program year shall be used[98]. For illustration purposes, this example uses 0.93.[99]

For example, the program averages for AIC's ARP in PY4 produce the following equation:

ΔkWh = [83.32 + (22.81 * 3.68) + (0.45 * 485.04) + (18.82 * 27.15) + (0.17 * 406.78) + (0.34 * 161.86) + (1.29 * 15.37) + (6.49 * -11.07)] * 0.93

= 969 * 0.93

= 900.9 kWh

Freezers:

Energy savings for freezers are based upon a linear regression model using the following coefficients[100]:

| Independent Variable Description | Estimate Coefficient |
|---|---|
| Intercept | 132.122 |
| Age (years) | 12.130 |
| Pre-1990 (=1 if manufactured pre-1990) | 156.181 |
| Size (cubic feet) | 31.839 |
| Chest Freezer Configuration (=1 if chest freezer) | -19.709 |

97 National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 65°F.

98 For example, the part-use factor that shall be applied to the current program year t (PYt) for savings verification purposes should be determined through the PYt-2 participant surveys conducted in the respective utility's service territory, if available. If an evaluation was not performed in PYt-2 the latest available evaluation should be used.

99 Most recent refrigerator part-use factor from Ameren Illinois PY5 evaluation.

100 Energy savings are based on an average 30-year TMY temperature of 51.1 degrees. Coefficients provided in January 31, 2013 memo from Cadmus: "Appliance Recycling Update".

| Independent Variable Description | Estimate Coefficient |
|---|---|
| Interaction: Located in Unconditioned Space x CDD/365.25 | 9.778 |
| Interaction: Located in Unconditioned Space x HDD/365.25 | -12.755 |

ΔkWh = [132.12 + (Age * 12.13) + (Pre-1990 * 156.18) + (Size * 31.84) + (Chest Freezer * -19.71) + (CDDs* unconditioned *9.78) + (HDDs*unconditioned *-12.75)] * Part Use Factor

Where:

Age = Age of retired unit

Pre-1990 = Pre-1990 dummy (=1 if manufactured pre-1990, else 0)

Size = Capacity (cubic feet) of retired unit

Chest Freezer = Chest Freezer dummy (= 1 if chest freezer, else 0)

Interaction: Located in Unconditioned Space x CDD/365.25

(=1 * CDD/365.25 if in unconditioned space)

CDD = Cooling Degree Days (see table above)

Interaction: Located in Unconditioned Space x HDD/365.25

(=1 * HDD/365.25 if in unconditioned space)

HDD = Heating Degree Days (see table above)

Part Use Factor = To account for those units that are not running throughout the entire year. The most recent part-use factor participant survey results available at the start of the current program year shall be used[101]. . For illustration purposes, the example uses 0.85.[102]

The program averages for AIC's ARP PY4 program are used as an example.

ΔkWh = [132.12 + (26.92 * 12.13) + (0.6 * 156.18) + (15.9 * 31.84) + (0.48 * -19.71) + (6.61 * 9.78) + (1.3 * -12.75)] * 0.825

= 977 * 0.825

= 905 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = kWh/8766 * CF

Where:

kWh = Savings provided in algorithm above

CF = Coincident factor defined as summer kW/average kW

= 1.081 for Refrigerators

= 1.028 for Freezers[103]

[101] For example, the part-use factor that shall be applied to the current program year t (PYt) for savings verification purposes should be determined through the PYt-2 participant surveys conducted in the respective utility's service territory, if available. If an evaluation was not performed in PYt-2 the latest available evaluation should be used.

[102] Most recent freezer part-use factor from Ameren Illinois Company PY5 evaluation.

[103] Cadmus memo, February 12, 2013; "Appliance Recycling Update"

For example, the program averages for AIC's ARP in PY4 produce the following equation:

$$\Delta kW = 806/8766 * 1.081$$
$$= 0.099 \text{ kW}$$

**NATURAL GAS SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-APL-RFRC-V07-190101**

**REVIEW DEADLINE: 1/1/2022**

## 5.1.9 Room Air Conditioner Recycling

### Description

This measure describes the savings resulting from running a drop off service taking existing residential, inefficient Room Air Conditioner units from service, prior to their natural end of life. This measure assumes that though a percentage of these units will be replaced this is not captured in the savings algorithm since it is unlikely that the incentive made someone retire a unit that they weren't already planning to retire. The savings therefore relate to the unit being taken off the grid as opposed to entering the secondary market. The Net to Gross factor applied to these units should incorporate adjustments that account for those participants who would have removed the unit from the grid anyway.

This measure was developed to be applicable to the following program types: ERET.

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

N/A. This measure relates to the retiring of an existing inefficient unit.

### Definition of Baseline Equipment

The baseline condition is the existing inefficient room air conditioning unit.

### Deemed Lifetime of Efficient Equipment

The assumed remaining useful life of the existing room air conditioning unit being retired is 4 years[104].

### Deemed Measure Cost

The actual implementation cost for recycling the existing unit should be used.

### Loadshape

Loadshape R08 - Residential Cooling

### Coincidence Factor

The coincidence factor for this measure is assumed to be 30%[105].

**Algorithm**

### Calculation of Savings

### Electric Energy Savings

$$\Delta kWh = ((FLH_{RoomAC} * Btu/hr * (1/EERexist))/1000)$$

Where:

$FLH_{RoomAC}$ = Full Load Hours of room air conditioning unit

= dependent on location[106]:

[104] A third of assumed measure life for Room AC.

[105] Consistent with coincidence factors found in: RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008.

[106] The average ratio of FLH for Room AC (provided in RLW Report: Final Report Coincidence Factor Study Residential Room Air

| Climate Zone (City based upon) | $FLH_{RoomAC}$ |
|---|---|
| 1 (Rockford) | 220 |
| 2 (Chicago) | 210 |
| 3 (Springfield) | 319 |
| 4 (Belleville) | 428 |
| 5 (Marion) | 374 |
| Weighted Average[107] | 248 |

Btu/H = Size of retired unit

= Actual. If unknown assume 8500 Btu/hr [108]

EERexist = Efficiency of existing unit

= 9.8[109]

For example for an 8500 Btu/h unit in Springfield:

$\Delta$kWh = ((319 * 8500 * (1/9.8)) / 1000)

= 276 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$\Delta$kW = (Btu/hr * (1/EERexist))/1000) * CF

Where:

CF = Summer Peak Coincidence Factor for measure

= 0.3[110]

For example an 8500 Btu/h unit:

$\Delta$kW = (8500 * (1/9.8)) / 1000) * 0.3

= 0.26 kW

**NATURAL GAS SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

Conditioners, June 23, 2008) to FLH for Central Cooling for the same location is 31%. This ratio is applied to those IL cities that have FLH for Central Cooling provided in the ENERGY STAR calculator. For other cities this is extrapolated using the FLH assumptions VEIC have developed for Central AC. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

[107] Weighted based on number of residential occupied housing units in each zone.

[108] Based on maximum capacity average from the RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008

[109] Minimum Federal Standard for most common room AC type (8000-14,999 capacity range with louvered sides) per federal standards from 10/1/2000 to 5/31/2014. Note that this value is the EER value, as CEER were introduced later.

[110] Consistent with coincidence factors found in:
RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008.

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-APL-RARC-V02-190101**

**REVIEW DEADLINE: 1/1/2023**

## 5.1.10 ENERGY STAR Clothes Dryer

**DESCRIPTION**

This measure relates to the installation of a residential clothes dryer meeting the ENERGY STAR criteria. ENERGY STAR qualified clothes dryers save energy through a combination of more efficient drying and reduced runtime of the drying cycle. More efficient drying is achieved through increased insulation, modifying operating conditions such as air flow and/or heat input rate, improving air circulation through better drum design or booster fans, and improving efficiency of motors. Reducing the runtime of dryers through automatic termination by temperature and moisture sensors is believed to have the greatest potential for reducing energy use in clothes dryers[111]. ENERGY STAR provides criteria for both gas and electric clothes dryers.

This measure was developed to be applicable to the following program types: TOS, NC. If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

Clothes dryer must meet the ENERGY STAR criteria, as required by the program.

**DEFINITION OF BASELINE EQUIPMENT**

The baseline condition is a clothes dryer meeting the minimum federal requirements for units manufactured on or after January 1, 2015.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected measure life is assumed to be 16 years[112].

**DEEMED MEASURE COST**

The incremental cost for an ENERGY STAR clothes dryer is assumed to be $152[113]

**LOADSHAPE**

N/A

**COINCIDENCE FACTOR**

The coincidence factor for this measure is 3.8%[114].

---

[111] ENERGY STAR Market & Industry Scoping Report. Residential Clothes Dryers. Table 8. November 2011.
[112] Based on DOE Rulemaking Technical Support Document, LCC Chapter, 2011, as recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.
[113] Based on the difference in installed cost for an efficient dryer ($716) and standard dryer ($564) (see "ACEEE Clothes Dryers.pdf").
[114] Based on coincidence factor of 3.8% for clothes washers

## Algorithm

### CALCULATION OF ENERGY SAVINGS

### ELECTRIC ENERGY SAVINGS

$$\Delta kWh = (Load/CEFbase - Load/CEFeff) * Ncycles * \%Electric$$

Where:

Load = The average total weight (lbs) of clothes per drying cycle. If dryer size is unknown, assume standard.

| Dryer Size | Load (lbs)[115] |
|---|---|
| Standard | 8.45 |
| Compact | 3 |

CEFbase = Combined energy factor (CEF) (lbs/kWh) of the baseline unit is based on existing federal standards energy factor and adjusted to CEF as performed in the ENERGY STAR analysis[116]. If product class unknown, assume electric, standard.

| Product Class | CEF (lbs/kWh) |
|---|---|
| Vented Electric, Standard (≥ 4.4 $ft^3$) | 3.11 |
| Vented Electric, Compact (120V) (< 4.4 $ft^3$) | 3.01 |
| Vented Electric, Compact (240V) (<4.4 $ft^3$) | 2.73 |
| Ventless Electric, Compact (240V) (<4.4 $ft^3$) | 2.13 |
| Vented Gas | 2.84[117] |

CEFeff = CEF (lbs/kWh) of the ENERGY STAR unit based on ENERGY STAR requirements.[118] If product class unknown, assume electric, standard.

| Product Class | CEF (lbs/kWh) |
|---|---|
| Vented or Ventless Electric, Standard (≥ 4.4 $ft^3$) | 3.93 |
| Vented or Ventless Electric, Compact (120V) (< 4.4 $ft^3$) | 3.80 |
| Vented Electric, Compact (240V) (< 4.4 $ft^3$) | 3.45 |
| Ventless Electric, Compact (240V) (< 4.4 $ft^3$) | 2.68 |
| Vented Gas | 3.48[119] |

Ncycles = Number of dryer cycles per year. Use actual data if available. If unknown, use 283 cycles per year.[120]

%Electric = The percent of overall savings coming from electricity

[115] Based on ENERGY STAR test procedures.
[116] ENERGY STAR Draft 2 Version 1.0 Clothes Dryers Data and Analysis
[117] Federal standards report CEF for gas clothes dryers in terms of lbs/kWh. To determine gas savings, this number is later converted to therms.
[118] ENERGY STAR Clothes Dryers Key Product Criteria.
[119] Federal standards report CEF for gas clothes dryers in terms of lbs/kWh. To determine gas savings, this number is later converted to therms.
[120] Appendix D to Subpart B of Part 430 – Uniform Test Method for Measuring the Energy Consumption of Dryers.

= 100% for electric dryers, 16% for gas dryers[121]

| Example |
|---|
| Time of Sale: For example, a standard, vented, electric clothes dryer: |
| ΔkWh = ((8.45/3.11 – 8.45/3.93) * 283 * 100%) |
| = 160 kWh |

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = ΔkWh/Hours * CF

Where:

ΔkWh = Energy Savings as calculated above

Hours = Annual run hours of clothes dryer. Use actual data if available. If unknown, use 283 hours per year.[122]

CF = Summer Peak Coincidence Factor for measure

= 3.8%[123]

| Example |
|---|
| Time of Sale: For example, a standard, vented, electric clothes dryer: |
| ΔkW = 160/283 * 3.8% |
| = 0.0215 kW |

**NATURAL GAS SAVINGS**

Natural gas savings only apply to ENERGY STAR vented gas clothes dryers.

ΔTherm = (Load/EFbase – Load/CEFeff) * Ncycles * Therm_convert * %Gas

Where:

Therm_convert = Conversion factor from kWh to Therm

= 0.03412

%Gas = Percent of overall savings coming from gas

= 0% for electric units and 84% for gas units[124]

[121] %Electric accounts for the fact that some of the savings on gas dryers comes from electricity (motors, controls, etc). 16% was determined using a ratio of the electric to total savings from gas dryers given by ENERGY STAR Draft 2 Version 1.0 Clothes Dryers Data and Analysis.

[122] ENERGY STAR qualified dryers have a maximum test cycle time of 80 minutes. Assume one hour per dryer cycle.

[123] Based on coincidence factor of 3.8% for clothes washers.

[124] %Gas accounts for the fact that some of the savings on gas dryers comes from electricity (motors, controls, etc). 84% was determined using a ratio of the gas to total savings from gas dryers given by ENERGY STAR Draft 2 Version 1.0 Clothes Dryers Data and Analysis.

Example

Time of Sale: For example, a standard, vented, gas clothes dryer:

$$\Delta Therm = (8.45/2.84 - 8.45/3.48) * 283 * 0.03412 * 0.84$$
$$= 4.44 \text{ therms}$$

## WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

## DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

**MEASURE CODE: RS-APL-ESDR-V02-190101**

**REVIEW DEADLINE: 1/1/2021**

## 5.1.11 ENERGY STAR Water Coolers

### DESCRIPTION

Water coolers are a home appliance that offer consumers the ability to enjoy hot and/or cold water on demand. This measure is the characterization of the purchasing and use of an ENERGY STAR certified water cooler in place of a conventional water cooler.

This measure was developed to be applicable to the following program types: TOS, NC.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

The high efficiency equipment is an ENERGY STAR certified water cooler meeting the ENERGY STAR 2.0 efficiency criteria.

### DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a standard or conventional, non-ENERGY STAR certified water cooler.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The estimated useful life for a water cooler is 10 years[125].

### DEEMED MEASURE COST

The incremental cost for this measure is estimated at $17[126].

### LOADSHAPE

Loadshape C53: Flat

### COINCIDENCE FACTOR

The summer peak coincidence factor is assumed to be 1.0.

**Algorithm**

### CALCULATION OF ENERGY SAVINGS

### ELECTRIC ENERGY SAVINGS

$$\Delta kWh = (kWh_{base} - kWh_{ee}) * Days$$

Where:

$kWh_{base}$ = Daily energy use (kWh/day) for baseline water cooler[127]

| Type of Water Cooler | kWhbase |
|---|---|
| Hot and Cold Water – Storage | 1.090 |
| Hot and Cold Water – On Demand | 0.330 |
| Cold Water Only | 0.290 |

[125] Savings Calculator for ENERGY STAR Certified Water Coolers, last updated 2009.
[126] Ameren Missouri PY3 Evaluation Report.
[127] Savings Calculator for ENERGY STAR Certified Water Coolers, last updated 2009.

$kWh_{ee}$ = Daily energy use (kWh/day) for ENERGY STAR water cooler[128]

| Type of Water Cooler | kWhee |
|---|---|
| Hot and Cold Water – Storage | 0.747 |
| Hot and Cold Water – On Demand | 0.170 |
| Cold Water Only | 0.157 |

Days = Number of days per year that the water cooler is in use
= 365.25 days[129]

Energy Savings:

| Type of Water Cooler | ΔkWh |
|---|---|
| Hot and Cold Water – Storage | 125.4 |
| Hot and Cold Water – On Demand | 58.4 |
| Cold Water Only | 48.7 |

**DEMAND SAVINGS**

$$\Delta kW = \Delta kWh / Hours * CF$$

Where:

Hours = Number of hours per year water cooler is in use
= 8766 hours[130]

CF = Summer Peak Coincidence Factor for measure

= 1.0

Demand Savings:

| Type of Water Cooler | ΔkW |
|---|---|
| Hot and Cold Water - Storage | 0.0143 |
| Hot and Cold Water – On Demand | 0.0067 |
| Cold Water Only | 0.0056 |

**NATURAL GAS SAVINGS**

N/A

**WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

[128] Average kWh/day for from the ENERGY STAR efficient product database.
[129] Savings Calculator for ENERGY STAR Certified Water Coolers, last updated 2009.
[130] Assumed 365 days per year and 24 hours per day as utilized in daily energy consumption from ENERGY STAR Program Requirements Product Specification for Water Coolers Test Method.

**MEASURE CODE: RS-APL-WTCL-V01-180101**

**REVIEW DEADLINE: 1/1/2024**

## 5.1.12 Ozone Laundry

### DESCRIPTION

A new ozone laundry system is added-on to new or existing residential clothes washing machine(s) currently using hot water heated with natural gas. The system generates ozone ($O_3$), a naturally occurring molecule, which helps clean fabrics by chemically reacting with soils in cold water. Adding an ozone laundry system(s) eliminate the use of chemicals, detergents, and hot water by residential washing machine(s).

Energy savings will be achieved at the domestic hot water heater as it will no longer supply hot water to the washing machine. Cold water usage by the clothes washer will increase, but overall water usage will stay constant.

This measure was developed to be applicable to the following program types: TOS, RNC, RF

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

A new, packaged ozone laundry system(s) rated for residential clothes washing machines is added-on to new or existing residential clothes washing machines. The ozone laundry system must be connected to both the hot and cold water inlets of the clothes washing machine so that hot water from the domestic hot water heater is no longer provided to the clothes washer.

The ozone laundry system(s) must transfer ozone into the water through:

- Venturi injection
- Bubble diffusion
- Additional applications may be considered upon program review and approval on a case by case basis

### DEFINITION OF BASELINE EQUIPMENT

The base case equipment is a conventional residential washing machine with no ozone generator installed. The washing machine is provided hot water from a domestic hot water heater.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure equipment effective useful life (EUL) is estimated at 8 years based on the typical lifetime of products currently available in the market.[131]

### DEEMED MEASURE COST

The deemed measure cost is $300 for a new residential ozone laundry system[132]

### LOADSHAPE

Loadshape R01 – Residential Clothes Washer

### COINCIDENCE FACTOR

The coincidence factor for this measure is 3.8%[133].

[131] Average based on conversations with manufacturers and distributors of the four residential ozone laundry systems tested in the 2018 GTI Residential Ozone Laundry Field Demonstration (O3 Pure, Pure Wash, Eco Washer, Scent Crusher).
[132] 2018 GTI Residential Ozone Laundry Field Demonstration (May 2018).
[133] Calculated from Itron eShapes, 8760 hourly data by end use for Missouri, as provided by Ameren.

**Algorithm**

## CALCULATION OF ENERGY SAVINGS

### ELECTRIC ENERGY SAVINGS

$$\Delta kWh = kWhHotWash * (\%HotWash_{base} - \%HotWash_{Ozone})$$

Where:

kWhHotWash = (%ElectricDHW * Capacity * IWF * %HotWater * ($T_{OUT}$ - $T_{IN}$) * 8.33 * 1.0 * Ncycles) / (RE_electric * 3.412)

%ElectricDHW = Proportion of water heating supplied by electric heating

| DHW fuel | %FossilDHW |
|---|---|
| Electric | 100% |
| Natural gas | 0% |
| Unknown | 16%[134] |

Capacity = Clothes washer capacity (cubic feet).

= Actual. If unknown, assume 4.96 cubic feet.[135]

IWF = Integrated water factor (gallons/cycle/ft$^3$).

= Actual. If unknown, use the following values:

| Efficiency Level | IWF (gallons/cycle/ft3 | |
|---|---|---|
| | Top loading > 2.5 Cu ft | Front Loading > 2.5 Cu ft |
| Federal Standard (as of March 2015) | 8.4 | 4.7 |
| ENERGY STAR (as of February 2018) | 4.3 | 3.2 |
| CEE Tier 3 | 3.2 | 3.2 |

%HotWater = Percentage of water usage that is supplied by the domestic hot water heater when the hot or warm wash cycles are selected.

= 0.1757[136]

$T_{OUT}$ = Tank temperature

= 125°F

$T_{IN}$ = Incoming water temperature from well or municipal system

[134] Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IL. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.

[135] Average data from GTI Residential Ozone Laundry Field Demonstration (May 2018). As an add on to existing equipment it is assumed this is a larger capacity than the assumption for new Clothes Washers as old machines tended to have larger capacities. See 'Residential Ozone Summary Calcs – May2018.xls' for more information. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.

[136] Averaged data from GTI Residential Ozone Laundry Field Demonstration (May 2018). Hot and warm wash cycles were combined because data from the EIA Resicential Energy Consumption Survey (RECS) 2015 East North Central Region show that, of the total hot and warm washes that occur, over 96% are warm washes. See 'Residential Ozone Summary Calcs – May2018.xls' for more information.

= 54.1°F[137]

8.33 = Specific weight of water (lbs/gallon)

1.0 = Heat capacity of water (Btu/lb °F)

Ncycles = Number of Cycles per year

= 264[138]

RE_electric = Recovery efficiency of electric water heater

= 98% [139]

3412 = Btus to kWh conversion (Btu/kWh)

$\%HotWash_{base}$ = Average percentage of loads that use hot or warm water with baseline equipment.

= 0.7743[140]

$\%HotWash_{Ozone}$ = Percentage of loads that use hot or warm water with efficient equipment.

= 0.0

For example, a residential ozone laundry system is installed in a single family home with an electric domestic hot water heater. The capacity and IWF of the baseline equipment is unknown.

ΔkWh = (1 * 4.96 * 8.4 * 0.1757 * (125 – 54.1) * 8.33 * 1.0 * 264) / (0.98 * 3412) * (0.7743 – 0)

= 264 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = ΔkWh/Hours * CF

Where:

ΔkWh = Energy Savings as calculated above

Hours = Assumed Run hours of Clothes Washer

= 264 hours[141]

CF = Summer Peak Coincidence Factor for measure.

= 0.038[142]

For example, a residential ozone laundry system is installed in a single family home with an electric domestic hot water heater. The capacity and IWF of the baseline equipment is unknown.

ΔkW = 264/264 * 0.038

= 0.038kW

---

[137] US DOE Building America Program. Building America Analysis Spreadsheet.

[138] Weighted average of clothes washer cycles per year (based on 2015 Residential Energy Consumption Survey (RECS) national sample survey of housing appliances section, Midwest Census Region, West North Central Census Division
If utilities have specific evaluation results providing a more appropriate assumption for single-family or Multifamily homes, in a particular market, or geographical area then that should be used.

[139] Electric water heaters have recovery efficiency of 98%.

[140] GTI Residential Ozone Laundry Field Demonstration (May 2018). See 'Residential Ozone Summary Calcs – May2018.xls' for more information.

[141] Based on a weighted average of 264 clothes washer cycles per year assuming an average load runs for one hour.

[142] Calculated from Itron eShapes, 8760 hourly data by end use for Missouri, as provided by Ameren.

**NATURAL GAS SAVINGS**

$$\Delta Therm = ThermHotWash * (\%HotWash_{base} - \%HotWash_{Ozone})$$

Where:

ThermHotWash = (%FossilDHW * Capacity * IWF * %HotWater * ($T_{OUT}$ - $T_{IN}$) * 8.33 * 1.0 * Ncycles) / (RE_gas * 100,000)

%FossilDHW = proportion of water heating supplied by natural gas heating

| DHW fuel | %FossilDHW |
|---|---|
| Electric | 0% |
| Natural gas | 100% |
| Unknown | 84%[143] |

RE_gas = Recovery efficiency of gas water heater

= 78% For SF homes[144]

= 67% For MF homes[145]

100,000 = Btus to Therms conversion (Btu/Therm).

For example, a residential ozone laundry system is installed in a single family home with a gas domestic hot water heater. The capacity and IWF of the baseline equipment is unknown.

ΔTherms = (1 * 4.96 * 8.4 * 0.1757 * (125 – 54.1) * 8.33 * 1.0 * 264) / (0.78 * 100,000) * (0.7743 – 0)

= 11.32 Therms

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

**LAUNDRY DETERGENT SAVINGS**

Annual savings from not purchasing laundry detergent that are realized by efficient equipment end-user(s) ($/year).

Detergent savings per year = Detergent_cost * Ncycles

Where:

Detergent_cost = Average laundry detergent cost per load ($/load).

[143] Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IL. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.

[144] DOE Final Rule discusses Recovery Efficiency with an average around 0.76 for Gas Fired Storage Water heaters and 0.78 for standard efficiency gas fired tankless water heaters up to 0.95 for the highest efficiency gas fired condensing tankless water heaters. These numbers represent the range of new units however, not the range of existing units in stock. Review of AHRI Directory suggests range of recovery efficiency ratings for new Gas DHW units of 70-87%. Average of existing units is estimated at 78%.

[145] Water heating in Multifamily buildings is often provided by a larger central boiler. This suggests that the average recovery efficiency is somewhere between a typical central boiler efficiency of 0.59 and the 0.75 for single family homes. An average efficiency of 0.67 is used for this analysis as a default for Multifamily buildings.

= 0.16[146]

| |
|---|
| For example, a residential ozone laundry system is installed in a single family home.<br>Detergent savings per year = 0.16 * 295<br>= $47.2 |

**MEASURE CODE: RS-APL-OZNE-V01-190101**

**REVIEW DEADLINE: 1/1/2023**

[146] Based on cost analysis of products available on www.Jet.com and www.Amazon.com.

## 5.2 Consumer Electronics End Use

### 5.2.1 Advanced Power Strip – Tier 1

**DESCRIPTION**

This measure relates to Advanced Power Strips – Tier 1 which are multi-plug surge protector power strips with the ability to automatically disconnect specific connected loads depending upon the power draw of a control load, also plugged into the strip. Power is disconnected from the switched (controlled) outlets when the control load power draw is reduced below a certain adjustable threshold, thus turning off the appliances plugged into the switched outlets. By disconnecting, the standby load of the controlled devices, the overall load of a centralized group of equipment (i.e. entertainment centers and home office) can be reduced. Uncontrolled outlets are also provided that are not affected by the control device and so are always providing power to any device plugged into it. This measure characterization provides savings for a 5-plug strip and a 7-plug strip.

This measure was developed to be applicable to the following program types: TOS, NC, DI, KITS.

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

The efficient case is the use of a 5 or 7-plug advanced power strip.

**DEFINITION OF BASELINE EQUIPMENT**

For time of sale or new construction applications, the assumed baseline is a standard power strip that does not control connected loads.

For direct install and kits, the baseline is the existing equipment utilized in the home.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The assumed lifetime of the advanced power strip is 7 years[147].

**DEEMED MEASURE COST**

For time of sale or new construction the incremental cost of an advanced Tier 1 power strip over a standard power strip with surge protection is assumed to be $10[148].

For direct install the actual full install cost (including labor) and for kits the full equipment cost should be used.

**LOADSHAPE**

Loadshape R13 - Residential Standby Losses – Entertainment

Loadshape R14 - Residential Standby Losses - Home Office

**COINCIDENCE FACTOR**

The summer peak coincidence factor for this measure is assumed to be 80%[149].

**Algorithm**

[147] This is a consistent assumption with 5.2.2 Advanced Power Strip – Tier 2.
[148] Price survey performed by Illume Advising LLC for IL TRM workpaper, see "Current Surge Protector Costs and Comparison 7-2016" spreadsheet.
[149] Efficiency Vermont 2016 TRM coincidence factor for advanced power strip measure –in the absence of empirical evaluation data, this was based on assumptions of the typical run pattern for televisions and computers in homes.

## Calculation of Savings

### Electric Energy Savings

$\Delta$kWh = kWh * ISR

Where:

kWh = Assumed annual kWh savings per unit

= 56.5 kWh for 5-plug units or 103 kWh for 7-plug units[150]

ISR = In Service Rate, dependent on delivery mechanism

| Delivery Mechanism | ISR |
|---|---|
| Energy Efficiency Kit, Leave behind | 69%[151] |
| Direct Install, Time of Sale | 100% |

Using assumptions above:

| # Plugs | Delivery Mechanism | ΔkWh |
|---|---|---|
| 5- plug | Energy Efficiency Kit, Leave behind | 39.0 |
| | Direct Install, Time of Sale | 56.5 |
| 7-plug | Energy Efficiency Kit, Leave behind | 71.1 |
| | Direct Install, Time of Sale | 103.0 |
| Unknown[152] | Energy Efficiency Kit, Leave behind | 55.0 |
| | Direct Install, Time of Sale | 80.0 |

### Summer Coincident Peak Demand Savings

$\Delta$kW = $\Delta$kWh / Hours * CF

Where:

Hours = Annual number of hours during which the controlled standby loads are turned off by the Tier 1 Advanced power Strip.

= 7,129 [153]

CF = Summer Peak Coincidence Factor for measure

[150] NYSERDA Measure Characterization for Advanced Power Strips. Study based on review of:
Smart Strip Electrical Savings and Usability, Power Smart Engineering, October 27, 2008.
Final Field Research Report, Ecos Consulting, October 31, 2006. Prepared for California Energy Commission's PIER Program.
Developing and Testing Low Power Mode Measurement Methods, Lawrence Berkeley National Laboratory (LBNL), September 2004. Prepared for California Energy Commission's Public Interest Energy Research (PIER) Program.
2005 Intrusive Residential Standby Survey Report, Energy Efficient Strategies, March, 2006.
Smart Strip Portfolio of the Future, Navigant Consulting for San Diego G&E, March 31, 2009.
"Smart strip" in this context refers to the category of Advanced Power Strips, does not specifically signify Smart Strip® from BITS Limited, and was used without permission. Smart Strip® is a registered trademark of BITS Smart Strip, LLC.
[151] Average of Ameren Missouri, Potomac Edison, and PPL Electric ISR for smart strips in kits.
Cadmus, "Ameren Missouri RebateSavers Impact and Process Evaluation: Program Year 2013" p. 75.
Cadmus, "Process Evaluation Report, PPL Electric EE&C Plan, Program Year Five." p. 94
"Smart strip" in this context refers to the category of Advanced Power Strips, does not specifically signify Smart Strip® from BITS Limited, and was used without permission. Smart Strip® is a registered trademark of BITS Smart Strip, LLC.
[152] Calculated as average of 5 and 7 plug savings assumptions.
[153] Average of hours for controlled TV and computer from; NYSERDA Measure Characterization for Advanced Power Strips

= 0.8 [154]

| # Plugs | Delivery Mechanism | ΔkW |
|---|---|---|
| 5- plug | Energy Efficiency Kit, Leave behind | 0.0044 |
| | Direct Install, Time of Sale | 0.0063 |
| 7-plug | Energy Efficiency Kit, Leave behind | 0.0080 |
| | Direct Install, Time of Sale | 0.0116 |
| Unknown[155] | Energy Efficiency Kit, Leave behind | 0.0062 |
| | Direct Install, Time of Sale | 0.0090 |

**NATURAL GAS SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-CEL-SSTR-V04-190101**

**REVIEW DEADLINE: 1/1/2021**

[154] Efficiency Vermont 2016 TRM coincidence factor for advanced power strip measure –in the absence of empirical evaluation data, this was based on assumptions of the typical run pattern for televisions and computers in homes.
[155] Calculated as average of 5 and 7 plug savings assumptions.

## 5.2.2 Tier 2 Advanced Power Strips (APS) – Residential Audio Visual

### Description

This measure relates to the installation of a Tier 2 Advanced Power Strip / surge protector for household audio visual environments (Tier 2 AV APS). Tier 2 AV APS are multi-plug power strips that remove power from audio visual equipment through intelligent control and monitoring strategies.

By utilizing advanced control strategies such as a countdown timer, external sensors (e.g. of infra-red remote usage and/or occupancy sensors, true RMS (Root Mean Square) power sensing; both active power loads and standby power loads of controlled devices are managed by Tier 2 AV APS devices[156]. Monitoring and controlling both active and standby power loads of controlled devices will reduce the overall load of a centralized group of electrical equipment (i.e. the home entertainment center). This more intelligent sensing and control process has been demonstrated to deliver increased energy savings and demand reduction compared with 'Tier 1 Advanced Power Strips'.

The Tier 2 APS market is a relatively new and developing one. With several new Tier 2 APS products coming to market, it is important that energy savings are clearly demonstrated through independent field trials. The IL Technical Advisory Committee have developed a protocol whereby product manufacturers must submit independent field trial evidence of the Energy Reduction Percentage of their particular product either to the TRM Administrator for consideration during the TRM update process (August – December), or engage with a Program Administrator's independent evaluation team to review at other times. The product will be assigned a Product Class (A-H) corresponding to the proven savings and all products in a class will claim consistent savings. The IL TRM Administrator will maintain a list of eligible product and class on the IL TRM Sharepoint site. If a mid-year review has taken place, supporting information should be posted on the Sharepoint site such that other program administrators can review.

Due to the inherent variance day to day and week to week for hours of use of AV systems, it is critical that field trial studies effectively address the variability in usage patterns. There is significant discussion in the EM&V and academic domain on the optimal methodology for controlling for these factors and in submitting evidence of energy savings, it is critical that it is demonstrated that these issues are adequately addressed.

This measure was developed to be applicable to the following program types: DI. If applied to other program delivery types, the installation characteristics including the number of AV devices under control and an appropriate in service rate should be verified through evaluation.

Current evaluation is limited to Direct Install applications. Through a Direct Install program it can be assured that the APS is appropriately set up and the customer is knowledgeable about its function and benefit. It is encouraged that additional implementation strategies are evaluated to provide an indication of whether the units are appropriately set up, used with AV equipment and that the customer is knowledgeable about its function and benefit. This will then facilitate a basis for broadening out the deployment methods of the APS technology category beyond Direct Install.

### Definition of Efficient Equipment

The efficient case is the use of a Tier 2 AV APS in a residential AV (home entertainment) environment that includes control of at least 2 AV devices with one being the television[157].

Only Tier 2 AV APS products that have independent demonstrated energy savings via field trials are eligible.

[156] Tier 2 AV APS identify when people are not engaged with their AV equipment and then remove power, for example a TV and its peripheral devices that are unintentionally left on when a person leaves the house or for instance where someone falls asleep while watching television.

[157] Given this requirement, an AV environment consisting of a television and DVD player or a TV and home theater would be eligible for a Tier 2 AV APS installation.

The minimum product specifications for Tier 2 AV APS are:

**Safety & longevity**

- Product and installation instructions shall comply with 2012 International Fire Code and 2000 NFPA 101 Life Safety Code (IL Fire Code).
- Third party tested to all applicable UL Standards.
- Contains a resettable circuit breaker
- Incorporates power switching electromechanical relays rated for 100,000 switching cycles at full 15 amp load (equivalent to more than 10 years of use).

**Energy efficiency functionality**

- Calculates real power as the time average of the instantaneous power, where instantaneous power is the product of instantaneous voltage and current.
- Delivers a warning when the countdown timer begins before an active power down event and maintains the warning until countdown is concluded or reset by use of the remote or other specified signal
- Uses an automatically adjustable power switching threshold.

### Definition of Baseline Equipment

The assumed baseline equipment is the existing equipment being used in the home (e.g. a standard power strip or wall socket) that does not control loads of connected AV equipment.

### Deemed Lifetime of Efficient Equipment

The default deemed lifetime value for Tier 2 AV APS is assumed to be 7 years[158].

### Deemed Measure Cost

Direct Installation: The actual installed cost (including labor) of the new Tier 2 AV APS equipment should be used.

### Loadshape

Loadshape R13 - Residential Standby Losses – Entertainment

### Coincidence Factor

The summer peak coincidence factor for this measure is assumed to be 80%[159]

## Algorithm

### Calculation of Energy Savings

### Electric Energy Savings

$$\Delta kWh = ERP * BaselineEnergy_{AV} * ISR$$

Where:

ERP = Energy Reduction Percentage of qualifying Tier2 AV APS product range as provided below. See reference documents for Product Classification memo.

[158] There is little evaluation to base a lifetime estimate upon. Based on review of assumptions from other jurisdictions and the relative treatment of In Service Rates and persistence, an estimate of 7 years was agreed by the Technical Advisory Committee, but further evaluation is recommended.
[159] In the absence of empirical evaluation data, this was based on assumptions of the typical run pattern for televisions and computers in homes.

| Product Class | Field trial ERP range | ERP used |
|---|---|---|
| A | 55 – 60% | 55% |
| B | 50 – 54% | 50% |
| C | 45 – 49% | 45% |
| D | 40 – 44% | 40% |
| E | 35 – 39% | 35% |
| F | 30 – 34% | 30% |
| G | 25 – 29% | 25% |
| H | 20 – 24% | 20% |

$BaselineEnergy_{AV}$ = 432 kWh[160]

ISR = In Service Rate. See reference documents for Product Classification memo.

### Summer Coincident Peak Demand Savings

ΔkW = ΔkWh / Hours * CF

Where:

ΔkWh = Energy savings as calculated above

Hours = Annual number of hours during which the APS provides savings.

= 4,380 [161]

CF = Summer Peak Coincidence Factor for measure

= 0.8 [162]

### Natural Gas Savings

N/A[163]

### Water and Other Non-Energy Impact Descriptions and Calculation

N/A

### Deemed O&M Cost Adjustment Calculation

N/A

### Measure Code: RS-CEL-APS2-V03-190101

### Review Deadline: 1/1/2020

---

[160] AESC, Inc, "Energy Savings of Tier 2 Advanced Power Strips in Residential AC Systems", p28. Note that this load represents the average *controlled* AV devices only and will likely be lower than total AC usage.

[161] This is estimate based on assumption that approximately half of savings are during active hours (supported by AESC study) (assumed to be 5.3 hrs/day, 1936 per year (NYSERDA 2011. "*Advanced Power Strip Research Report*")) and half during standby hours (8760-1936 = 6824 hours). The weighted average is 4380.

[162] In the absence of empirical evaluation data, this was based on assumptions of the typical run pattern for televisions and computers in homes. This appears to be supported by the Average Weekday AV Demand Profile and Reduction charts in the AESC study (p33-34). These show that the average demand reduction is relatively flat.

[163] Interactive effects of Tier 2 APS on space conditioning loads has not yet been adequately studied.

# 5.3 HVAC End Use

## 5.3.1 Air Source Heat Pump

**DESCRIPTION**

A heat pump provides heating or cooling by moving heat between indoor and outdoor air.

This measure characterizes:

a) Time of Sale:

- The installation of a new residential sized (<= 65,000 Btu/hr) air source heat pump that is more efficient than required by federal standards. This could relate to the replacement of an existing unit at the end of its useful life, or the installation of a new system in a new home.

b) Early Replacement:

The early removal of functioning electric heating and cooling (SEER 10 or under if present) systems from service, prior to its natural end of life, and replacement with a new high efficiency air source heat pump unit.

Early Replacement determination will be based on meeting the following conditions:

- The existing unit is operational when replaced, or
- The existing unit requires minor repairs (<$276 per ton)[164].
- All other conditions will be considered Time of Sale.

The Baseline SEER of the existing unit replaced:

- If the SEER of the existing unit is known and <=10, the Baseline SEER is the actual SEER value of the unit replaced. If the SEER is >10, the Baseline SEER = 14.
- If the SEER of the existing unit is unknown use assumptions in variable list below (SEER_exist and HSPF_exist).
- If the operational status or repair cost of the existing unit is unknown, use time of sale assumptions.

A weighted average early replacement rate is provided for use when the actual baseline early replacement rates are unknown.[165]

**Deemed Early Replacement Rates For ASHP**

| | Deemed Early Replacement Rate |
|---|---|
| Early Replacement Rate for ASHP participants | 7% |

Note it is not appropriate to claim additional ECM fan savings (from 5.3.5 Furnace Blower Motor) due to installing new ASHP units with an ECM, since the SEER/EER/HSPF ratings already account for this electrical load.

Quality Installation:

[164] The Technical Advisory Committee agreed that if the cost of repair is less than 20% of the new baseline replacement cost it can be considered early replacement. Note the non-inflated cost is used as this would be a cost consideration in the program year.

[165] Based upon research from "Home Energy Efficiency Rebate Program GPY2 Evaluation Report" which outlines early replacement rates for both primary and secondary central air cooling (CAC) and residential furnaces. This is used as a reasonable proxy for ASHP installations since ASHP specific data is not available. Report presented to Nicor Gas Company February 27, 2014.

Additional savings are attributed to the Quality Installation (QI) of the system. QI programs should follow industry standards such as those described in ENERGY STAR Verified HVAC Installation Program (ESVI), ANSI ACCA QI5 and QI9vp. This must include considerations of system design (including sizing, matching, ventilation calculations) and equipment installation (including static pressure, airflow, refrigerant charge) and may also consider distribution.

This measure was developed to be applicable to the following program types: TOS, NC, EREP. If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

A new residential sized (<= 65,000 Btu/hr) air source heat pump with specifications to be determined by program.

### DEFINITION OF BASELINE EQUIPMENT

A new residential sized (<= 65,000 Btu/hr) air source heat pump meeting federal standards.

The baseline for the Time of Sale measure is based on the current Federal Standard efficiency level as of January 1st 2015; 14 SEER and 8.2HSPF an estimate of expected peak rated efficiency of 11.

The baseline for the early replacement measure is the efficiency of the existing equipment for the assumed remaining useful life of the unit and the new baseline as defined above for the remainder of the measure life.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 16 years.[166]

Remaining life of existing ASHP/CAC equipment is assumed to be 6 years[167] and 18 years for electric resistance.

### DEEMED MEASURE COST

Time of sale: The incremental capital cost for this measure is dependent on the efficiency of the new unit[168].

| Efficiency (SEER) | Incremental Cost ($/unit) |
|---|---|
| 14.5 | $123 |
| 15 | $303 |
| 16 | $438 |
| 17 | $724 |
| 18 | $724 |

Early replacement: The full install cost for this measure is the actual cost of removing the existing unit and installing the new one. If this is unknown, assume the following (note these costs are per ton of unit capacity)[169]:

| Efficiency (SEER) | Full Retrofit Cost (including labor) |
|---|---|
| 14.5 | $1,381 / ton + $123 |
| 15 | $1,381 / ton + $303 |
| 16 | $1,381 / ton + $438 |
| 17 | $1,381 / ton + $724 |
| 18 | $1,381 / ton + $724 |

166 Based on 2016 DOE Rulemaking Technical Support document, as recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.
167 Assumed to be one third of effective useful life
168 Based on incremental cost results from Cadmus "HVAC Program: Incremental Cost Analysis Update", December 19, 2016.
169 Baseline cost per ton derived from DEER 2008 Database Technology and Measure Cost Data. See 'ASHP_Revised DEER Measure Cost Summary.xls' for calculation. Efficiency cost increment consistent with Cadmus study results.

Assumed deferred cost (after 6 years) of replacing existing equipment with new baseline unit is assumed to be $1,518 per ton of capacity[170]. This cost should be discounted to present value using the nominal societal discount rate.

Quality Installation: The additional design and installation work associated with quality installation has been estimated to cost an additional $150[171].

**LOADSHAPE**

Loadshape R10 - Residential Electric Heating and Cooling

**COINCIDENCE FACTOR**

The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the *average* savings over the defined summer peak period, and is presented so that savings can be bid into PJM's Forward Capacity Market.

$CF_{SSP\ SF}$ = Summer System Peak Coincidence Factor for Heat Pumps in single-family homes (during utility peak hour)

= 72%[172]

$CF_{PJM\ SF}$ = PJM Summer Peak Coincidence Factor for Heat Pumps in single-family homes (average during PJM peak period)

= 46.6%[173]

$CF_{SSP,\ MF}$ = Summer System Peak Coincidence Factor for Heat Pumps in multi-family homes (during system peak hour)

= 67%[174]

$CF_{PJM,\ MF}$ = PJM Summer Peak Coincidence Factor for Heat Pumps in multi-family homes (average during peak period)

= 28.5%

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

Time of sale:

ΔkWh = ((FLH_cooling * Capacity_cooling * (1/(SEER_base * (1 – $DeratingCool_{Base}$)) - 1/(SEER_ee * SEERadj * (1 – $DeratingCool_{Eff}$)))) / 1000) + ((FLH_heat * Capacity_heating * (1/(HSPF_base * (1 – $DeratingHeat_{Base}$)) - 1/(HSPF_ee * HSPFadj * (1 – $DeratingHeat_{Eff}$)))) / 1000)

Early replacement[175]:

[170] Ibid. $1381 per ton inflated using rate of 1.91%.
[171] Based on data provided by Mid American in April 2018 summarizing survey results from 11 HVAC suppliers in Iowa.
[172] Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC's 2010 system peak; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.
[173] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.
[174] Multifamily coincidence factors both from; *All-Electric Homes PY6 Metering Results: Multifamily HVAC Systems*, Cadmus, October 2015
[175] The two equations are provided to show how savings are determined during the initial phase of the measure (existing to

ΔkWH for remaining life of existing unit (1st 6 years for replacing an ASHP, 18 years for replacing electric resistance):

= ((FLH_cooling * Capacity_cooling * (1/(SEER_exist * (1 – $DeratingCool_{Base}$)) - 1/(SEER_ee * SEERadj * (1 – $DeratingCool_{Eff}$)))) / 1000) + ((FLH_heat * Capacity_heating * (1/(HSPF_exist * (1 – $DeratingHeat_{Base}$)) - 1/(HSPF_ee * HSPFadj * (1 – $DeratingHeat_{Eff}$)))) / 1000)

ΔkWH for remaining measure life (next 12 years if replacing an ASHP):

= ((FLH_cooling * Capacity_cooling * (1/(SEER_base * (1 – $DeratingCool_{Base}$)) - 1/(SEER_ee * SEERadj * (1 – $DeratingCool_{Eff}$)))) / 1000) + ((FLH_heat * Capacity_heating * (1/(HSPF_base * (1 – $DeratingHeat_{Base}$)) - 1/(HSPF_ee * HSPFadj * (1 – $DeratingHeat_{Eff}$)))) / 1000)

Where:

FLH_cooling = Full load hours of air conditioning

= dependent on location:

| Climate Zone (City based upon) | FLH_cooling (single family) [176] | FLH_cooling (general multifamily) [177] | FLH_cooling (weatherized multifamily) [178] |
|---|---|---|---|
| 1 (Rockford) | 512 | 467 | 299 |
| 2 (Chicago) | 570 | 506 | 324 |
| 3 (Springfield) | 730 | 663 | 425 |
| 4 (Belleville) | 1,035 | 940 | 603 |
| 5 (Marion) | 903 | 820 | 526 |
| Weighted Average [179] | 629 | 564 | 362 |

Use Multifamily if: Building has shared HVAC or meets utility’s definition for multifamily

Capacity_cooling = Cooling Capacity of Air Source Heat Pump (Btu/hr)

= Actual (1 ton = 12,000Btu/hr)

SEER_exist = Seasonal Energy Efficiency Ratio of existing cooling system (kBtu/kWh)

= Use actual SEER rating where it is possible to measure or reasonably estimate. If using rated efficiencies, derate efficiency value by 1% per year to account for degradation over time[180], or use defaults provided below:

| Existing Cooling System | SEER_exist [181] |
|---|---|
| Air Source Heat Pump | 9.3 |

efficient) and the remaining phase (new baseline to efficient). In practice, the screening tools used may either require a First Year savings (using the first equation) and then a “number of years to adjustment” and “savings adjustment” input which would be the (new base to efficient savings)/(existing to efficient savings).

[176] Full load hours for Chicago, Moline and Rockford are provided in “Final Evaluation Report: Central Air Conditioning Efficiency Services (CACES), 2010, Navigant Consulting”, p.33. An average FLH/Cooling Degree Day (from NCDC) ratio was calculated for these locations and applied to the CDD of the other locations in order to estimate FLH. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

[177] Ibid.

[178] *All-Electric Homes PY6 Metering Results: Multifamily HVAC Systems*, Cadmus, October 2015. The multifamily units within this study had undergone significant shell improvements (air sealing and insulation) and therefore this set of assumptions is only appropriate for units that have recently participated in a weatherization or other shell program. Note that the FLHcool where recalculated based on existing efficiencies consistent with the TRM rather than from the metering study.

[179] Weighted based on number of occupied residential housing units in each zone.

[180] Justification for degradation factors can be found on page 21 of ‘AIC HVAC Metering Study Memo FINAL 2_28_2018’

[181] Based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See ‘AIC HVAC Metering Study Memo FINAL 2_28_2018’.

| Existing Cooling System | SEER_exist[181] |
|---|---|
| Central AC | |
| No central cooling[182] | Make '1/SEER_exist' = 0 |

SEER_base = Seasonal Energy Efficiency Ratio of baseline Air Source Heat Pump (kBtu/kWh)

= 14 [183]

SEER_ee = Rated Seasonal Energy Efficiency Ratio of ENERGY STAR unit (kBtu/kWh)

= Actual, or 15 if unknown.

SEERadj = Adjustment percentage to account for in-situ performance of the unit

= $[(0.805 \times \left(\frac{EER_{ee}}{SEER_{ee}}\right) + 0.367]$

$\text{DeratingCool}_{\text{Eff}}$ = Efficent ASHP Cooling derating

= 0% if Quality Installation is performed

= 10% if Quality Installation is not performed or unknown[185]

$\text{DeratingCool}_{\text{Base}}$ = Baseline Cooling derating

= 10%

FLH_heat = Full load hours of heating

= Dependent on location and home type:

| Climate Zone (City based upon) | FLH_heat (single family and general multifamily)[186] | FLH heat (weatherized multifamily)[187] |
|---|---|---|
| 1 (Rockford) | 1,969 | 748 |
| 2 (Chicago) | 1,840 | 699 |
| 3 (Springfield) | 1,754 | 667 |
| 4 (Belleville) | 1,266 | 481 |
| 5 (Marion) | 1,288 | 489 |
| Weighted Average[188] | 1,821 | 692 |

[182] If there is no central cooling in place but the incentive encourages installation of a new ASHP with cooling, the added cooling load should be subtracted from any heating benefit.

[183] Based on Minimum Federal Standard effective 1/1/2015.

[184] In situ performance based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study Memo FINAL 2_28_2018'.

[185] Based on Cadmus assumption provided in preparation of the 2014 Interstate Power and Light TRM based upon proper refrigerant charge, evaporator airflow, and unit sizing, Appears conservative in comparison to ENERGY STAR statements (see 'Sponsoring an ENERGY STAR Verified HVAC Installation (ESVI) Program'). Note pending ComEd evaluation will provide an update to these assumptions.

[186] Full load heating hours for heat pumps are provided for Rockford, Chicago and Springfield in the ENERGY STAR Calculator. Estimates for the other locations were calculated based on the FLH to Heating Degree Day (from NCDC) ratio. VEIC consider ENERGY STAR estimates to be high due to oversizing not being adequately addressed. Using average Illinois billing data (from ICC commerce Commission) VEIC estimated the average gas heating load and used this to estimate the average home heating output (using 83% average gas heat efficiency). Dividing this by a typical 36,000 Btu/hr ASHP gives an estimate of average ASHP FLH_heat of 1821 hours. We used the ratio of this value to the average of the locations using the ENERGY STAR data (1994 hours) to scale down the ENERGY STAR estimates. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

[187] *All-Electric Homes PY6 Metering Results: Multifamily HVAC Systems*, Cadmus, October 2015.

[188] Weighted based on number of occupied residential housing units in each zone.

Use Multifamily if: Building has shared HVAC or meets utility's definition for multifamily

Capacity_heating = Heating Capacity of Air Source Heat Pump (Btu/hr)

= Actual (1 ton = 12,000Btu/hr)

HSPF_exist =Heating System Performance Factor[189] of existing heating system (kBtu/kWh)

= Use actual HSPF rating where it is possible to measure or reasonably estimate. If not available use:

| Existing Heating System | HSPF_exist |
|---|---|
| Air Source Heat Pump | 5.54 [190] |
| Electric Resistance | 3.41[191] |

HSPF_base =Heating System Performance Factor of baseline Air Source Heat Pump (kBtu/kWh)

= 8.2 [192]

HSPF_ee =Heating System Performance Factor of efficient Air Source Heat Pump

(kBtu/kWh)

= Actual or 8.5 if unknown

HSPFadj = Adjustment percentage to account for in-situ performance of the unit

$= \left[\left(\frac{17\,°F\ Capacity}{47\,°F\ Capacity}\right) \times 0.158 + 0.899\right]$

$DeratingHeat_{Eff}$ = Efficent ASHP Heating derating

= 0% if Quality Installation is performed

= 10% if Quality Installation is not performed[194]

$DeratingHeat_{Base}$ = Baseline Heatin derating

= 10%

[189] HSPF ratings for Heat Pumps account for the seasonal average efficiency of the units and are based on testing within zone 4 which encompasses most of Illinois. Furthermore, a recent Cadmus/Opinion Dynamics metering study, "Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)", found no significant variance between metered performance and that presented in the TRM

[190] Based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study Memo FINAL 2_28_2018'.

[191] Electric resistance has a COP of 1.0 which equals 1/0.293 = 3.41 HSPF.

[192] Based on Minimum Federal Standard effective 1/1/2015.

[193] In situ performance based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study Memo FINAL 2_28_2018'.

[194] Based on Cadmus assumption provided in preparation of the 2014 Interstate Power and Light TRM based upon proper refrigerant charge, evaporator airflow, and unit sizing, Assumed consistent for heating and cooling. Appears conservative in comparison to ENERGY STAR statements (see 'Sponsoring an ENERGY STAR Verified HVAC Installation (ESVI) Program'). Note pending ComEd evaluation will provide an update to these assumptions.

Time of Sale:

For example, an ASHP is installed in a single-family home in Marion with the following nameplate information: 15 SEER, 12EER, 9 HSPF; Cooling capacity: 34,800 Btuh; Heating capacity at 47°F: 33,000 Btuh; Heating capacity at 17°F: 21,200 Btuh with Quality Installation;

$$\% \, SEER_{adj} = 0.805 \times \left(\frac{EER_{ee}}{SEER_{ee}}\right) + 0.367 = 1.011$$

$$\% \, HSPF_{adj} = \left(\frac{17\ °F\ Capacity}{47\ °F\ Capacity}\right) \times 0.158 + 0.899 = 1.001$$

ΔkWh = ((903 * 34,800 * (1/(14 * (1 - 0.1)) - 1/(15 * 1.011 * (1 – 0)))) / 1000) + ((1,288 * 33,000 * (1/(8.2 * (1 – 0.1)) - 1/(9 * 1.001 * (1-0)))) / 1000)

= 1463 kWh

Early Replacement:

For example, a 15 SEER, 12EER, 9 HSPF Air Source Heat Pump with nameplate information as above replaces an existing working Air Source Heat Pump with unknown efficiency ratings in a single family home in Marion:

ΔkWH for remaining life of existing unit (1st 6 years):

= ((903 * 34,800 * (1/(9.3 * (1-0.1)) - 1/(15 * 1.011 * (1-0)))) / 1000) + ((1,288 * 33,000 * (1/(5.54 * (1-0.1)) - 1/(9 * 1.001 * (1-0)))) / 1000)

= 5489 kWh

ΔkWH for remaining measure life (next 12 years):

= ((903 * 34,800 * (1/(14 * (1 - 0.1)) - 1/(15 * 1.011 * (1 – 0)))) / 1000) + ((1,288 * 33,000 * (1/(8.2 * (1 – 0.1)) - 1/(9 * 1.001 * (1-0)))) / 1000)

= 1463 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

Time of sale:

ΔkW = (Capacity_cooling * (1/(EER_base * (1 – $DeratingCool_{Base}$)) - 1/(EER_ee * (1 – $DeratingCool_{Eff}$)))) / 1000 * CF

Early replacement[195]:

ΔkW for remaining life of existing unit (1st 6 years for replacing an ASHP, 18 years for replacing electric resistance):

= (Capacity_cooling * (1/(EERexist * (1 – $DeratingCool_{Base}$)) - 1/(EERee * (1 – $DeratingCool_{Eff}$)))) / 1000 * CF

ΔkW for remaining measure life (next 12 years if replacing an ASHP):

= (Capacity_cooling * (1/(EER_base * (1 – $DeratingCool_{Base}$)) - 1/(EER_ee * (1 – $DeratingCool_{Eff}$)))) / 1000 * CF

Where:

EER_exist = Energy Efficiency Ratio of existing cooling system (kBtu/hr / kW)

= Use actual EER rating where it is possible to measure or reasonably estimate. If using

[195] The two equations are provided to show how savings are determined during the initial phase of the measure (existing to efficient) and the remaining phase (new baseline to efficient). In practice, the screening tools used may either require a First Year savings (using the first equation) and then a “number of years to adjustment” and “savings adjustment” input which would be the (new base to efficient savings)/(existing to efficient savings).

rated efficiencies, derate efficiency value by 1% per year to account for degradation over time[196], or use defaults provided below:

| Existing Cooling System | EER_exist[197] |
|---|---|
| Air Source Heat Pump | 7.5 |
| Central AC | |
| No central cooling[198] | Make '1/EER_exist' = 0 |

EER_base = Energy Efficiency Ratio of baseline Air Source Heat Pump (kBtu/hr / kW)

= 11 [199]

EER_ee = Energy Efficiency Ratio of efficient Air Source Heat Pump (kBtu/hr / kW)

= Actual. If unknown assume 12.5 EER.

$CF_{SSP\ SF}$ = Summer System Peak Coincidence Factor for Heat Pumps in single-family homes (during system peak hour)

= 72%%[200]

$CF_{PJM\ SF}$ = PJM Summer Peak Coincidence Factor for Heat Pumps in single-family homes (average during peak period)

= 46.6%[201]

$CF_{SSP,\ MF}$ = Summer System Peak Coincidence Factor for Heat Pumps in multi-family homes (during system peak hour)

= 67%[202]

$CF_{PJM,\ MF}$ = PJM Summer Peak Coincidence Factor for Heat Pumps in multi-family homes (average during peak period)

= 28.5%[35]

Use Multifamily if: Building has shared HVAC or meets utility's definition for multifamily

[196] Justification for degradation factors can be found on page 21 of 'AIC HVAC Metering Study Memo FINAL 2_28_2018'

[197] Based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study Memo FINAL 2_28_2018'.

[198] If there is no central cooling in place but the incentive encourages installation of a new ASHP with cooling, the added cooling load should be subtracted from any heating benefit.

[199] The Federal Standard does not include an EER requirement. The value provided is based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study Memo FINAL 2_28_2018'.

[200] Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC's 2010 system peak; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.

[201] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.

[202] *All-Electric Homes PY6 Metering Results: Multifamily HVAC Systems*, Cadmus, October 2015

Time of Sale:

For example, a three ton, 15 SEER, 12EER, 9 HSPF Air Source Heat Pump installed in single-family home in Marion with Quality Installation:

$\Delta kW_{SSP}$ = (36,000 * (1/(11 * (1-0.1)) – 1/(12 * (1-0)))) / 1000 * 0.72

= 0.458 kW

$\Delta kW_{PJM}$ = (36,000 * (1/(11 * (1-0.1)) – 1/(12 * (1-0)))) / 1000 * 0.466

= 0.297 kW

Early Replacement:

For example, a three ton, 15 SEER, 12EER, 9 HSPF Air Source Heat Pump replaces an existing working Air Source Heat Pump with unknown efficiency ratings in single-family home in Marion with Quality Installation:

$\Delta kW_{SSP}$ for remaining life of existing unit (1st 6 years):

= (36,000 * (1/(7.5 * (1-0.1)) - 1/(12 * (1-0)))) / 1000 * 0.72

= 1.68 kW

$\Delta kW_{SSP}$ for remaining measure life (next 12 years):

= (36,000 * (1/(11 * (1-0.1)) – 1/(12 * (1-0)))) / 1000 * 0.72

= 0.458 kW

$\Delta kW_{PJM}$ for remaining life of existing unit (1st 6 years):

= (36,000 * (1/(7.5 * (1-0.1)) - 1/(12 * (1-0)))) / 1000 * 0.466

= 1.087 kW

$\Delta kW_{PJM}$ for remaining measure life (next 12 years):

= (36,000 * (1/(11 * (1-0.1)) – 1/(12 * (1-0)))) / 1000 * 0.466

= 0.297 kW

### Natural Gas Savings

N/A

### Water Impact Descriptions and Calculation

N/A

### Deemed O&M Cost Adjustment Calculation

N/A

### Measure Code: RS-HVC-ASHP-V08-190101

### Review Deadline: 1/1/2021

## 5.3.2 Boiler Pipe Insulation

### Description

This measure describes adding insulation to un-insulated boiler pipes in un-conditioned basements or crawlspaces.

This measure was developed to be applicable to the following program types: TOS, RNC, RF, DI.

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

The efficient case is installing pipe wrap insulation to a length of boiler pipe.

### Definition of Baseline Equipment

The baseline is an un-insulated boiler pipe.

### Deemed Lifetime of Efficient Equipment

The measure life is assumed to be 15 years[203].

Note a mid-life adjustment to account for replacement of HVAC equipment during the measure life should be applied after 13 years[204]. See section below for detail.

### Deemed Measure Cost

The measure cost including material and installation is assumed to be $3 per linear foot[205].

### Loadshape

N/A

### Coincidence Factor

N/A

**Algorithm**

### Calculation of Savings

### Electric Energy Savings

N/A

### Summer Coincident Peak Demand Savings

N/A

### Natural Gas Savings

$$\Delta Therm = (((1/R_{exist} * C_{exist}) - (1/R_{new} * C_{new})) * FLH\_heat * L * \Delta T) / \eta Boiler / 100{,}000$$

[203] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
[204] This is intentionally longer than the assumptions found in the early replacement measures as the application of this measure will occur in a variety of homes that will not be targeted for early replacement HVAC systems.
[205] Consistent with DEER 2008 Database Technology and Measure Cost Data.

Where:

$R_{exist}$ = Pipe heat loss coefficient of uninsulated pipe (existing) [(hr-°F-ft$^2$)/Btu]

= 0.5[206]

$R_{new}$ = Pipe heat loss coefficient of insulated pipe (new) [(hr-°F-ft$^2$)/Btu]

= Actual (0.5 + R value of insulation)

FLH_heat = Full load hours of heating

= Dependent on location[207]:

| Climate Zone (City based upon) | FLH_heat |
|---|---|
| 1 (Rockford) | 1,969 |
| 2 (Chicago) | 1,840 |
| 3 (Springfield) | 1,754 |
| 4 (Belleville) | 1,266 |
| 5 (Marion) | 1,288 |
| Weighted Average[208] | 1,821 |

L = Length of boiler pipe in unconditioned space covered by pipe wrap (ft)

= Actual

$C_{exist}$ = Circumference of bare pipe (ft) (Diameter (in) * π/12)

= Actual (0.5" pipe = 0.131ft, 0.75" pipe = 0.196ft)

$C_{new}$ = Circumference of pipe with insulation (ft) ([Diameter of pipe (in)] + ([Thickness of Insulation (in)]*2)) * π/12)

= Actual

ΔT = Average temperature difference between circulated heated water and unconditioned space air temperature (°F) [209]

Pipes in unconditioned basement:

| Outdoor reset controls | ΔT (°F) |
|---|---|
| Boiler without reset control | 110 |
| Boiler with reset control | 70 |

[206] Assumption based on data obtained from the 3E Plus heat loss calculation software provided by the NAIMA (North American Insulation Manufacturer Association) and derived from Table 15 and Table 16 of 2009 ASHRAE Fundamentals Handbook, Chapter 23 Insulation for Mechanical Systems, page 23.17.

[207] Full load heating hours for heat pumps are provided for Rockford, Chicago and Springfield in the ENERGY STAR Calculator. Estimates for the other locations were calculated based on the FLH to Heating Degree Day (from NCDC) ratio. VEIC consider ENERGY STAR estimates to be high due to oversizing not being adequately addressed. Using average Illinois billing data (from Illinois Commerce Commission) VEIC estimated the average gas heating load and used this to estimate the average home heating output (using 83% average gas heat efficiency). Dividing this by a typical 36,000 Btu/hr ASHP gives an estimate of average ASHP FLH_heat of 1821 hours. We used the ratio of this value to the average of the locations using the ENERGY STAR data (1994 hours) to scale down the ENERGY STARr estimates. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

[208] Weighted based on number of occupied residential housing units in each zone.

[209] Assumes 160°F water temp for a boiler without reset control, 120°F for a boiler with reset control, and 50°F air temperature for pipes in unconditioned basements and the following average heating season outdoor temperatures as the air temperature in crawl spaces: Zone 1 – 33.1, Zone 2 – 34.4, Zone 3 – 37.7, Zone 4 – 40.0, Zone 5 – 39.8, Weighted Average – 35.3 (NCDC 1881-2010 Normals, average of monthly averages Nov – Apr for zones 1-3 and Nov-March for zones 4 and 5).

Pipes in crawl space:

| Climate Zone (City based upon) | ΔT (°F) | |
|---|---|---|
| | Boiler without reset control | Boiler with reset control |
| 1 (Rockford) | 127 | 87 |
| 2 (Chicago) | 126 | 86 |
| 3 (Springfield) | 122 | 82 |
| 4 (Belleville) | 120 | 80 |
| 5 (Marion) | 120 | 80 |
| Weighted Average[210] | 125 | 85 |

ηBoiler = Efficiency of boiler

= 0.819 [211]

For example, insulating 10 feet of 0.75" pipe with R-3 wrap (0.75" thickness) in a crawl space of a Marion home with a boiler without reset control:

ΔTherm = (((1/0.5 * 0.196) – (1/3.5 * 0.589)) * 10 * 120 * 1288) / 0.819 / 100,067

= 4.2 therms

**Mid-Life adjustment**

In order to account for the likely replacement of existing heating equipment during the lifetime of this measure, a mid-life adjustment should be applied. To calculate the adjustment, re-calculate the savings above using the following new baseline system efficiency assumptions:

| Efficiency Assumption | System Type | New Baseline Efficiency |
|---|---|---|
| ηHeat | Boiler | 82% AFUE |

This reduced annual savings should be applied following the assumed remaining useful life of the existing equipment, estimate to be 13 years[212].

### WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

### DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

[210] Weighted based on number of occupied residential housing units in each zone.
[211] Average efficiency of boiler units found in Ameren PY3-PY4 data.
[212] This is intentionally longer than the assumption found in the early replacement measures as the application of this measure will occur in a variety of homes and will not be targeting those homes appropriate for early replacement HVAC systems.

**MEASURE CODE: RS-HVC-PINS-V03-190101**

**REVIEW DEADLINE: 1/1/2022**

## 5.3.3 Central Air Conditioning

**DESCRIPTION**

This measure characterizes:

a) Time of Sale:

   a. The installation of a new residential sized (<= 65,000 Btu/hr) Central Air Conditioning ducted split system meeting ENERGY STAR efficiency standards presented below. This could relate to the replacement of an existing unit at the end of its useful life, or the installation of a new system in a new home.

b) Early Replacement:

   Early Replacement determination will be based on meeting the following conditions:

   - The existing unit is operational when replaced, or
   - The existing unit requires minor repairs (<$190 per ton)[213].
   - All other conditions will be considered Time of Sale.

   The Baseline SEER of the existing Central Air Conditioning unit replaced:

   - If the SEER of the existing unit is known and <=10, the Baseline SEER is the actual SEER value of the unit replaced. If the SEER is >10, the Baseline SEER = 13.
   - If the SEER of the existing unit is unknown, use assumptions in variable list below (SEER_exist).
   - If the operational status or repair cost of the existing unit is unknown, use time of sale assumptions.

   A weighted average early replacement rate is provided for use when the actual baseline early replacement rate is unknown[214].

**Deemed Early Replacement Rates For CAC Units in Combined System Replacement (CSR) Projects**

| Replacement Scenario for the CAC Unit | Deemed Early Replacement Rate |
|---|---|
| Early Replacement Rate for a CAC unit when the CAC unit is the Primary unit in a CSR project | 14% |
| Early Replacement Rate for a CAC unit when the CAC unit is the Secondary unit in a CSR project | 40% |

Note it is not appropriate to claim additional ECM fan savings (from 5.3.5 Furnace Blower Motor) due to installing new CAC units with an ECM, since the SEER/EER ratings already account for this electrical load.

Quality Installation:

Additional savings are attributed to the Quality Installation (QI) of the system. QI programs should follow industry standards such as those described in ENERGY STAR Verified HVAC Installation Program (ESVI), ANSI ACCA QI5 and QI9vp. This must include considerations of system design (including sizing, matching, ventilation calculations) and

---

[213] The Technical Advisory Committee agreed that if the cost of repair is less than 20% of the new baseline replacement cost it can be considered early replacement. Note the non-inflated cost is used as this would be a cost consideration in the program year.

[214] Based upon research from “Home Energy Efficiency Rebate Program GPY2 Evaluation Report” which outlines early replacement rates for both primary and secondary central air cooling (CAC) and residential funaces. The unit (furnace or CAC unit) that initially caused the customer to contact a trade ally is defined as the “primary unit”. The furnace or CAC unit that was also replaced but did not initially prompt the customer to contact a trade ally is defined as the “secondary unit”. This evaluation used different criteria for early replacement due to the availability of data after the fact; cost of any repairs < $550 and age of unit < 20 years. Report presented to Nicor Gas Company February 27, 2014.

equipment installation (including static pressure, airflow, refrigerant charge) and may also consider distribution.

This measure was developed to be applicable to the following program types: TOS, NC, EREP. If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the efficient equipment is assumed to be a ducted split central air conditioning unit meeting at least the minimum ENERGY STAR efficiency level standards; 15 SEER and 12.5 EER.

### DEFINITION OF BASELINE EQUIPMENT

The baseline for the Time of Sale measure is based on the current Federal Standard efficiency level; 13 SEER and an estimate of expected peak rated efficiency of 10.5 EER. It is assumed that 'Quality Installation' did not occur.

The baseline for the early replacement measure is the efficiency of the existing equipment for the assumed remaining useful life of the unit and the new baseline as defined above[215] for the remainder of the measure life.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 18 years [216].

Remaining life of existing equipment is assumed to be 6 years[217].

### DEEMED MEASURE COST

Time of sale: The incremental capital cost for this measure is dependent on efficiency. Assumed incremental costs are provided below[218]:

| Efficiency Level (SEER) | Incremental Cost |
|---|---|
| 14 | $104 |
| 15 | $108 |
| 16 | $221 |
| 17 | $620 |
| 18 | $620 |

Early replacement: The full install cost for this measure is the actual cost of removing the existing unit and installing the new one. If this is unknown, assume defaults below[219].

| Efficiency Level (SEER) | Full Retrofit Cost (including labor) |
|---|---|
| 14 | $952 / ton + $104 |
| 15 | $952 / ton + $108 |
| 16 | $952 / ton + $221 |
| 17 | $952 / ton + $620 |
| 18 | $952 / ton + $620 |

Assumed deferred cost (after 6 years) of replacing existing equipment with new baseline unit is assumed to be

[215] Baseline SEER and EER should be updated when new minimum federal standards become effective.
[216] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
[217] Assumed to be one third of effective useful life
[218] Based on incremental cost results from Cadmus "HVAC Program: Incremental Cost Analysis Update", December 19, 2016.
[219] Based on 3 ton initial cost estimate for a conventional unit from ENERGY STAR Central AC calculator, $2,857. Efficiency cost increment consistent with Cadmus study results.

$3,140[220]. This cost should be discounted to present value using the nominal societal discount rate.

Quality Installation: The additional design and installation work associated with quality installation has been estimated to cost an additional $150[221].

#### LOADSHAPE

Loadshape R08 - Residential Cooling

#### COINCIDENCE FACTOR

The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the *average* savings over the defined summer peak period, and is presented so that savings can be bid into PJM's Forward Capacity Market.

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)
= 68%[222]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period)
= 46.6%[223]

## Algorithm

#### CALCULATION OF SAVINGS

#### ELECTRIC ENERGY SAVINGS

Time of sale:

$$\Delta kWH = (FLHcool * Capacity * (1/(SEERbase * (1 - DeratingCool_{Base})) - 1/(SEERee * SEERadj * (1 - DeratingCool_{Eff}))))/1000$$

Early replacement[224]:

ΔkWH for remaining life of existing unit (1st 6 years):

$$=(FLHcool * Capacity * (1/(SEERexist * (1 - DeratingCool_{Base})) - 1/(SEERee * SEERadj * (1 - DeratingCool_{Eff}))))/1000$$

ΔkWH for remaining measure life (next 12 years):

$$= (FLHcool * Capacity * (1/(SEERbase * (1 - DeratingCool_{Base})) - 1/(SEERee * SEERadj * (1 - DeratingCool_{Eff}))))/1000$$

Where:

---

[220] Based on 3 ton initial cost estimate for a conventional unit from ENERGY STAR Central AC calculator, $2,857, and applying inflation rate of 1.91%. While baselines are likely to shift in the future, there is currently no good indication of what the cost of a new baseline unit will be in 6 years. In the absence of this information, assuming a constant federal baseline cost is within the range of error for this prescriptive measure.
[221] Based on data provided by Mid American in April 2018 summarizing survey results from 11 HVAC suppliers in Iowa.
[222] Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.
[223] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.
[224] The two equations are provided to show how savings are determined during the initial phase of the measure (existing to efficient) and the remaining phase (new baseline to efficient). In practice, the screening tools used may either require a First Year savings (using the first equation) and then a "number of years to adjustment" and "savings adjustment" input which would be the (new base to efficient savings)/(existing to efficient savings).

FLHcool = Full load cooling hours

= dependent on location and building type[225]:

| Climate Zone (City based upon) | FLHcool (single family) | FLHcool (multifamily) | FLH_cooling (weatherized multifamily) [226] |
|---|---|---|---|
| 1 (Rockford) | 512 | 467 | 299 |
| 2 (Chicago) | 570 | 506 | 324 |
| 3 (Springfield) | 730 | 663 | 425 |
| 4 (Belleville) | 1035 | 940 | 603 |
| 5 (Marion) | 903 | 820 | 526 |
| Weighted Average[227] | 629 | 564 | 362 |

Use Multifamily if: Building has shared HVAC or meets utility's definition for multifamily

Capacity = Size of new equipment in Btu/hr (note 1 ton = 12,000Btu/hr)

= Use actual when program delivery allows size of AC unit to be known. If unknown assume 33,600 Btu/hr for single family homes, 28,000 Btu/hr for multifamily or 24,000 Btu/hr for mobile homes[228]. If building type is unknown, assume 31,864Btu/hr[229].

SEERbase = Seasonal Energy Efficiency Ratio of baseline unit (kBtu/kWh)

= 13[230]

SEERexist = Seasonal Energy Efficiency Ratio f existing unit (kBtu/kWh)

= Use actual SEER rating where it is possible to measure or reasonably estimate. If using rated efficiencies, derate efficiency value by 1% per year to account for degradation over time[231], or if unknown assume 9.3[232].

SEERee = Rated Seasonal Energy Efficiency Ratio of ENERGY STAR unit (kBtu/kWh)

= Actual, or 15 if unknown.

SEERadj = Adjustment percentage to account for in-situ performance of the unit

---

225 Full load hours for Chicago, Moline and Rockford are provided in "Final Evaluation Report: Central Air Conditioning Efficiency Services (CACES), 2010, Navigant Consulting", p.33. An average FLH/Cooling Degree Day (from NCDC) ratio was calculated for these locations and applied to the CDD of the other locations in order to estimate FLH. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

226 *All-Electric Homes PY6 Metering Results: Multifamily HVAC Systems*, Cadmus, October 2015. The multifamily units within this study had undergone significant shell improvements (air sealing and insulation) and therefore this set of assumptions is only appropriate for units that have recently participated in a weatherization or other shell program. Note that the FLHcool where recalculated based on existing efficiencies consistent with the TRM rather than from the metering study.

227 Weighted based on number of residential occupied housing units in each zone.

228 Single family cooling capacity based on Final Evaluation Report: Central Air Conditioning Efficiency Services (CACES), October 19, 2010, ComEd, Navigant Consulting. Multifamily capacity based on weighted average of PY9 Ameren and ComEd MF cooling capacities. Mobile home capacity based on ENERGY STAR's Manufactured Home Cooling Equipment Sizing Guidelines which vary by climate zone and home size. The average size of a mobile home in the East North Central region (1,120 square feet) from the 2015 RECS data is used to calculated appropriate size.

229 Unknown is based on statewide weighted average of 69% single family and 31% multifamily, based on IL data from 2009 RECS Table HC2.9 Structural and Geographic Characteristics of Homes in Midwest Region, Divisions and States, 2009.

230 Based on Minimum Federal Standard.

231 Justification for degradation factors can be found on page 21 of 'AIC HVAC Metering Study Memo FINAL 2_28_2018'

232 Based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study Memo FINAL 2_28_2018'

233 In situ performance based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC

$= [(0.805 \times \left(\frac{EER_{ee}}{SEER_{ee}}\right) + 0.367]$

$DeratingCool_{Eff}$ = Efficent Central Air Conditioner Cooling derating

= 0% if Quality Installation is performed

= 10% if Quality Installation is not performed or unknown[234]

$DeratingCool_{Base}$ = Baseline Central Air Conditioner Cooling derating

= 10%

Time of sale example: a 3 ton unit with SEER rating of 17, EER rating of 12.5 in unknown location without Quality Install:

SEERadj = (0.805 * (12.5/17) + 0.367)

= 0.959

ΔkWH = (629 * 36,000 * (1/(13 * (1-0.1)) – 1 / (17 * 0.959 * (1-0.1)))) / 1000

= 392 kWh

Time of sale example: a 3 ton unit with SEER rating of 17, EER rating of 12.5 in unknown location with Quality Install:

ΔkWH = (629 * 36,000 * (1/(13 * (1-0.1)) – 1 / (17 * 0.959 * (1-0)))) / 1000

= 546 kWh

Early replacement example: a 3 ton unit, with SEER rating of 17, EER rating of 12.5 replaces an existing unit in unknown location with quality installation:

ΔkWH(for first 6 years) = (629 * 36,000 * (1/(9.3 * (1-0.1)) - 1/(17* 0.959 * (1-0))))/1000

= 1,316 kWh

ΔkWH(for next 12 years) = (629 * 36,000 * (1/(13 * (1-0.1)) - 1/(17* 0.959 * (1-0))))/1000

= 546 kWh

Therefore savings adjustment of 41% (546/1316) after 6 years.

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

Time of sale:

ΔkW = (Capacity * (1/(EERbase * (1 – $DeratingCool_{Base}$)) - 1/(EERee * (1 – $DeratingCool_{Eff}$))))/1000 * CF

Early replacement[235]:

ΔkW for remaining life of existing unit (1st 6 years):

= (Capacity * (1/(EERexist * (1 – $DeratingCool_{Base}$)) - 1/(EERee* (1 – $DeratingCool_{Eff}$))))/1000 * CF

ΔkW for remaining measure life (next 12 years):

HVAC Metering Study Memo FINAL 2_28_2018'.

[234] Based on Cadmus assumption provided in preparation of the 2014 Interstate Power and Light TRM based upon proper refrigerant charge, evaporator airflow, and unit sizing, Appears conservative in comparison to ENERGY STAR statements (see 'Sponsoring an ENERGY STAR Verified HVAC Installation (ESVI) Program'). Note pending ComEd evaluation will provide an update to these assumptions.

[235] The two equations are provided to show how savings are determined during the initial phase of the measure (existing to efficient) and the remaining phase (new baseline to efficient). In practice, the screening tools used may either require a First Year savings (using the first equation) and then a "number of years to adjustment" and "savings adjustment" input which would be the (new base to efficient savings)/(existing to efficient savings).

$$= (Capacity * (1/(EERbase * (1 – DeratingCool_{Base})) - 1/(EERee* (1 – DeratingCool_{Eff}))))/1000 * CF$$

Where:

EERbase = EER Efficiency of baseline unit

= 10.5 [236]

EERexist = EER Efficiency of existing unit

= Use actual EER rating where it is possible to measure or reasonably estimate. If using rated efficiencies, derate efficiency value by 1% per year to account for degradation over time[237]. If unknown assume 7.5[238]

EERee = EER Efficiency of ENERGY STAR unit

= Actual installed or 12 if unknown

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)

= 68%[239]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Central A/C (average during peak period)

= 46.6%[240]

Time of sale example: a 3 ton unit with EER rating of 12 with Quality Install:

$\Delta kW_{SSP}$ = (36,000 * (1/(10.5 * (1-0.1)) – 1/(12 * (1-0)))) / 1000 * 0.68

= 0.550 kW

$\Delta kW_{PJM}$ = (36,000 * (1/(10.5 * (1-0.1)) – 1/(12 * (1-0)))) / 1000 * 0.466

= 0.377 kW

Early replacement example: a 3 ton unit with EER rating of 12 replaces an existing unit with Quality Install:

$\Delta kW_{SSP}$ (for first 6 years) = (36,000 * (1/(7.5 * (1-0.1)) – 1/(12 * (1-0)))) / 1000 * 0.68

= 1.587 kW

$\Delta kW_{SSP}$ (for next 12 years) = (36,000 * (1/(10.5 * (1-0.1)) – 1/(12 * (1-0)))) / 1000 * 0.68

= 0.550 kW

$\Delta kW_{PJM}$ (for first 6 years) = (36,000 * (1/(7.5 * (1-0.1)) – 1/(12 * (1-0)))) / 1000 * 0.466

= 1.087 kW

$\Delta kW_{PJM}$ (for next 12 years) = (36,000 * (1/(10.5 * (1-0.1)) – 1/(12 * (1-0)))) / 1000 * 0.466

= 0.377 kW

**NATURAL GAS SAVINGS**

N/A

[236] The federal Standard does not currently include an EER component. The value provided is based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study Memo FINAL 2_28_2018'.

[237] Justification for degradation factors can be found on page 21 of 'AIC HVAC Metering Study Memo FINAL 2_28_2018'

[238] Based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study Memo FINAL 2_28_2018'.

[239] Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

[240] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.

## WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

## DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

**MEASURE CODE: RS-HVC-CAC1-V08-190101**

**REVIEW DEADLINE: 1/1/2021**

## 5.3.4 Duct Insulation and Sealing

### Description

This measure describes evaluating the savings associated with performing duct sealing using mastic sealant or metal tape to the distribution system of homes with either central air conditioning or a ducted heating system.

Two methodologies for estimating the savings associate from sealing the ducts are provided. The first preferred method requires the use of a blower door and the second requires careful inspection of the duct work.

1. **Modified Blower Door Subtraction** – this technique is described in detail on p.44 of the Energy Conservatory Blower Door Manual; which can be found on the Energy Conservatory website (As of Oct 2014: http://www.energyconservatory.com/sites/default/files/documents/mod_3-4_dg700_-_new_flow_rings_-_cr_-_tpt_-_no_fr_switch_manual_ce_0.pdf)
2. **Evaluation of Distribution Efficiency** – this methodology requires the evaluation of three duct characteristics below, and use of the Building Performance Institutes 'Distribution Efficiency Look-Up Table'; http://www.bpi.org/files/pdf/DistributionEfficiencyTable-BlueSheet.pdf
    a. Percentage of duct work found within the conditioned space
    b. Duct leakage evaluation
    c. Duct insulation evaluation

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

The efficient condition is sealed duct work throughout the unconditioned or semi-conditioned space in the home. A non-conditioned space is defined as a space outside of the thermal envelope of the building that is not intentionally heated for occupancy (crawl space, roof attic, etc). A semi-conditioned space is defined as a space within the thermal envelop that is not intentionally heated for occupancy (unfinished basement)[241].

### Definition of Baseline Equipment

The existing baseline condition is leaky duct work within the unconditioned or semi-conditioned space in the home.

### Deemed Lifetime of Efficient Equipment

The assumed lifetime of this measure is 20 years[242].

Note a mid-life adjustment to account for replacement of HVAC equipment during the measure life should be applied after 10 years[243]. See section below for detail.

### Deemed Measure Cost

The actual duct sealing measure cost should be used.

### Loadshape

Loadshape R08 - Residential Cooling

[241] Definition matches Regain factor discussed in Home Energy Services Impact Evaluation, prepared for the Massachusetts Residential Retrofit and Low Income Program Area Evaluation, Cadmus Group, Inc., August 2012
[242] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
[243] This is intentionally longer than the assumptions found in the early replacement measures as the application of this measure will occur in a variety of homes that will not be targeted for early replacement HVAC systems.

Loadshape R09 - Residential Electric Space Heat

Loadshape R10 - Residential Electric Heating and Cooling (Shell Measures)

**COINCIDENCE FACTOR**

The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the *average* savings over the defined summer peak period, and is presented so that savings can be bid into PJM's Forward Capacity Market.

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Central A/C (during utility peak hour)

= 68%[244]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period)

= 46.6%[245]

## Algorithm

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

***Methodology 1: Modified Blower Door Subtraction***

a) Determine Duct Leakage rate before and after performing duct sealing:

Duct Leakage ($CFM50_{DL}$) = ($CFM50_{Whole\ House}$ – $CFM50_{Envelope\ Only}$) * SCF

Where:

$CFM50_{Whole\ House}$ = Standard Blower Door test result finding Cubic Feet per Minute at 50 Pascal pressure differential

$CFM50_{Envelope\ Only}$ = Blower Door test result finding Cubic Feet per Minute at 50 Pascal pressure differential with all supply and return registers sealed.

SCF = Subtraction Correction Factor to account for underestimation of duct leakage due to connections between the duct system and the home. Determined by measuring pressure in duct system with registers sealed and using look up table provided by Energy Conservatory.

b) Calculate duct leakage reduction, convert to $CFM25_{DL}$ and factor in Supply and Return Loss Factors

Duct Leakage Reduction ($\Delta CFM25_{DL}$) = (Pre $CFM50_{DL}$ – Post $CFM50_{DL}$) * 0.64 * (SLF + RLF)

Where:

0.64 = Converts CFM50 to CFM25[246]

SLF = Supply Loss Factor

= % leaks sealed located in Supply ducts * 1 [247]

---

[244] Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

[245] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.

[246] 25 Pascals is the standard assumption for typical pressures experienced in the duct system under normal operating conditions. To convert CFM50 to CFM25 you multiply by 0.64 (inverse of the "Can't Reach Fifty" factor for CFM25; see Energy Conservatory Blower Door Manual).

[247] Assumes that for each percent of supply air loss there is one percent annual energy penalty. This assumes supply side leaks

Default = 0.5[248]

RLF = Return Loss Factor

= % leaks sealed located in Return ducts * 0.5[249]

Default = 0.25[250]

c) Calculate Electric Energy Savings:

$\Delta kWh = \Delta kWh_{cooling} + \Delta kWh_{Fan}$

$\Delta kWh_{cooling} = ((\Delta CFM25_{DL} / ((CapacityCool/12{,}000) * 400)) * FLHcool * CapacityCool * TRFcool) / 1000 / \eta Cool$

$\Delta kWh_{Fan} = (\Delta Therms * F_e * 29.3)$

Where:

$\Delta CFM25_{DL}$ = Duct leakage reduction in CFM25

= calculated above

CapacityCool = Capacity of Air Cooling system (Btu/hr)

=Actual

12,000 = Converts Btu/H capacity to tons

400 = Converts capacity in tons to CFM (400CFM / ton)[251]

FLHcool = Full load cooling hours

= Dependent on location as below[252]:

| Climate Zone (City based upon) | FLHcool Single Family | FLHcool Multifamily |
|---|---|---|
| 1 (Rockford) | 512 | 467 |
| 2 (Chicago) | 570 | 506 |
| 3 (Springfield) | 730 | 663 |
| 4 (Belleville) | 1,035 | 940 |
| 5 (Marion) | 903 | 820 |
| Weighted Average[253] | 629 | 564 |

are direct losses to the outside and are not recaptured back to the house. This could be adjusted downward to reflect regain of usable energy to the house from duct leaks. For example, during the winter some of the energy lost from supply leaks in a crawlspace will probably be regained back to the house (sometimes 1/2 or more may be regained). More information provided in “Appendix E Estimating HVAC System Loss From Duct Airtightness Measurements” from Energy Conservatory ‘Minneapolis Duct Blaster Operation Manual’.

[248] Assumes 50% of leaks are in supply ducts.

[249] Assumes that for each percent of return air loss there is a half percent annual energy penalty. Note that this assumes that return leaks contribute less to energy losses than do supply leaks. This value could be adjusted upward if there was reason to suspect that the return leaks contribute significantly more energy loss than “average” (e.g. pulling return air from a super heated attic), or can be adjusted downward to represent significantly less energy loss (e.g. pulling return air from a moderate temperature crawl space) . More information provided in “Appendix E Estimating HVAC System Loss From Duct Airtightness Measurements” from Energy Conservatory ‘Minneapolis Duct Blaster Operation Manual’.

[250] Assumes 50% of leaks are in return ducts.

[251] This conversion is an industry rule of thumb; e.g. see ‘Why 400 CFM per ton.pdf’.

[252] Based on Full Load Hours from ENERGY STAR with adjustments made in a Navigant Evaluation, other cities were scaled using those results and CDD. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

[253] Weighted based on number of occupied residential housing units in each zone.

Use Multifamily if: Building has shared HVAC or meets utility's definition for multifamily

TRFcool = Thermal Regain Factor for cooling by space type

= 1.0 for Unconditioned Spaces

= 0.4 for Semi-Conditioned Spaces[254]

1000 = Converts Btu to kBtu

ηCool = Efficiency (SEER) of Air Conditioning equipment (kBtu/kWh)

= Actual. If unknown assume the following[255]:

| Age of Equipment | SEER Estimate |
|---|---|
| Before 2006 | 10 |
| After 2006 - 2014 | 13 |
| Central AC After 1/1/2015 | 13 |
| Heat Pump After 1/1/2015 | 14 |

ΔTherms = Therm savings as calculated in Natural Gas Savings

$F_e$ = Furnace Fan energy consumption as a percentage of annual fuel consumption

= 3.14%[256]

29.3 = kWh per therm

[254] Thermal regain (i.e. the potential for conditioned air escaping from ducts not being lost to the atmosphere) for residential pipe insulation measures is discussed in Home Energy Services Impact Evaluation, prepared for the Massachusetts Residential Retrofit and Low Income Program Area Evaluation, Cadmus Group, Inc., August 2012.

[255] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Central AC was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.

[256] $F_e$ is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR version 3 criteria for 2% $F_e$. See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference.

For example, duct sealing in unconditioned space a single family house in Springfield with a 36,000 Btu/H, SEER 11 central air conditioning, an 80% AFUE, 105,000 Btu/H natural gas furnace and the following blower door test results:

Before: $CFM50_{Whole\ House}$ = 4800 CFM50

$CFM50_{Envelope\ Only}$ = 4500 CFM50

House to duct pressure of 45 Pascals. = 1.29 SCF (Energy Conservatory look up table)

After: $CFM50_{Whole\ House}$ = 4600 CFM50

$CFM50_{Envelope\ Only}$ = 4500 CFM50

House to duct pressure of 43 Pascals = 1.39 SCF (Energy Conservatory look up table)

Duct Leakage:

$CFM50_{DL\ before}$ = (4800 – 4500) * 1.29

= 387 CFM

$CFM50_{DL\ after}$ = (4600 – 4500) * 1.39

= 139 CFM

Duct Leakage reduction at CFM25:

$\Delta CFM25_{DL}$ = (387 – 139) * 0.64 * (0.5 + 0.25)

= 119 CFM25

Energy Savings:

$\Delta kWh_{cooling}$ = [((119 / ((36,000/12,000) * 400)) * 730 * 36,000 * 1) / 1000 / 11] + (212 * 0.0314 * 29.3)

= 237 + 195

= 432 kWh

Heating savings for homes with electric heat:

$\Delta kWh_{heating}$ = (($\Delta CFM25_{DL}$ /((OutputCapacityHeat/12,000) * 400)) * FLHheat * OutputCapacityHeat * TRFheat) / ηHeat / 3412

Where:

OutputCapacityHeat = Heating output capacity (Btu/hr) of electric heat

=Actual

FLHheat = Full load heating hours

= Dependent on location as below[257]:

| Climate Zone (City based upon) | FLH_heat |
|---|---|
| 1 (Rockford) | 1,969 |
| 2 (Chicago) | 1,840 |
| 3 (Springfield) | 1,754 |
| 4 (Belleville) | 1,266 |
| 5 (Marion) | 1,288 |
| Weighted Average[258] | 1,821 |

[257] Heating EFLH based on ENERGY STAR EFLH for Rockford, Chicago, and Springfield and on NCDC/NOAA HDD for the other two cities. In all cases, the hours were adjusted based on average natural gas heating consumption in IL.
[258] Weighted based on number of occupied residential housing units in each zone.

TRFheat = Thermal Regain Factor for heating by space type

= 0.40 for Semi-Conditioned Spaces

= 1.0 for Unconditioned Spaces[259]

ηHeat = Efficiency in COP of Heating equipment

= Actual. If not available use[260]:

| System Type | Age of Equipment | HSPF Estimate | COP Estimate |
|---|---|---|---|
| Heat Pump | Before 2006 | 6.8 | 2.00 |
| | After 2006 - 2014 | 7.7 | 2.26 |
| | 2015 on | 8.2 | 2.40 |
| Resistance | N/A | N/A | 1.00 |

3412 = Converts Btu to kWh

For example, duct sealing in unconditioned space in a 36,000 Btu/H 2.5 COP heat pump heated single family house in Springfield with the blower door results described above:

$\Delta kWh_{heating}$ = ((119 / ((36,000/12,000) * 400)) * 1,754 * 36,000 * 1) / 2.5 / 3412

= 734 kWh

***Methodology 2: Evaluation of Distribution Efficiency***

Determine Distribution Efficiency by evaluating duct system before and after duct sealing using Building Performance Institute "Distribution Efficiency Look-Up Table"

$$\Delta kWh = ((((DE_{after} - DE_{before}) / DE_{after}) * FLHcool * CapacityCool * TRFcool)/1000 / \eta Cool) + (\Delta Therms * F_e * 29.3)$$

Where:

$DE_{after}$ = Distribution Efficiency after duct sealing

$DE_{before}$ = Distribution Efficiency before duct sealing

FLHcool = Full load cooling hours

= Dependent on location as below[261]:

| Climate Zone (City based upon) | FLHcool Single Family | FLHcool Multifamily |
|---|---|---|
| 1 (Rockford) | 512 | 467 |
| 2 (Chicago) | 570 | 506 |
| 3 (Springfield) | 730 | 663 |

[259] Thermal regain (i.e. the potential for conditioned air escaping from ducts not being lost to the atmosphere) for residential pipe insulation measures is discussed in Home Energy Services Impact Evaluation, prepared for the Massachusetts Residential Retrofit and Low Income Program Area Evaluation, Cadmus Group, Inc., August 2012.

[260] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.

[261] Based on Full Load Hours from ENERGY STAR with adjustments made in a Navigant Evaluation, other cities were scaled using those results and CDD. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

| Climate Zone (City based upon) | FLHcool Single Family | FLHcool Multifamily |
|---|---|---|
| 4 (Belleville) | 1,035 | 940 |
| 5 (Marion) | 903 | 820 |
| Weighted Average[262] | 629 | 564 |

Use Multifamily if: Building has shared HVAC or meets utility's definition for multifamily

CapacityCool = Capacity of Air Cooling system (Btu/hr)

=Actual

TRFcool = Thermal Regain Factor for cooling by space type

= 1.0 for Unconditioned Spaces

= 0.4 for Semi-Conditioned Spaces[263]

1000 = Converts Btu to kBtu

ηCool = Efficiency (SEER) of Air Conditioning equipment (kBtu/kWh)

= Actual. If unknown assume[264]:

| Age of Equipment | SEER Estimate |
|---|---|
| Before 2006 | 10 |
| After 2006 - 2014 | 13 |
| Central AC After 1/1/2015 | 13 |
| Heat Pump After 1/1/2015 | 14 |

For example, duct sealing in unconditioned space in a single family house in Springfield, with 36,000 Btu/H SEER 11 central air conditioning, an 80% AFUE, 105,000 Btu/H natural gas furnace and the following duct evaluation results:

$DE_{before}$ = 0.85

$DE_{after}$ = 0.92

Energy Savings:

$\Delta kWh_{cooling}$ = ((((0.92 – 0.85)/0.92) * 730 * 36,000 * 1) / 1000 / 11) + (212 * 0.0314 * 29.3)

= 182 + 195

= 377 kWh

Heating savings for homes with electric heat:

$$\Delta kWh_{heating} = ((DE_{after} - DE_{before}) / DE_{after})) * FLHheat * OutputCapacityHeat * TRFheat) / \eta Heat / 3412$$

Where:

[262] Weighted based on number of occupied residential housing units in each zone.

[263] Thermal regain for residential pipe insulation measures is discussed in Home Energy Services Impact Evaluation, prepared for the Massachusetts Residential Retrofit and Low Income Program Area Evaluation, Cadmus Group, Inc., August 2012.

[264] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Central AC was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.

OutputCapacityHeat = Heating output capacity (Btu/hr) of the electric heat

=Actual

FLHheat = Full load heating hours

= Dependent on location as below[265]:

| Climate Zone (City based upon) | FLH_heat |
|---|---|
| 1 (Rockford) | 1,969 |
| 2 (Chicago) | 1,840 |
| 3 (Springfield) | 1,754 |
| 4 (Belleville) | 1,266 |
| 5 (Marion) | 1,288 |
| Weighted Average[266] | 1,821 |

TRFheat = Thermal Regain Factor for heating by space type

= 0.40 for Semi-Conditioned Spaces

= 1.0 for Unconditioned Spaces[267]

COP = Coefficient of Performance of electric heating system[268]

= Actual. If not available use[269]:

| System Type | Age of Equipment | HSPF Estimate | COP Estimate |
|---|---|---|---|
| Heat Pump | Before 2006 | 6.8 | 2.00 |
| | After 2006 - 2014 | 7.7 | 2.26 |
| | 2015 on | 8.2 | 2.40 |
| Resistance | N/A | N/A | 1.00 |

For example, duct sealing in unconditioned space in a 36,000 Btu/H, 2.5 COP heat pump heated single family house in Springfield with the following duct evaluation results:

$DE_{after}$ = 0.92

$DE_{before}$ = 0.85

Energy Savings:

$\Delta kWh_{heating}$ = ((0.92 – 0.85)/0.92) * 1,754 * 36,000 * 1) / 2.5) / 3412

= 563 kWh

[265] Heating EFLH based on ENERGY Star EFLH for Rockford, Chicago, and Springfield and on NCDC/NOAA HDD for the other two cities. In all cases, the hours were adjusted based on average natural gas heating consumption in IL.
[266] Weighted based on number of occupied residential housing units in each zone.
[267] Thermal regain for residential pipe insulation measures is discussed in Home Energy Services Impact Evaluation, prepared for the Massachusetts Residential Retrofit and Low Income Program Area Evaluation, Cadmus Group, Inc., August 2012.
[268] Note that the HSPF of a heat pump is equal to the COP * 3.413.
[269] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta kW = \Delta kWh_{cooling} / FLHcool * CF$

Where:

FLHcool = Full load cooling hours:

= Dependent on location as below[270]:

| Climate Zone (City based upon) | FLHcool Single Family | FLHcool Multifamily |
|---|---|---|
| 1 (Rockford) | 512 | 467 |
| 2 (Chicago) | 570 | 506 |
| 3 (Springfield) | 730 | 663 |
| 4 (Belleville) | 1,035 | 940 |
| 5 (Marion) | 903 | 820 |
| Weighted Average[271] | 629 | 564 |

Use Multifamily if: Building has shared HVAC or meets utility's definition for multifamily

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)

= 68%[272]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Central A/C (average during peak period)

= 46.6%[273]

### NATURAL GAS SAVINGS

<u>For homes with Natural Gas Heating:</u>

***Methodology 1: Modified Blower Door Subtraction***

$\Delta Therm = (((\Delta CFM25_{DL} / (InputCapacityHeat * 0.0123)) * FLHheat * InputCapacityHeat * TRFheat * (\eta Equipment / \eta System)) / 100{,}000$

Where:

$\Delta CFM25_{DL}$ = Duct leakage reduction in CFM25

InputCapacityHeat = Heating input capacity (Btu/hr)

=Actual

0.0123 = Conversion of Capacity to CFM (0.0123CFM / Btu/hr)[274]

---

[270] Based on Full Load Hours from ENERGY Star with adjustments made in a Navigant Evaluation, other cities were scaled using those results and CDD. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

[271] Weighted based on number of occupied residential housing units in each zone.

[272] Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

[273] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.

[274] Based on Natural Draft Furnaces requiring 100 CFM per 10,000 Btu, Induced Draft Furnaces requiring 130CFM per 10,000Btu and Condensing Furnaces requiring 150 CFM per 10,000 Btu (rule of thumb from 'Practical Standards to Measure HVAC System Performance'). Data provided by GAMA during the federal rule-making process for furnace efficiency standards, suggested that in 2000, 24% of furnaces purchased in Illinois were condensing units. Therefore a weighted average required airflow rate is calculated assuming a 50:50 split of natural v induced draft non-condensing furnaces, as 123 per 10,000Btu or 0.0123/Btu.

FLHheat = Full load heating hours

=Dependent on location as below[275]:

| Climate Zone (City based upon) | FLH_heat |
|---|---|
| 1 (Rockford) | 1,969 |
| 2 (Chicago) | 1,840 |
| 3 (Springfield) | 1,754 |
| 4 (Belleville) | 1,266 |
| 5 (Marion) | 1,288 |
| Weighted Average[276] | 1,821 |

TRFheat = Thermal Regain Factor for heating by space type

= 0.40 for Semi-Conditioned Spaces

= 1.0 for Unconditioned Spaces[277]

100,000 = Converts Btu to therms

ηEquipment = Heating Equipment Efficiency

= Actual[278]. If not available use 83%[279]

ηSystem = Pre duct sealing Heating System Efficiency (Equipment Efficiency * Pre Distribution Efficiency)[280]

= Actual. If not available use 70%[281]

[275] Heating EFLH based on ENERGY Star EFLH for Rockford, Chicago, and Springfield and on NCDC/NOAA HDD for the other two cities. In all cases, the hours were adjusted based on average natural gas heating consumption in IL.
[276] Weighted based on number of occupied residential housing units in each zone.
[277] Thermal regain for residential pipe insulation measures is discussed in Home Energy Services Impact Evaluation, prepared for the Massachusetts Residential Retrofit and Low Income Program Area Evaluation, Cadmus Group, Inc., August 2012.
[278] The Equipment Efficiency can be obtained either by recording the AFUE of the unit, or performing a steady state efficiency test.
If there are more than one heating systems, the weighted (by consumption) average efficiency should be used.
If the heating system or distribution is being upgraded within a package of measures together with the insulation upgrade, the new average heating system efficiency should be used.
[279] This has been estimated assuming that natural gas central furnace heating is typical for Illinois residences (66% of Illinois homes have a Natural Gas Furnace (based on Energy Information Administration, 2009 Residential Energy Consumption Survey). In 2000, 24% of furnaces purchased in Illinois were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 10 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows:
(0.24*0.92) + (0.76*0.8) = 0.829
[280] The Distribution Efficiency can be estimated via a visual inspection and by referring to a look up table such as that provided by the Building Performance Institute: (see 'DistributionEfficiencyTable-Blue Sheet') or by performing duct blaster testing.
[281] Estimated as follows: 0.829 * (1-0.15) = 0.70

For example, duct sealing in unconditioned space in a house in Springfield with an 80% AFUE, 105,000 Btu/H (input capacity) natural gas furnace and the following blower door test results:

Before: $CFM50_{Whole\ House}$ = 4800 CFM50

$CFM50_{Envelope\ Only}$ = 4500CFM50

House to duct pressure of 45 Pascals = 1.29 SCF (Energy Conservatory look up table)

After: $CFM50_{Whole\ House}$ = 4600 CFM50

$CFM50_{Envelope\ Only}$ = 4500CFM50

House to duct pressure of 43 Pascals = 1.39 SCF (Energy Conservatory look up table)

Duct Leakage:

$CFM50_{DL\ before}$ = (4800 – 4500) * 1.29

= 387 CFM

$CFM50_{DL\ after}$ = (4600 – 4500) * 1.39

= 119 CFM

Duct Leakage reduction at CFM25:

$\Delta CFM25_{DL}$ = (387 – 139) * 0.64 * (0.5 + 0.25)

= 119 CFM25

Energy Savings:

Pre Distribution Efficiency = 1 – (387/4800) = 92%

ηSystem = 80% * 92% = 74%

ΔTherm = ((119/ (105,000 * 0.0123)) * 1,754 * 105,000 * 1 *(0.8/0.74)) / 100,000

= 183 therms

***Methodology 2: Evaluation of Distribution Efficiency***

$$\Delta Therm = ((DE_{after} - DE_{before})/ DE_{after})) * FLHheat * InputCapacityHeat * TRFheat * (\eta Equipment / \eta System)) / 100,000$$

Where:

$DE_{after}$ = Distribution Efficiency after duct sealing

$DE_{before}$ = Distribution Efficiency before duct sealing

Other variables as defined above

For example, duct sealing in unconditioned space in a house in Springfield an 80% AFUE, 105,000 Btu/H (input capacity) natural gas furnace and the following duct evaluation results:

$DE_{after}$ = 0.92

$DE_{before}$ = 0.85

Energy Savings:

ηSystem = 80% * 85% = 68%

ΔTherm = (((0.92 – 0.85)/0.92) * 1,754 * 105,000 * 1 * (0.8/0.68)) / 100,067

= 165 therm

**Mid-Life adjustment**

In order to account for the likely replacement of existing heating and cooling equipment during the lifetime of this measure, a mid-life adjustment should be applied. To calculate the adjustment, re-calculate the savings above using the following new baseline system efficiency assumptions:

| Efficiency Assumption | System Type | New Baseline Efficiency |
|---|---|---|
| ηCool | Central AC | 13 SEER |
| | Heat Pump | 14 SEER |
| ηHeat | Heat Pump<br>(8.2HSPF/3.413)*0.85 | 2.04 COP |
| | Furnace<br>90% AFUE * 0.85 | 76.5% AFUE |

This reduced annual savings should be applied following the assumed remaining useful life of the existing equipment, estimate to be 10 years[282].

#### WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

#### DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

#### MEASURE CODE: RS-HVC-DINS-V07-190101

#### REVIEW DEADLINE: 1/1/2022

[282] This is intentionally longer than the assumption found in the early replacement measures as the application of this measure will occur in a variety of homes and will not be targeting those homes appropriate for early replacement HVAC systems.

## 5.3.5 Furnace Blower Motor

### DESCRIPTION

An brushless permanent magnet (BPM) motor (known and referred in this measure as an electronically commutated motor (ECM)) is installed instead of a lower efficiency motor. This measure characterizes the electric savings associated with the fan and the interactive negative therm savings due to a reduction in waste heat of the fan when operating in heating mode. The efficiency ratings of high efficiency ASHP and CAC systems already account for the use of an ECM furnace blower motor, therefore incremental ECM savings are not incurred during heating or cooling for ASHP's or cooling for CAC's if savings are calculated for these systems using their AHRI efficiency ratings.

Savings decrease sharply with static pressure so duct improvements, and clean, low pressure drop filters can maximize savings. Savings occur when the blower is used for heating, cooling as well as when it is used for continuous ventilation, but only if the non-ECM motor would have been used for continuous ventilation too. If the resident runs the ECM blower continuously because it is a more efficient motor and would not run a non-ECM motor that way, savings are near zero and possibly negative. This characterization uses a 2016 Ameren Illinois study of ECM blower motors in Illinois, which accounted for the effects of this behavioral impact.

This measure was developed to be applicable to the following program types: TOS, NC.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

A brushless permanent magnet (ECM) blower motor, also known by the trademark ECM, BLDC, and other names.

### DEFINITION OF BASELINE EQUIPMENT

A non-ECM blower motor.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years[283].

### DEEMED MEASURE COST

The capital cost for this measure is assumed to be $97[284].

### LOADSHAPE

Loadshape R08 - Residential Cooling

Loadshape R09 - Residential Electric Space Heat

Loadshape R10 - Residential Electric Heating and Cooling

### COINCIDENCE FACTOR

ECMs installed in high efficiency CACs and ASHPs do not generate peak demand cooling savings if demand savings are claimed for these systems. However, some savings are realized for fans operating in circulation mode, even during peak demand cooling periods. Circulation mode operation during peak cooling periods would only occur when a system is not operating in cooling mode, with the percent time in circulation mode calculated using the summer system peak and PJM peak coincidence factors. A metering study[285] found 23% of fans operated continuously during

---

[283] Consistent with assumed life of a BPM/ECM motor, Appendix 8-E of the DOE Technical support documents for federal residential appliance standards.

[284] Adapted from Tables 8.2.3 and 8.2.13 in the DOE Technical support documents for federal residential appliance standards.

[285] See Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study

the summer peak periods therefore ECMs do generate some demand savings during peak periods (when the system is not cooling). ECMs installed with CACs or ASHPs not receiving a rebate improve the cooling efficiency and therefore generate additional peak demand savings (when the system is cooling). Demand savings vary with system size and can be calculated using factors listed in the demand savings calculation table in the next section which incorporate coincidence with peak in their calculation.

## Algorithm

### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

ΔkWh = Capacity_cooling * kWhSavingsPerTon

Where:

Capacity_cooling = Capacity of cooling system in tons

= Actual (1 ton = 12,000Btu/hr)

kWhSavingsPerTon = Blower fan kWh savings per ton of cooling[286]

The per-ton energy savings values vary by system installation scenario and location as provided below. Where new *high efficiency* cooling systems are being installed, savings from the blower motor are lower as the efficiency rating of the new cooling system will include this benefit. If a lower efficiency cooling system is installed or an existing one is not replaced, additional savings are claimed due to reduced fan energy during the cooling season. Assumptions are also provided for installation with no or unknown cooling system.

| Region | ASHP Receiving Rebate (Most Common) | Existing or Federal Minimum Efficiency ASHP | CAC Receiving Rebate (Most Common) | Existing or Federal Minimum Efficiency CAC | Furnace, No Cooling System* | Furnace, Cooling System unknown* [287] |
|---|---|---|---|---|---|---|
| Rockford | 114 | 247 | 198 | 229 | 210 | 223 |
| Chicago | 116 | 245 | 195 | 230 | 208 | 222 |
| Springfield | 115 | 249 | 186 | 231 | 203 | 221 |
| Belleville | 121 | 247 | 171 | 235 | 196 | 222 |
| Marion | 123 | 242 | 175 | 231 | 196 | 219 |
| Average | 115 | 247 | 192 | 230 | 206 | 222 |
| *Multiply kWh saved value by 2 tons for furnaces <70 kBTU, by 3 tons for furnaces 70 kBTU – 90 kBTU and by 4 tons for furnaces 90+ kBTU. | | | | | | |

Memo FINAL 2_28_2018'.

[286] Tons of cooling was determined to be the most straightforward multiplier to apply to systems in which the BPM is installed. The basis of the values and for more information see Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study Memo FINAL 2_28_2018'.

[287] Unknown cooling system values are based on a weight of 66% existing CAC and 34% no cooling factors. Based on 66% of homes in Illinois having central cooling ("Table HC7.9 Air Conditioning in Homes in Midwest Region, Divisions, and States, 2009 from Energy Information Administration", 2009 Residential Energy Consumption Survey)

For example, an BPM installed with a three ton, 16 SEER CAC receiving a rebate in a home in Marion:

$\Delta$kWh = 3 * 175

= 525 kWh

#### SUMMER COINCIDENT PEAK DEMAND SAVINGS

$\Delta$kW = Capacity_cooling * kWSavingsPerTon

Where:

kWSavingsPerTon = Blower fan kW savings per ton of cooling[288]

The per-ton energy savings values vary by system installation scenario and location as provided below. Where new *high efficiency* cooling systems are being installed, savings from the blower motor are lower as the efficiency rating of the new cooling system will include this benefit. If a lower efficiency cooling system is installed or an existing one is not replaced, additional savings are claimed due to reduced fan energy during the cooling season. Assumptions are also provided for installation with no or unknown cooling system.

| Demand Savings Type | ASHP Receiving Rebate (Most Common) | Existing or Federal Minimum Efficiency ASHP | CAC Receiving Rebate (Most Common) | Existing or Federal Minimum Efficiency CAC | Furnace, No Cooling System* | Furnace, Cooling System unknown* [289] |
|---|---|---|---|---|---|---|
| SSP | 0.006 | 0.085 | 0.006 | 0.085 | 0.013 | 0.065 |
| PJM | 0.01 | 0.064 | 0.01 | 0.064 | 0.009 | 0.048 |
| *Multiply kWh saved value by 2 tons for furnaces <70 kBTU, by 3 tons for furnaces 70 kBTU – 90 kBTU and by 4 tons for furnaces 90+ kBTU. | | | | | | |

For example, a BPM installed with a three ton, 16 SEER CAC receiving a rebate in a home in Marion:

$\Delta kW_{ssp}$ = 3 * 0.006

= 0.018 kW

$\Delta kW_{pjm}$ = 3 * 0.010

= 0.030 kW

#### NATURAL GAS SAVINGS

$\Delta$therms[290] = - HeatingkWhSavings * 0.03412/ AFUE

Where:

[288] Tons of cooling was determined to be the most straightforward multiplier to apply to systems in which the BPM is installed. The basis of the values and for more information see Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study Memo FINAL 2_28_2018'.

[289] Unknown cooling system values are based on a weight of 66% existing CAC and 34% no cooling factors. Based on 66% of homes in Illinois having central cooling ("Table HC7.9 Air Conditioning in Homes in Midwest Region, Divisions, and States, 2009 from Energy Information Administration", 2009 Residential Energy Consumption Survey)

[290] The blower fan is in the heating duct so all, or very nearly all, of its waste heat is delivered to the conditioned space. Negative value since this measure will increase the heating load due to reduced waste heat.

HeatingkWhSavings = Heating kWh savings per ton of cooling[291]

Use the location-specific values in the following table to determine heating savings based on the size of the cooling system. If cooling size is unknown, assume 2 tons for furnaces <70 kBTU, 3 tons for furnaces 70 kBTU – 90 kBTU and 4 tons for furnaces 90+ kBTU. If heating size is unknown or if the system does not include cooling, assume a 3-ton system.

| Region | Heating Savings (kWh per ton of cooling) |
|---|---|
| Rockford | 61 |
| Chicago | 59 |
| Springfield | 50 |
| Belleville | 39 |
| Marion | 39 |
| Average | 56 |

0.03412 = Converts kWh to therms

AFUE = Efficiency of the Furnace

= Actual. If unknown assume 95%[292] if in new furnace or 64.4 AFUE% [293] if in existing furnace

For example, an ECM installed with a three ton CAC and 95% AFUE furnace in a home in Marion:

Δtherms = (-39 kWh * 3 tons * 0.03412) / 0.95

Δtherms = - 4.2 therms

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-HVC-FBMT-V04-190101**

**REVIEW DEADLINE: 1/1/2022**

[291] Tons of cooling was determined to be the most straightforward multiplier to apply to systems in which the BPM is installed. The basis of the values and for more information see Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study Memo FINAL 2_28_2018'.
[292] Minimum ENERGY STAR efficiency after 2.1.2012.
[293] Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren PY3-PY4.

## 5.3.6 Gas High Efficiency Boiler

### DESCRIPTION

High efficiency boilers achieve most gas savings through the utilization of a sealed combustion chamber and multiple heat exchangers that remove a significant portion of the waste heat from flue gasses. Because multiple heat exchangers are used to remove waste heat from the escaping flue gasses, some of the flue gasses condense and must be drained.

This measure characterizes:

a) Time of Sale:

   a. The installation of a new high efficiency, gas-fired hot water boiler in a residential location. This could relate to the replacement of an existing unit at the end of its useful life, or the installation of a new system in a new home.

b) Early Replacement:

   Early Replacement determination will be based on meeting the following conditions:

   - The existing unit is operational when replaced, or
   - The existing unit requires minor repairs (<$709)[294].
   - All other conditions will be considered Time of Sale.

   The Baseline AFUE of the existing unit replaced:

   - If the AFUE of the existing unit is known and <=75%, the Baseline AFUE is the actual AFUE value of the unit replaced. If the AFUE is >75%, the Baseline AFUE = 82%.
   - If the AFUE of the existing unit is unknown, use assumptions in variable list below (AFUE(exist)).
   - If the operational status or repair cost of the existing unit is unknown, use time of sale assumptions.

   A weighted average early replacement rate is provided for use when the actual baseline early replacement rates are unknown[295].

**Deemed Early Replacement Rates For Boilers**

| | Deemed Early Replacement Rate |
|---|---|
| Early Replacement Rate for Boiler participants | 7% |

This measure was developed to be applicable to the following program types: TOS, NC, EREP. If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed Boiler must be ENERGY STAR qualified (AFUE rated at or greater than 85% and input capacity less than 300,000 Btu/hr).

---

[294] The Technical Advisory Committee agreed that if the cost of repair is less than 20% of the new baseline replacement cost it can be considered early replacement. Note the non-inflated cost is used as this would be a cost consideration in the program year.

[295] Based upon research from “Home Energy Efficiency Rebate Program GPY2 Evaluation Report” which outlines early replacement rates for both primary and secondary central air cooling (CAC) and residential furnaces. This is used as a reasonable proxy for boiler installations since boiler specific data is not available. Report presented to Nicor Gas Company February 27, 2014.

### DEFINITION OF BASELINE EQUIPMENT

Time of sale: The baseline equipment for this measure is a new, gas-fired, standard-efficiency water boiler. The current Federal Standard minimum is 82% AFUE.

Early replacement: The baseline for this measure is the efficiency of the existing equipment for the assumed remaining useful life of the unit and the new baseline as defined above for the remainder of the measure life.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 25 years[296].

Early replacement: Remaining life of existing equipment is assumed to be 8 years[297].

### DEEMED MEASURE COST

Time of sale: The incremental install cost for this measure is dependent on tier[298]:

| Measure Type | Installation Cost | Incremental Install Cost |
|---|---|---|
| AFUE 82% | $3543 | n/a |
| AFUE 85% (ENERGY STAR Minimum) | $4268 | $725 |
| AFUE 90% | $4815 | $1,272 |
| AFUE 95% | $5328 | $1,785 |

Early Replacement: The full installation cost is provided in the table above. The assumed deferred cost (after 8 years) of replacing existing equipment with a new baseline unit is assumed to be $4,045[299]. This cost should be discounted to present value using the nominal discount rate.

### LOADSHAPE

N/A

### COINCIDENCE FACTOR

N/A

## Algorithm

### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

N/A

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

[296] Table 8.3.3 The Technical support documents for federal residential appliance standards.
[297] Assumed to be one third of effective useful life
[298] Based on data provided in Appendix E of the Appliance Standards Technical Support Documents including equipment cost and installation labor. Where efficiency ratings are not provided, the values are interpolated from those that are.
[299] $3543 inflated using 1.91% rate.

## NATURAL GAS SAVINGS

Time of Sale:

ΔTherms = (EFLH * CAPInput * (AFUE(eff) / AFUE(base) -1)) / 100000

Early replacement[300]:

ΔTherms for remaining life of existing unit (1st 8 years):

= (EFLH * CAPInput * (AFUE(eff) / AFUE(exist) -1)) / 100000

ΔTherms for remaining measure life (next 17 years):

= (EFLH * CAPInput * (AFUE(eff) / AFUE(base) -1)) / 100000

Where:

CAPInput = Gas Boiler input capacity (Btuh)

= Actual

EFLH = Equivalent Full Load Hours for gas heating

| Climate Zone (City based upon) | EFLH[301] |
|---|---|
| 1 (Rockford) | 1022 |
| 2 (Chicago) | 976 |
| 3 (Springfield) | 836 |
| 4 (Belleville) | 645 |
| 5 (Marion) | 656 |
| Weighted Average[302] | 928 |

AFUE(exist) = Existing Boiler Annual Fuel Utilization Efficiency Rating

= Use actual AFUE rating where it is possible to measure or reasonably estimate.

If unknown, assume 61.6 AFUE% [303].

AFUE(base) = Baseline Boiler Annual Fuel Utilization Efficiency Rating

= 82%

AFUE(eff) = Efficent Boiler Annual Fuel Utilization Efficiency Rating

= Actual. If unknown, use defaults dependent[304] on tier as listed below:

| Measure Type | AFUE(eff) |
|---|---|
| ENERGY STAR® | 87.5% |
| AFUE 90% | 92.5% |

---

300 The two equations are provided to show how savings are determined during the initial phase of the measure (existing to efficient) and the remaining phase (new baseline to efficient). In practice, the screening tools used may either require a First Year savings (using the first equation) and then a “number of years to adjustment” and “savings adjustment” input which would be the (new base to efficient savings)/(existing to efficient savings).

301 Full load hours for Chicago, are based on findings in ‘Energy Efficiency / Demand Response Nicor Gas Plan Year 1 (6/1/2011-5/31/2012) Research Report: Furnace Metering Study (August 1, 2013), prepared by Navigant Consulting, Inc. Values for other cities are then calculated by comparing relative HDD at base 60F.

302 Weighted based on number of occupied residential housing units in each zone.

303 Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren PY3-PY4.

304 Default values per tier selected based upon the average AFUE value for the tier range except for the top tier where the minimum is used due to proximity to the maximum possible.

| Measure Type | AFUE(eff) |
|---|---|
| AFUE 95% | 95% |

Time of Sale:

For example, a 100,000 Btuh, 90%AFUE ENERGY STAR boiler purchased and installed near Springfield

$$\Delta Therms = (836 * 100000 * (0.90/0.82 – 1)) / 100000$$

$$= 81.6 \text{ Therms}$$

Early Replacement:

For example, an existing function boiler with unknown efficiency is replaced with a 100,000 Btuh, 90%AFUE ENERGY STAR boiler purchased and installed in Springfield.

ΔTherms for remaining life of existing unit (1st 8 years):

$$= (836 * 100000 * (0.90/0.616 – 1)) / 100000$$

$$= 385.4 \text{ Therms}$$

ΔTherms for remaining measure life (next 17 years):

$$= (836 * 100000 * (0.90/0.82 – 1)) / 100000$$

$$= 81.6 \text{ Therms}$$

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-HVC-GHEB-V07-190101**

**REVIEW DEADLINE: 1/1/2021**

## 5.3.7 Gas High Efficiency Furnace

**DESCRIPTION**

High efficiency furnace features may include improved heat exchangers and modulating multi-stage burners.

This measure characterizes:

a) Time of sale:

   a. The installation of a new high efficiency, gas-fired condensing furnace in a residential location. This could relate to the replacement of an existing unit at the end of its useful life, or the installation of a new system in a new home.

b) Early Replacement:

Early Replacement determination will be based on meeting the following conditions:

- The existing unit is operational when replaced, or
- The existing unit requires minor repairs (<$528)[305].
- All other conditions will be considered Time of Sale.

The Baseline AFUE of the existing unit replaced:

- If the AFUE of the existing unit is known and <=75%, the Baseline AFUE is the actual AFUE value of the unit replaced. If the AFUE is >75%, the Baseline AFUE = 80%.
- If the AFUE of the existing unit is unknown, use assumptions in variable list below (AFUE(exist)).
- If the operational status or repair cost of the existing unit is unknown, use time of sale assumptions.

A weighted average early replacement rate is provided for use when the actual baseline early replacement rate is unknown[306].

**Deemed Early Replacement Rates For Furnaces**

| Replacement Scenario for the Furnace | Deemed Early Replacement Rate |
|---|---|
| Early Replacement Rate for Furnace-only participants | 7% |
| Early Replacement Rate for a furnace when the furnace is the Primary unit in a Combined System Replacement (CSR) project | 14% |
| Early Replacement Rate for a furnace when the furnace is the Secondary unit in a CSR project | 46% |

Verified Quality Installation

This approach uses in-field measurement and interpretation of static pressures, identification and plotting of airflow, airflow measurement, temperature measurement and diagnostics, pressure measurements and duct design, and BTU measurement to ensure that newly installed equipment is operating according to manufacturers' published potential performance. Installed equipment operating efficiency is largely dependent on the efficiency rating of the

[305] The Technical Advisory Committee agreed that if the cost of repair is less than 20% of the new baseline replacement cost it can be considered early replacement. Note the non-inflated cost is used as this would be a cost consideration in the program year.

[306] Based upon research from "Home Energy Efficiency Rebate Program GPY2 Evaluation Report" which outlines early replacement rates for both primary and secondary central air cooling (CAC) and residential funaces. The unit (furnace or CAC unit) that initially caused the customer to contact a trade ally is defined as the "primary unit". The furnace or CAC unit that was also replaced but did not initially prompt the customer to contact a trade ally is defined as the "secondary unit". This evaluation used different criteria for early replacement due to the availability of data after the fact; cost of any repairs < $550 and age of unit < 20 years. Report presented to Nicor Gas Company February 27, 2014.

equipment, the skill of the installation contractor, the degree to which the equipment has aged or drifted from initial settings, and the system level constraints. When one or more of these key dependencies are operating sub-optimally, the overall efficiency of the equipment is degraded. A Verified Quality Install identifies sub-optimal performance and prescribes a solution during furnace installation.

This measure was developed to be applicable to the following program types: TOS, NC, EREP. If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

To qualify for this measure the installed equipment must be a residential sized (input energy less than 225,000 Btu/hr) natural gas fired furnace with an Annual Fuel Utilization Efficiency (AFUE) rating exceeding the program requirements.

### Definition of Baseline Equipment

Time of Sale: The current Federal Standard for gas furnaces is an AFUE rating of 80%. The baseline will be adjusted when the Federal Standard is updated.

Early replacement: The baseline for this measure is the efficiency of the existing equipment for the assumed remaining useful life of the unit and a new baseline unit for the remainder of the measure life. We estimate that the new baseline unit that could be purchased in the year the existing unit would have needed replacing is 90%.

### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 20 years[307].

For early replacement: Remaining life of existing equipment is assumed to be 6 years[308].

### Deemed Measure Cost

Time of sale: The incremental installed cost (retail equipment cost plus installation cost) for this measure depends on efficiency as listed below[309]:

| AFUE | Installed Cost | Incremental Installed Cost |
|---|---|---|
| 80% | $2011 | n/a |
| 90% | $2641 | $630 |
| 91% | $2727 | $716 |
| 92% | $2813 | $802 |
| 93% | $3025 | $1014 |
| 94% | $3237 | $1226 |
| 95% | $3449 | $1438 |
| 96% | $3661 | $1650 |

Early Replacement: The full installed cost is provided in the table above. The assumed deferred cost (after 6 years) of replacing existing equipment with a new 90% baseline unit is assumed to be $2903[310]. This cost should be discounted to present value using the nominal discount rate.

Verified Quality Installation: The additional design and installation work associated with verified quality installation

[307] Table 8.3.3 The Technical support documents for federal residential appliance standards.
[308] Assumed to be one third of effective useful life
[309] Based on data from Table E.1.1 of Appendix E of the Appliance Standards Technical Support Documents including equipment cost and installation labor. Where efficiency ratings are not provided, the values are interpolated from those that are. Note that ECM furnace fan cost (refer to other measure in TRM) has been deducted from the 93%-96% AFUE values to avoid double counting.
[310] $2641 inflated using 1.91% rate.

has been estimated to take 1-2 hours (Tim Hanes, ESI). At $40/hr, VQI adds $60 to the installed cost.

**LOADSHAPE**

N/A

**COINCIDENCE FACTOR**

N/A

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

Electrical energy savings from the more fan-efficient (typically using brushless permanent magnet (BPM) blower motor) should also be claimed, please refer to "Furnace Blower Motor" characterization for details.

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

If the blower motor is also used for cooling, coincident peak demand savings should also be claimed, please refer to "Furnace Blower Motor" characterization for savings details.

**NATURAL GAS SAVINGS**

Time of Sale:

$$\Delta Therms = \frac{\frac{EFLH * CAPInput}{(1 - Derating_{eff})} * \left(\frac{AFUE(eff) * (1 - Derating(eff))}{AFUE(base) * (1 - Derating(base))} - 1\right)}{100{,}000}$$

Early replacement[311]:

ΔTherms for remaining life of existing unit (1st 6 years):

$$= \frac{\frac{EFLH * CAPInput}{(1 - Derating_{eff})} * \left(\frac{AFUE(eff) * (1 - Derating(eff))}{AFUE(exist) * (1 - Derating(base))} - 1\right)}{100{,}000}$$

ΔTherms for remaining measure life (next 14 years):

$$= \frac{\frac{EFLH * CAPInput}{(1 - Derating_{eff})} * \left(\frac{AFUE(eff) * (1 - Derating(eff))}{AFUE(base) * (1 - Derating(base))} - 1\right)}{100{,}000}$$

Where:

CAPInput = Gas Furnace input capacity (Btuh)

= Actual

EFLH = Equivalent Full Load Hours for gas heating

[311] The two equations are provided to show how savings are determined during the initial phase of the measure (existing to efficient) and the remaining phase (new baseline to efficient). In practice, the screening tools used may either require a First Year savings (using the first equation) and then a "number of years to adjustment" and "savings adjustment" input which would be the (new base to efficient savings)/(existing to efficient savings).

| Climate Zone (City based upon) | EFLH[312] |
|---|---|
| 1 (Rockford) | 1022 |
| 2 (Chicago) | 976 |
| 3 (Springfield) | 836 |
| 4 (Belleville) | 645 |
| 5 (Marion) | 656 |
| Weighted Average[313] | 928 |

AFUE(exist) = Existing Furnace Annual Fuel Utilization Efficiency Rating

= Use actual AFUE rating where it is possible to measure or reasonably estimate.

If unknown, assume 64.4 AFUE% [314].

AFUE(base) = Baseline Furnace Annual Fuel Utilization Efficiency Rating

= Dependent on program type as listed below[315]:

| Program Year | AFUE(base) |
|---|---|
| Time of Sale | 80% |
| Early Replacement [316] | 90% |

AFUE(eff) = Efficent Furnace Annual Fuel Utilization Efficiency Rating

= Actual. If unknown, assume 95%[317]

Derating(base) =Baseline furnace AFUE derating

= 6.4%[318]

Derating(eff) =Efficent furnace AFUE derating

=0% if verified quality installation is performed

=6.4% if verified quality installation is not performed or unknown[319]

[312] Full load hours for Chicago, are based on findings in 'Energy Efficiency / Demand Response Nicor Gas Plan Year 1 (6/1/2011-5/31/2012) Research Report: Furnace Metering Study (August 1, 2013), prepared by Navigant Consulting, Inc. Values for other cities are then calculated by comparing relative HDD at base 60F.

[313] Weighted based on number of occupied residential housing units in each zone.

[314] Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren PY3-PY4.

[315] Though the Federal Minimum AFUE is 78%, there were only 50 models listed in the AHRI database at that level. At AFUE 79% the total rises to 308. There are 3,548 active furnace models listed with AFUE ratings between 78 and 80.

[316] We estimate that the new baseline unit that could be purchased in the year the existing unit would have needed replacing is 90%.

[317] Minimum ENERGY STAR efficiency after 2.1.2012.

[318] Brand, L., Yee, S., and Baker, J. "Improving Gas Furnace Performance: A Field and Laboratory Study at End of Life." Building Technologies Office. National Renewable Energy Laboratory. 2015 accessed September 6th, 2016.

[319] Ibid

Time of Sale:

For example, a 95% AFUE, 80,000Btuh furnace purchased and installed with verified quality installation for an existing home near Rockford:

ΔTherms = ((1022 * 80,000)/(1-0) * (((0.95 * (1-0)) / (0.8 * (1-0.064))) – 1)) / 100067

= 220 therms

For example, a 95% AFUE, 80,000Btuh furnace purchased and installed without verified quality installation for an existing home near Rockford:

ΔTherms = ((1022 * 80,000)/(1-0.064) * (((0.95 * (1-0.064)) / (0.8 * (1-0.064))) – 1)) / 100067

=164 therms

Early Replacement:

For example, an existing functioning furnace with unknown efficiency is replaced with an 95% AFUE, 80,000Btuh furnace using quality installation in Rockford:

ΔTherms for remaining life of existing unit (1st 6 years):

= ((1022 * 80,000)/(1-0) * (((0.95 * (1-0)) / (0.644 * (1-0.064))) – 1)) / 100067

= 471 therms

ΔTherms for remaining measure life (next 14 years):

= ((1022 * 80,000)/(1-0) * (((0.95 * (1-0)) / (0.9 * (1-0.064))) – 1)) / 100067

= 104 therms

## WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

## DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

## MEASURE CODE: RS-HVC-GHEF-V08-190101

## REVIEW DEADLINE: 1/1/2021

## 5.3.8 Ground Source Heat Pump

### DESCRIPTION

This measure characterizes the installation of a Ground Source Heat Pump under the following scenarios:

a) New Construction:

   i. The installation of a new residential sized Ground Source Heat Pump system meeting ENERGY STAR efficiency standards presented below in a new home.
   ii. Note the baseline in this case should be determined via EM&V and the algorithms are provided to allow savings to be calculated from any baseline condition.

b) Time of Sale:

   i. The planned installation of a new residential sized Ground Source Heat Pump system meeting ENERGY STAR efficiency standards presented below to replace an existing system(s) that does not meet the criteria for early replacement described in section c below.
   ii. Note the baseline in this case is an equivalent replacement system to that which exists currently in the home. The calculation of savings is dependent on whether an incentive for the installation has been provided by both a gas and electric utility, just an electric utility or just a gas utility.
   iii. Additional DHW savings are calculated based upon the fuel and efficiency of the existing unit.

c) Early Replacement/Retrofit:

   i. The early removal of functioning either electric or gas space heating and/or cooling systems from service, prior to the natural end of life, and replacement with a new high efficiency Ground Source Heat Pump system.
   ii. Note the baseline in this case is the existing equipment being replaced. The calculation of savings is dependent on whether an incentive for the installation has been provided by both a gas and electric utility, just an electric utility or just a gas utility.
   iii. Additional DHW savings are calculated based upon the fuel and efficiency of the existing unit.
   iv. Early Replacement determination will be based on meeting the following conditions:
      - The existing unit is operational when replaced, or
      - The existing unit requires minor repairs, defined as costing less than[320]:

| Existing System | Maximum repair cost |
|---|---|
| Air Source Heat Pump | $276 per ton |
| Central Air Conditioner | $190 per ton |
| Boiler | $709 |
| Furnace | $528 |
| Ground Source Heat Pump | <$249 per ton |

      - All other conditions will be considered Time of Sale.

   v. The Baseline efficiency of the existing unit replaced:
      - If the efficiency of the existing unit is less than the maximum shown below, the Baseline efficiency is the actual efficiency value of the unit replaced. If the efficiency is greater than the maximum, the Baseline efficiency is shown in the "New Baseline" column below:

[320] The Technical Advisory Committee agreed that if the cost of repair is less than 20% of the new baseline replacement cost it can be considered early replacement.

| Existing System | Maximum efficiency for Actual | New Baseline |
|---|---|---|
| Air Source Heat Pump | 10 SEER | 14 SEER |
| Central Air Conditioner | 10 SEER | 13 SEER |
| Boiler | 75% AFUE | 82% AFUE |
| Furnace | 75% AFUE | 80% AFUE |
| Ground Source Heat Pump | 10 SEER | 13 SEER |

- If the efficiency of the existing unit is unknown, use assumptions in variable list below (SEER, HSPF or AFUE exist).
- If the operational status or repair cost of the existing unit is unknown use time of sale assumptions.

This measure was developed to be applicable to the following program types: TOS, NC, EREP. If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

In order for this characterization to apply, the efficient equipment must be a Ground Source Heat Pump unit meeting the minimum ENERGY STAR efficiency level standards effective at the time of installation as detailed below:

ENERGY STAR Requirements (Effective January 1, 2012)

| Product Type | Cooling EER | Heating COP |
|---|---|---|
| **Water-to-air** | | |
| Closed Loop | 17.1 | 3.6 |
| Open Loop | 21.1 | 4.1 |
| **Water-to-Water** | | |
| Closed Loop | 16.1 | 3.1 |
| Open Loop | 20.1 | 3.5 |
| DGX | 16 | 3.6 |

**DEFINITION OF BASELINE EQUIPMENT**

For these products, baseline equipment includes Air Conditioning, Space Heating and Water Heating.

New Construction:

To calculate savings with an electric baseline, the baseline equipment is assumed to be an Air Source Heat Pump meeting the Federal Standard efficiency level; 14 SEER, 8.2 HSPF and 11.8[321] EER and a Federal Standard electric hot water heater.

To calculate savings with a furnace/central AC baseline, the baseline equipment is assumed to be an 80% AFUE Furnace and central AC meeting the Federal Standard efficiency level; 13 SEER, 11 EER. If a gas water heater, the Federal Standard baseline is calculated as follows; 0.6483 – (0.0017 * storage capacity in gallons) for tanks<=55 gallons and 0.7897 − (0.0004 × storage capacity in gallons) for greater than 55 gallon storage water heaters.[322]. For a 40-gallon storage water heater this would be 0.58 EF.

Time of Sale: The baseline for this measure is a new replacement unit of the same system type as the existing unit,

[321] The Federal Standard does not include an EER requirement, so it is approximated with this formula: (-0.02 * SEER2) + (1.12 * SEER) Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder.
[322] Minimum Federal standard as of 4/16/2015.

meeting the baselines provided below.

| Unit Type | Efficiency Standard |
|---|---|
| ASHP | 14 SEER, 11.8 EER, 8.2 HSPF |
| Gas Furnace | 80% AFUE |
| Gas Boiler | 82% AFUE |
| Central AC | 13 SEER, 11 EER |

Early replacement / Retrofit: The baseline for this measure is the efficiency of the *existing* heating, cooling and hot water equipment for the assumed remaining useful life of the existing unit and a new baseline heating and cooling system for the remainder of the measure life (as provided in table above except for Gas Furnace where new baseline assumption is 90% due to pending standard change).

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 25 years[323].

For early replacement, the remaining life of existing equipment is assumed to be 8 years[324].

### DEEMED MEASURE COST

New Construction and Time of Sale: The actual installed cost of the Ground Source Heat Pump should be used (default of $3957 per ton[325]), minus the assumed installation cost of the baseline equipment ($1381 per ton for ASHP[326] or $2011 for a new baseline 80% AFUE furnace or $3543 for a new 82% AFUE boiler[327] and $952 per ton[328] for new baseline Central AC replacement).

Early Replacement: The full installation cost of the Ground Source Heat Pump should be used (default provided above). The assumed deferred cost (after 8 years) of replacing existing equipment with a new baseline unit is assumed to be $1,518 per ton for a new baseline Air Source Heat Pump, or $2,903 for a new baseline 90% AFUE furnace or $4,045 for a new 82% AFUE boiler and 1,047 per ton for new baseline Central AC replacement[329]. This future cost should be discounted to present value using the nominal societal discount rate.

### LOADSHAPE

Loadshape R10 - Residential Electric Heating and Cooling (if replacing gas heat and central AC)[330]

Loadshape R09 - Residential Electric Space Heat (if replacing electric heat with no cooling)

Loadshape R10 - Residential Electric Heating and Cooling (if replacing ASHP)

Note for purpose of cost effectiveness screening a fuel switch scenario, the heating kWh increase and cooling kWh decrease should be calculated separately such that the appropriate loadshape (i.e. Loadshape R09 - Residential Electric Space Heat and Loadshape R08 – Residential Cooling respectively) can be applied.

---

[323] System life of indoor components as per DOE estimate (see 'Geothermal Heat Pumps Department of Energy'). The ground loop has a much longer life, but the compressor and other mechanical components are the same as an ASHP.

[324] Assumed to be one third of effective useful life

[325] Based on data provided in 'Results of HomE geothermal and air source heat pump rebate incentives documented by IL electric cooperatives'.

[326] Baseline cost per ton derived from DEER 2008 Database Technology and Measure Cost Data. See 'ASHP_Revised DEER Measure Cost Summary.xls' for calculation.

[327] Furnace and boiler costs are based on data provided in Appendix E of the Appliance Standards Technical Support Documents including equipment cost and installation labor.

[328] Based on 3 ton initial cost estimate for a conventional unit from ENERGY STAR Central AC calculator.

[329] All baseline replacement costs are consistent with their respective measures and include inflation rate of 1.91%.

[330] The baseline for calculating electric savings is an Air Source Heat Pump.

### COINCIDENCE FACTOR

The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the *average* savings over the defined summer peak period, and is presented so that savings can be bid into PJM's Forward Capacity Market.

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Heat Pumps (during utility peak hour)

= 72%%[331]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Heat Pumps (average during PJM peak period)

= 46.6%[332]

**Algorithm**

### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

New Construction and Time of Sale (non-fuel switch only):

ΔkWh = [Cooling savings] + [Heating savings] + [DHW savings]

= [FLHcool * Capacity_cooling * (1/$SEER_{base}$– 1/$EER_{PL}$)/1000] + [Elecheat * FLHheat * Capacity_heating * (1/$HSPF_{base}$ – 1/($COP_{PL}$ * 3.412))/1000] + [ElecDHW * %DHWDisplaced * ((1/$EF_{ELEC}$ * GPD * Household * 365.25 * γWater * ($T_{OUT}$ – $T_{IN}$) * 1.0) / 3412)]

New Construction and Time of Sale (fuel switch only):

If measure is supported by gas utility only, ΔkWH = 0

If measure is supported by gas and electric utility or electric utility only, electric utility claim savings calculated below:

ΔkWh = [Cooling savings] + [Heating savings from base ASHP to GSHP] + [DHW savings]

= [FLHcool * Capacity_cooling * (1/$SEER_{base}$ – 1/$EER_{PL}$)/1000] + [FLHheat * Capacity_heating * (1/$HSPF_{ASHP}$ – 1/($COP_{PL}$ * 3.412))/1000] + [ElecDHW * %DHWDisplaced * ((1/$EF_{ELEC}$ * GPD * Household * 365.25 * γWater * ($T_{OUT}$ – $T_{IN}$) * 1.0) / 3412)]

Early replacement (non-fuel switch only)[333]:

ΔkWH for remaining life of existing unit (1st 8 years):

= [Cooling savings] + [Heating savings] + [DHW savings]

= [FLHcool * Capacity_cooling * (1/SEERexist – 1/$EER_{PL}$)/1000] + [ElecHeat * FLHheat * Capacity_heating * (1/HSPFexist – 1/($COP_{PL}$ * 3.412))/1000] + [ElecDHW * %DHWDisplaced * ((1/ $EF_{ELEC}$ * GPD * Household * 365.25 * γWater * ($T_{OUT}$ – $T_{IN}$) * 1.0) / 3412)]

---

[331] Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC's 2010 system peak; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.

[332] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.

[333] The two equations are provided to show how savings are determined during the initial phase of the measure (existing to efficient) and the remaining phase (new baseline to efficient). In practice, the screening tools used may either require a First Year savings (using the first equation) and then a "number of years to adjustment" and "savings adjustment" input which would be the (new base to efficient savings)/(existing to efficient savings).

ΔkWH for remaining measure life (next 17 years):

= [FLHcool * Capacity_cooling * (1/SEERbase – 1/$EER_{PL}$)/1000] + [ElecHeat * FLHheat * Capacity_heating * (1/HSPFbase – (1/($COP_{PL}$ * 3.412))/1000] + [ElecDHW * %DHWDisplaced * ((1/ $EF_{ELEC}$ * GPD * Household * 365.25 * γWater * ($T_{OUT}$ – $T_{IN}$) * 1.0) / 3412)]

Early replacement - fuel switch only (see illustrative examples after Natural Gas section):

If measure is supported by gas utility only, ΔkWH = 0

If measure is supported by gas and electric utility or electric utility only, electric utility claim savings calculated below:

ΔkWh for remaining life of existing unit (1st 8 years):

= [Cooling savings] + [Heating savings from base ASHP to GSHP] + [DHW savings]

= [FLHcool * Capacity_cooling * (1/SEERexist – 1/$EER_{PL}$)/1000] + [FLHheat * Capacity_heating * (1/$HSPF_{ASHP}$ – 1/($COP_{PL}$ * 3.412))/1000] + [ElecDHW * %DHWDisplaced * ((1/ $EF_{ELEC}$ * GPD * Household * 365.25 * γWater * ($T_{OUT}$ – $T_{IN}$) * 1.0) / 3412)]

ΔkWh for remaining measure life (next 17 years):

= [Cooling savings] + [Heating savings from base ASHP to GSHP] + [DHW savings]

= [FLHcool * Capacity_cooling * (1/$SEER_{base}$ – 1/$EER_{PL}$)/1000] + [FLHheat * Capacity_heating * (1/$HSPF_{ASHP}$ – 1/($COP_{PL}$ * 3.412))/1000] + [ElecDHW * %DHWDisplaced * ((1/ $EF_{ELEC}$ * GPD * Household * 365.25 * γWater * ($T_{OUT}$ – $T_{IN}$) * 1.0) / 3412)]

Where:

FLHcool = Full load cooling hours

Dependent on location as below[334]:

| Climate Zone (City based upon) | FLHcool Single Family | FLHcool Multifamily | FLH_cooling (weatherized multifamily) [335] |
|---|---|---|---|
| 1 (Rockford) | 512 | 467 | 299 |
| 2 (Chicago) | 570 | 506 | 324 |
| 3 (Springfield) | 730 | 663 | 425 |
| 4 (Belleville) | 1,035 | 940 | 603 |
| 5 (Marion) | 903 | 820 | 526 |
| Weighted Average[336] | 629 | 564 | 362 |

Use Multifamily if: Building has shared HVAC or meets utility's definition for multifamily

Capacity_cooling = Cooling Capacity of Ground Source Heat Pump (Btu/hr)

= Actual (1 ton = 12,000Btu/hr)

[334] Based on Full Load Hours from ENERGY STAR with adjustments made in a Navigant Evaluation, other cities were scaled using those results and CDD. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

[335] *All-Electric Homes PY6 Metering Results: Multifamily HVAC Systems*, Cadmus, October 2015. The multifamily units within this study had undergone significant shell improvements (air sealing and insulation) and therefore this set of assumptions is only appropriate for units that have recently participated in a weatherization or other shell program. Note that the FLHcool where recalculated based on existing efficiencies consistent with the TRM rather than from the metering study.

[336] Weighted based on number of occupied residential housing units in each zone.

SEERbase = SEER Efficiency of new replacement baseline unit

| Existing Cooling System | SEERbase |
|---|---|
| Air Source Heat Pump | 14[337] |
| Central AC | 13[338] |
| No central cooling | 13[339] |

SEERexist = SEER Efficiency of existing cooling unit

= Use actual SEER rating where it is possible to measure or reasonably estimate, if unknown assume default provided below:

| Existing Cooling System | SEER_exist |
|---|---|
| Air Source Heat Pump | 9.3[340] |
| Ground Source Heat Pump | 10[341] |
| Central AC | 9.3[342] |
| No central cooling | 13 [343] |

$SEER_{ASHP}$ = SEER Efficiency of new baseline Air Source Heat Pump unit (for fuel switch)

= 14 [344]

$EER_{PL}$ = Part Load EER Efficiency of efficient GSHP unit[345]

= Actual installed

ElecHeat = 1 if existing building is electrically heated

= 0 if existing building is not electrically heated

FLHheat = Full load heating hours

Dependent on location as below[346]:

| Climate Zone (City based upon) | FLH_heat |
|---|---|
| 1 (Rockford) | 1,969 |
| 2 (Chicago) | 1,840 |
| 3 (Springfield) | 1,754 |
| 4 (Belleville) | 1,266 |

337 Minimum Federal Standard as of 1/1/2015

338 Minimum Federal Standard; Federal Register, Vol. 66, No. 14, Monday, January 22, 2001/Rules and Regulations, p. 7170-7200.

339 Assumes that the decision to replace existing systems includes desire to add cooling.

340 Based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study Memo FINAL 2_28_2018'

341 Estimate of existing GSHP efficiency is based upon assumptions used by ICF in Missouri. It is recommended that this value be evaluated and adjusted for a future version.

342 Based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study Memo FINAL 2_28_2018'

343 Assumes that the decision to replace existing systems includes desire to add cooling.

344 Minimum Federal Standard as of 1/1/2015.

345 As per conversations with David Buss territory manager for Connor Co, the SEER and COP ratings of an ASHP equate most appropriately with the part load EER and COP of a GSHP.

346 Heating EFLH based on ENERGY STAR EFLH for Rockford, Chicago, and Springfield and on NCDC/NOAA HDD for the other two cities. In all cases, the hours were adjusted based on average natural gas heating consumption in IL. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

| Climate Zone (City based upon) | FLH_heat |
|---|---|
| 5 (Marion) | 1,288 |
| Weighted Average[347] | 1,821 |

Capacity_heating = Heating Capacity of Ground Source Heat Pump (Btu/hr)

= Actual (1 ton = 12,000Btu/hr)

$HSPF_{base}$ =Heating System Performance Factor of new replacement baseline heating system (kBtu/kWh)

| Existing Heating System | HSPF_base |
|---|---|
| Air Source Heat Pump | 8.2 |
| Electric Resistance | 3.41[348] |

HSPF_exist =Heating System Performance Factor of existing heating system (kBtu/kWh)

= Use actual HSPF rating where it is possible to measure or reasonably estimate. If unknown assume default:

| Existing Heating System | HSPF_exist |
|---|---|
| Air Source Heat Pump | 5.54[349] |
| Ground Source Heat Pump | 8.2[350] |
| Electric Resistance | 3.41 |

$HSPF_{ASHP}$ =Heating Season Performance Factor for new ASHP baseline unit (for fuel switch)

=8.2 [351]

$COP_{PL}$ = Part Load Coefficient of Performance of efficient unit[352]

= Actual Installed

3.412 = Constant to convert the COP of the unit to the Heating Season Performance Factor (HSPF).

ElecDHW = 1 if existing DHW is electrically heated

= 0 if existing DHW is not electrically heated

%DHWDisplaced = Percentage of total DHW load that the GSHP will provide

= Actual if known

= If unknown and if desuperheater installed assume 44%[353]

[347] Weighted based on number of occupied residential housing units in each zone.
[348] Electric resistance has a COP of 1.0 which equals 1/0.293 = 3.41 HSPF.
[349] Based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study Memo FINAL 2_28_2018'
[350] Estimate of existing GSHP efficiency is assumed equivalent to a new baseline ASHP. It is recommended that this value be evaluated and adjusted for a future version.
[351] Minimum Federal Standard as of 1/1/2015
[352] As per conversations with David Buss territory manager for Connor Co, the SEER and COP ratings of an ASHP equate most appropriately with the part load EER and COP of a GSHP.
[353] Assumes that the desuperheater can provide two thirds of hot water needs for eight months of the year (2/3 * 2/3 = 44%). Based on input from Doug Dougherty, Geothermal Exchange Organization.

= 0% if no desuperheater installed

$EF_{ELEC}$ = Energy Factor (efficiency) of electric water heater

= Actual. If unknown or for new construction assume federal standard[354]:

For <=55 gallons: 0.96 – (0.0003 * rated volume in gallons)

For >55 gallons: 2.057 – (0.00113 * rated volume in gallons)

GPD = Gallons Per Day of hot water use per person

= 45.5 gallons hot water per day per household/2.59 people per household[355]

= 17.6

Household = Average number of people per household

| Household Unit Type | Household |
|---|---|
| Single-Family - Deemed | 2.56[356] |
| Multifamily - Deemed | 2.1[357] |
| Custom | Actual Occupancy or Number of Bedrooms[358] |

Use Multifamily if: Building meets utility's definition for multifamily

365.25 = Days per year

γWater = Specific weight of water

= 8.33 pounds per gallon

$T_{OUT}$ = Tank temperature

= 125°F

$T_{IN}$ = Incoming water temperature from well or municiplal system

= 54°F[359]

1.0 = Heat Capacity of water (1 Btu/lb*°F)

3412 = Conversion from Btu to kWh

[354] Minimum Federal Standard as of 4/1/2015;.

[355] Deoreo, B., and P. Mayer. Residential End Uses of Water Study Update. Forthcoming. ©2015 Water Research Foundation. Reprinted With Permission.

[356] ComEd Energy Efficiency/ Demand Response Plan: Plan Year 2 (6/1/2009-5/31/2010) Evaluation Report: All Electric Single Family Home Energy Performance Tune-Up Program citing 2006-2008 American Community Survey data from the US Census Bureau for Illinois cited on p. 17 of the PY2 Evaluation report. 2.75 * 93% evaluation adjustment

[357] ComEd PY3 Multifamily Evaluation Report REVISED DRAFT v5 2011-12-08.docx

[358] Bedrooms are suitable proxies for household occupancy, and may be preferable to actual occupancy due to turnover rates in residency and non-adult population impacts.

[359] US DOE Building America Program. Building America Analysis Spreadsheet.

Illustrative Examples

New Construction using ASHP baseline:

For example, a 3 ton unit with Part Load EER rating of 19 and Part Load COP of 4.4 with desuperheater is installed with a 50 gallon electric water heater in single family house in Springfield:

ΔkWh = [FLHcool * Capacity_cooling * (1/$SEER_{base}$ – 1/$EER_{PL}$)/1000] + [FLHheat * Capacity_heating * (1/HSPFbase – 1/($COP_{PL}$ * 3.412))/1000] + [ElecDHW * %DHWDisplaced * ((1/ $EF_{ELEC\ EXIST}$ * GPD * Household * 365.25 * γWater * ($T_{OUT}$ – $T_{IN}$) * 1.0) / 3412)]

ΔkWh = [730 * 36,000 * (1/14 – 1/19) / 1000] + [1754* 36,000 * (1/8.2 – 1/(4.4*3.412)) / 1000] + [1 * 0.44 * ((1/0.945 * 17.6 * 2.56 *365.25 * 8.33 * (125-54) * 1)/3412)]

= 494 + 3494 + 1328

= 5316 kWh

Early Replacement – non-fuel switch (see example after Natural gas section for Fuel switch):

For example, a 3 ton unit with Part Load EER rating of 19 and Part Load COP of 4.4 with desuperheater is installed in single family house in Springfield with a 50 gallon electric water heater replacing an existing working Air Source Heat Pump with unknown efficiency ratings:

ΔkWH for remaining life of existing unit (1st 8 years):

= [730 * 36,000 * (1/9.3 - 1/19) / 1000] + [1754 * 36,000 * (1/5.54 - 1/(4.4 * 3.412)) / 1000] + [0.44 * 1 * ((1/0.945 * 17.6 * 2.56 *365.25 * 8.33 * (125-54) * 1)/3412)]

= 1443 + 7191 + 1328

= 9,963 kWh

ΔkWH for remaining measure life (next 17 years):

= (730 * 36,000 * (1/14 – 1/28) / 1000] + [1967 * 36,000 * (1/8.2 – 1/ (4.4 * 3.412)) / 1000] + [0.44 * 1 * ((1/0.945 * 17.6 * 2.56 *365.25 * 8.33 * (125-54) * 1)/3412)]

= 494 + 3494 + 1328

= 5316 kWh

#### SUMMER COINCIDENT PEAK DEMAND SAVINGS

New Construction and Time of Sale:

ΔkW = (Capacity_cooling * (1/EERbase - 1/$EER_{FL}$))/1000 * CF

Early replacement:

ΔkW for remaining life of existing unit (1st 8 years):

= (Capacity_cooling * (1/EERexist - 1/$EER_{FL}$))/1000 * CF

ΔkW for remaining measure life (next 17 years):

= (Capacity_cooling * (1/EERbase - 1/$EER_{FL}$))/1000 * CF

Where:

EERbase = EER Efficiency of new replacement unit

| Existing Cooling System | EER_base |
|---|---|
| Air Source Heat Pump | 11.8[360] |

[360] The Federal Standard does not include an EER requirement, so it is approximated with the conversion formula from Wassmer, M. 2003 thesis referenced below.

| Existing Cooling System | EER_base |
|---|---|
| Central AC | 11 [361] |
| No central cooling | 11[362] |

EERexist = Energy Efficiency Ratio of existing cooling unit (kBtu/hr / kW)

= Use actual EER rating where it is possible to measure or reasonably estimate. If EER unknown but SEER available convert using the equation:

$EERexist = (-0.02 * SEERexist^2) + (1.12 * SEERexist)$ [363]

If SEER rating unavailable use:

| Existing Cooling System | EER_exist |
|---|---|
| Air Source Heat Pump | 7.5[364] |
| Ground Source Heat Pump | 11[366] |
| Central AC | 7.5[367] |
| No central cooling | 11 [368] |

$EER_{FL}$ = Full Load EER Efficiency of ENERGY STAR GSHP unit [369]

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)

= 72%%[370]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Central A/C (average during peak period)

= 46.6%[371]

361 Minimum Federal Standard; Federal Register, Vol. 66, No. 14, Monday, January 22, 2001/Rules and Regulations, p. 7170-7200.

362 Assumes that the decision to replace existing systems includes desire to add cooling.

363 From Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder.

364 Based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study Memo FINAL 2_28_2018'.

366 Assumed equal to ASHP.

367 Based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study Memo FINAL 2_28_2018'.

368 Assumes that the decision to replace existing systems includes desire to add cooling.

369 As per conversations with David Buss territory manager for Connor Co, the EER rating of an ASHP equate most appropriately with the full load EER of a GSHP.

370 Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC's 2010 system peak; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.

371 Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.

New Construction or Time of Sale:

For example, a 3 ton unit with Full Load EER rating of 19:

$\Delta kW_{SSP}$ = (36,000 * (1/11.8 – 1/19))/1000 * 0.72

= 0.83 kW

$\Delta kW_{PJM}$ = (36,000 * (1/11 – 1/19))/1000 * 0.466

= 0.54 kW

Early Replacement:

For example, a 3 ton Full Load 19 EER replaces an existing working Air Source Heat Pump with unknown efficiency ratings in Marion:

$\Delta kW_{SSP}$ for remaining life of existing unit (1st 8 years):

= (36,000 * (1/7.5 – 1/19))/1000 * 0.72

= 2.09 kW

$\Delta kW_{SSP}$ for remaining measure life (next 17 years):

= (36,000 * (1/11.8 – 1/19))/1000 * 0.72

= 0.83 kW

$\Delta kW_{PJM}$ for remaining life of existing unit (1st 8 years):

= (36,000 * (1/7.5 – 1/19))/1000 * 0.466

= 1.35 kW

$\Delta kW_{PJM}$ for remaining measure life (next 17 years):

= (36,000 * (1/11.8 – 1/19))/1000 * 0.466

= 0.54 kW

**NATURAL GAS SAVINGS**

New Construction and Time of Sale with baseline gas heat and/or hot water:

If measure is supported by gas utility only, gas utility claim savings calculated below:

ΔTherms = [Heating Savings] + [DHW Savings]

= [Replaced gas consumption – therm equivalent of GSHP source kWh] + [DHW Savings]

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEbase) – (kWhtoTherm * FLHheat * Capacity_heating * 1/($COP_{PL}$ * 3.412))/1000)] + [(1 – ElecDHW) * %DHWDisplaced * (1/ $EF_{GAS\ EXIST}$ * GPD * Household * 365.25 * γWater * ($T_{OUT}$ – $T_{IN}$) * 1.0) / 100,000)]

If measure is supported by electric utility only, ΔTherms = 0

If measure is supported by gas and electric utility, gas utility claim savings calculated below, (electric savings is provided in Electric Energy Savings section):

ΔTherms = [Heating Savings] + [DHW Savings]

= [Replaced gas consumption – therm equivalent of base ASHP source kWh] + [DHW Savings]

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEbase) – (kWhtoTherm * FLHheat * Capacity_heating * 1/$HSPF_{ASHP}$)/1000)] + [(1 – ElecDHW) * %DHWDisplaced * (1/ $EF_{GAS\ EXIST}$ * GPD * Household * 365.25 * γWater * ($T_{OUT}$ – $T_{IN}$) * 1.0) / 100,000)]

Early replacement for homes with existing gas heat and/or hot water:

If measure is supported by gas utility only, gas utility claim savings calculated below:

ΔTherms for remaining life of existing unit (1st 8 years):

= [Heating Savings] + [DHW Savings]

= [Replaced gas consumption – therm equivalent of GSHP source kWh] + [DHW Savings]

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEexist) – (kWhtoTherm * FLHheat * Capacity_heating * 1/($COP_{PL}$ * 3.412))/1000)] + [(1 – ElecDHW) * %DHWDisplaced * (1/ $EF_{GAS\ EXIST}$ * GPD * Household * 365.25 * γWater * ($T_{OUT}$ – $T_{IN}$) * 1.0) / 100,000)]

ΔTherms for remaining measure life (next 17 years):

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEbaseER) – (kWhtoTherm * FLHheat * Capacity_heating * 1/($COP_{PL}$ * 3.412))/1000)] + [(1 – ElecDHW) * %DHWDisplaced * (1/ $EF_{GAS\ EXIST}$ * GPD * Household * 365.25 * γWater * ($T_{OUT}$ – $T_{IN}$) * 1.0) / 100,000)]

If measure is supported by electric utility only, ΔTherms = 0

If measure is supported by gas and electric utility, gas utility claim savings calculated below:

ΔTherms for remaining life of existing unit (1st 8 years):

ΔTherms = [Heating Savings] + [DHW Savings]

= [Replaced gas consumption – therm equivalent of base ASHP source kWh] + [DHW Savings]

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEexist) – (kWhtoTherm * FLHheat * Capacity_heating * 1/$HSPF_{ASHP}$)/1000)] + [(1 – ElecDHW) * %DHWDisplaced * (1/ $EF_{GAS\ EXIST}$ * GPD * Household * 365.25 * γWater * ($T_{OUT}$ – $T_{IN}$) * 1.0) / 100,000)]

ΔTherms for remaining measure life (next 17 years):

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEbaseER) – (kWhtoTherm * FLHheat * Capacity_heating * 1/$HSPF_{ASHP}$)/1000)] + [(1 – ElecDHW) * %DHWDisplaced * (1/ $EF_{GAS\ EXIST}$ * GPD * Household * 365.25 * γWater * ($T_{OUT}$ – $T_{IN}$) * 1.0) / 100,000)]

Where:

ElecHeat = 1 if existing building is electrically heated

= 0 if existing building is not electrically heated

Gas_Heating_Load

= Estimate of annual household heating load [372] for gas furnace heated single-family homes. If location is unknown, assume the average below.

= Actual if informed by site-specific load calculations, ACCA Manual J or equivalent[373].

[372] Heating load is used to describe the household heating need, which is equal to (gas consumption * AFUE )
[373] The Air Conditioning Contractors of America Manual J, Residential Load Calculation 8th Edition produces equipment sizing loads for Single Family, Multi-single, and Condominiums using input characteristics of the home. A best practice for equipment selection and installation of Heating and Air Conditioning, load calculations are commonly completed by contractors during the selection process and may be readily available for program data purposes.

| Climate Zone (City based upon) | Gas_Heating_Load if Furnace (therms) [374] | Gas_Heating_Load if Boiler (therms) [375] |
|---|---|---|
| 1 (Rockford) | 873 | 1275 |
| 2 (Chicago) | 834 | 1218 |
| 3 (Springfield) | 714 | 1043 |
| 4 (Belleville) | 551 | 805 |
| 5 (Marion) | 561 | 819 |
| Average | 793 | 1158 |

AFUEbase = Baseline Annual Fuel Utilization Efficiency Rating

= 80% if furnace and 82% if boiler.

AFUEexist = Existing Annual Fuel Utilization Efficiency Rating

= Use actual AFUE rating where it is possible to measure or reasonably estimate.

If unknown, assume 64.4% if furnace and 61.6% [376] if boiler.

AFUEbaseER = Baseline Annual Fuel Utilization Efficiency Rating for early replacement measure

= 90%[377] if furnace and 82% if boiler.

kWhtoTherm = Converts source kWh to Therms

= $H_{grid}$ / 100000

$H_{grid}$ = Heat rate of the grid in btu/kWh based on the average fossil heat rate for the EPA eGRID subregion and includes a factor that takes into account T&D losses.

For systems operating less than 6,500 hrs per year:

Use the Non-baseload heat rate provided by EPA eGRID for RFC West region for ComEd territory (including independent providers connected to RFC West), and SERC Midwest region for Ameren territory (including independent providers connected to SERC Midwest)[378]. Also include any line losses.

For systems operating more than 6,500 hrs per year:

Use the All Fossil Average heat rate provided by EPA eGRID for RFC West region for ComEd territory, and SERC Midwest region for Ameren territory. Also include

374 Values are based on household heating consumption values and inferred average AFUE results from Table 2-1, *Energy Efficiency / Demand Response Nicor Gas Plan Year 1 (6/1/2011-5/31/2012) Research Report: Furnace Metering Study* (August 1, 2013) (prepared by Navigant Consulting, Inc.) and adjusting to a statewide average using relative HDD values to adjust for the evaluation results focus on northern region. Values for individual cities are then calculated by comparing average HDD to the individual city's HDD.

375 Boiler consumption values are informed by an evaluation which did not identify any fraction of heating load due to domestic hot water (DHW) provided by the boiler. Thus these values are an average of both homes with boilers only providing heat, and homes with boilers that also provide DHW. Values are based on household heating consumption values and inferred average AFUE results from Table 3-4, Program Sample Analysis, *Nicor R29 Res Rebate Evaluation Report 092611_REV FINAL to Nicor*). Adjusting to a statewide average using relative HDD values to adjust for the evaluation results focus on northern region. Values for individual cities are then calculated by comparing average HDD to the individual city's HDD.

376 Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren PY3-PY4.

377 Assumes that Federal Standard will have been increased to 90% by the time the existing unit would have to have been replaced.

378 Refer to the latest EPA eGRID data. Current values, based on eGrid 2016 are:

- Non-Baseload RFC West: 10,539 Btu/kWh * (1 + Line Losses)
- Non-Baseload SERC Midwest: 9,968 Btu/kWh * (1 + Line Losses)
- All Fossil Average RFC West: 9,962 Btu/kWh * (1 + Line Losses)
- All Fossil Average SERC Midwest: 9,996 Btu/kWh * (1 + Line Losses)

any line losses.

3.412 = Converts COP to HSPF

$EF_{GAS\ EXIST}$ = Energy Factor (efficiency) of existing gas water heater

= Actual. If unknown assume federal standard[379]:

For <=55 gallons: 0.6483 – (0.0017 * storage capacity in gallons)

For > 55 gallons 0.7897 – (0.0004 * storage capacity in gallons)

= If tank size unknown assume 40 gallons and EF_Baseline of 0.58

All other variables provided above

Illustrative Examples *[for illustrative purposes a Heat Rate of 10,000 Btu/kWh is used]*

New construction using gas furnace and central AC baseline, *supported by Gas utility only*:

For example, a 3 ton unit with Part Load EER rating of 19 and Part Load COP of 4.4 in single family house in Springfield with a 40 gallon gas water heater is installed in place of a natural gas furnace and 3 ton Central AC unit:

ΔkWH = 0

ΔTherms = [Heating Savings] + [DHW Savings]

= [Replaced gas consumption – therm equivalent of GSHP source kWh] + [DHW Savings]

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEbase) – (kWhtoTherm * FLHheat * Capacity_heating * 1/($COP_{PL}$ * 3.412)/1000)] + [(1 – ElecDHW) * %DHWDisplaced * (1/ $EF_{GAS\ EXIST}$ * GPD * Household * 365.25 * γWater * ($T_{OUT}$ – $T_{IN}$) * 1.0) / 100,067)]

= [(1-0) * ((714/0.80) – (10000/100000 * 1754 * 36,000 * 1/(4.4 * 3.412))/1000)] + [(1 – 0) * (0.44 * (1/ 0.58 * 17.6 * 2.56 *365.25 * 8.33 * (125-54) * 1) / 100,067)]

= 472 + 74

= 546 therms

Early Replacement fuel switch, *supported by gas and electric utility*:

For example, a 3 ton unit with Part Load EER rating of 19 and Part Load COP of 4.4 in single family house in Springfield with a 40 gallon gas water heater replaces an existing working natural gas furnace and 3 ton Central AC unit with unknown efficiency ratings:

ΔkWh for remaining life of existing unit (1st 8 years):

= [Cooling savings] + [Heating savings from base ASHP to GSHP] + [DHW savings]

= [(FLHcool * Capacity_cooling * (1/SEERexist – (1/$EER_{PL}$)/1000] + [(FLHheat * Capacity_heating * (1/$HSPF_{ASHP}$ – (1/$COP_{PL}$ * 3.412)))/1000] + [ElecDHW * %DHWDisplaced * (((1/ $EF_{ELEC}$) * GPD * Household * 365.25 * γWater * ($T_{OUT}$ – $T_{IN}$) * 1.0) / 3412)]

= [(730* 36,000 * (1/8.6 - 1/19)) / 1000] + [(1754 * 36,000 * (1/8.2 - 1/(4.4 * 3.412))) / 1000] + [0 * 0.44 * (((1/0.904) * 17.6 * 2.56 *365.25 * 8.33 * (125-54) * 1)/3412)]

= 1673 + 3494 + 0

= 5167 kWh

Continued on next page.

[379] Minimum Federal Standard as of 4/1/2015.

Illustrative Example continued

ΔkWh for remaining measure life (next 17 years):

= [Cooling savings] + [Heating savings] + [DHW savings]

= [(FLHcool * Capacity_cooling * (1/$SEER_{base}$ – (1/$EER_{PL}$)/1000] + [(FLHheat * Capacity_heating * (1/$HSPF_{ASHP}$ – (1/$COP_{PL}$ * 3.412)))/1000] + [ElecDHW * %DHWDisplaced * (((1/ $EF_{ELEC}$) * GPD * Household * 365.25 * γWater * ($T_{OUT}$ – $T_{IN}$) * 1.0) /3412)]

= [(730 * 36,000 * (1/13 – 1/19)) / 1000] + [1754 * 36,000 * (1/8.2 – 1/ (4.4 *3.412)) / 1000] + [0 * 0.44 * (((1/0.904) * 17.6 * 2.56 *365.25 * 8.33 * (125-54) *1)/3412)]

= 638 + 3494 + 0

= 4132 kWh

ΔTherms for remaining life of existing unit (1st 8 years):

= [Heating Savings] + [DHW Savings]

= [Replaced gas consumption – therm equivalent of base ASHP source kWh] + [DHW Savings]

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEexist) – (kWhtoTherm * FLHheat * Capacity_heating * 1/$HSPF_{ASHP}$)/1000)] + [(1 – ElecDHW) * %DHWDisplaced * (1/ $EF_{GAS\ EXIST}$ * GPD * Household * 365.25 * γWater * ($T_{OUT}$ – $T_{IN}$) * 1.0) / 100,000)]

= [(1-0) * ((714/0.644) – (10000/100000 * 1754 * 36,000 * 1/8.2)/1000)] + [(1 – 0) * (0.44 * (1/ 0.58 * 17.6 * 2.56 *365.25 * 8.33 * (125-54) * 1) / 100,000)]

= 339 + 74

= 412 therms

ΔTherms for remaining measure life (next 17 years):

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEbaseER) – (kWhtoTherm * FLHheat * Capacity_heating * 1/$HSPF_{ASHP}$)/1000)] + [(1 – ElecDHW) * %DHWDisplaced * (1/ $EF_{GAS\ EXIST}$ * GPD * Household * 365.25 * γWater * ($T_{OUT}$ – $T_{IN}$) * 1.0) / 100,000)]

= [(1-0) * ((714/0.9) – (10000/100000 * 1754 * 36,000 * 1/8.2)/1000)] + [(1 – 0) * (0.44 * (1/ 0.58 * 17.6 * 2.56 *365.25 * 8.33 * (125-54) * 1) / 100,000)]

= 23 + 74

= 97 therms

## WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

## DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

## COST EFFECTIVENESS SCREENING AND LOAD REDUCTION FORECASTING WHEN FUEL SWITCHING

This measure can involve fuel switching from gas to electric.

For the purposes of forecasting load reductions due to fuel switch GSHP projects per Section 16-111.5B, changes in site energy use at the customer's meter (using ΔkWh algorithm below) adjusted for utility line losses (at-the-busbar savings), customer switching estimates, NTG, and any other adjustment factors deemed appropriate, should be used.

The inputs to cost effectiveness screening should reflect the actual impacts on the electric and fuel consumption at the customer meter and, for fuel switching measures, this will not match the output of the calculation/allocation methodology presented in the "Electric Energy Savings" and "Natural Gas Savings" sections above. Therefore in addition to the calculation of savings claimed, the following values should be used to assess the cost effectiveness of the measure.

ΔTherms = [Heating Consumption Replaced[380]] + [DHW Savings if gas]

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEbase)] + [(1 – ElecDHW) * %DHWDisplaced * (1/ $EF_{GAS\ EXIST}$ * GPD * Household * 365.25 * γWater * ($T_{OUT}$ – $T_{IN}$) * 1.0) / 100,000)]

ΔkWh = - [GSHP heating consumption] + [Cooling savings[381]] + [DHW savings if electric]

= - [(FLHheat * Capacity_heating * (1/$COP_{PL}$ * 3.412))/1000] + [(FLHcool * Capacity_cooling * (1/SEERbase - 1/$EER_{PL}$))/1000] + [ElecDHW * %DHWDisplaced * ((1/$EF_{ELEC}$ * GPD * Household * 365.25 * γWater * ($T_{OUT}$ – $T_{IN}$) * 1.0) / 3412)]

Illustrative Example of Cost Effectiveness Inputs for Fuel Switching

For example, a 3 ton unit with Part Load EER rating of 19 and Part Load COP of 4.4 in single family house in Springfield with a 40 gallon gas water heater replaces an existing working natural gas furnace and 3 ton Central AC unit with unknown efficiency ratings. [Note the calculation provides the annual savings for the first 8 years of the measure life, an additional calculation (not shown) would be required to calculated the annual savings for the remaining life (years 9-25)]:

ΔTherms = [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEexist)] + [(1 – ElecDHW) * %DHWDisplaced * (1/ $EF_{GAS\ EXIST}$ * GPD * Household * 365.25 * γWater * ($T_{OUT}$ – $T_{IN}$) * 1.0) / 100,067)]

= [(1-0) * (714/0.644)] + [((1 – 0) * 0.44 * (1/ 0.58 * 17.6 * 2.56 *365.25 * 8.33 * (125-54) * 1) / 100,0067)]

= 1109 + 74

= 1183 therms

ΔkWh = - [(FLHheat * Capacity_heating * (1/$COP_{PL}$ * 3.412))/1000] + [(FLHcool * Capacity_cooling * (1/SEERexist - 1/$EER_{PL}$))/1000] + [ElecDHW * %DHWDisplaced * (((1/$EF_{ELEC}$) * GPD * Household * 365.25 * γWater * ($T_{OUT}$ – $T_{IN}$) * 1.0) / 3412)]

= - [(1754 * 36,000 * (1/(4.4 * 3.412)))/ 1000] + [(730 * 36,000 * (1/9.3 - 1/19))/ 1000)] + [0 * 0.44 * (((1/0.904) * 17.6 * 2.56 *365.25 * 8.33 * (125-54) * 1)/3412)]

= -4206 + 1443 + 0

= -2763 kWh

**MEASURE CODE: RS-HVC-GSHP-V08-190101**

**REVIEW DEADLINE: 1/1/2023**

380 Note AFUEbase in the algorithm should be replaced with AFUEexist for early replacement measures.

381 Note SEERbase in the algorithm should be replaced with SEERexist for early replacement measures.

## 5.3.9 High Efficiency Bathroom Exhaust Fan

### DESCRIPTION

This market opportunity measure is split in to the purchase of a new bathroom fan for typical usage, and to meet the need for continuous mechanical ventilation due to reduced air-infiltration from a tighter building shell. In retrofit projects, existing fans may be too loud, or insufficient in other ways, to be operated as required for proper ventilation. This measure assumes fan capacities between 10 and 200 CFM rated at a sound level of less than 2.0 sones at 0.1 inches of water column static pressure, or 50 CFM if used for continuous ventilation. All eligible installations shall be sized to provide the mechanical ventilation rate indicated by ASHRAE 62.2.

This measure was developed to be applicable to the following program types: TOS, NC, RF.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

New efficient ENERGY STAR or ENERGY STAR Most Efficient exhaust-only ventilation fan, quiet (< 2.0 sones) operating in accordance with recommended ventilation rate indicated by ASHRAE 62.2 - 2016[382]. ENERGY STAR specifications (effective October 1 2015) and 2018 Most Efficient specifications are provided below:

| Efficiency Level | Fan Capacity | Minimum Efficacy Level (CFM/Watts) | Maximum Allowable Sound Level (sones) |
|---|---|---|---|
| ENERGY STAR | 10 – 89 CFM | 2.8 | 2.0 |
| | 90 – 200 CFM | 3.5 | |
| ENERGY STAR Most Efficient | All | 10 | |

### DEFINITION OF BASELINE EQUIPMENT

New standard efficiency exhaust-only ventilation fan.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 19 years[383].

### DEEMED MEASURE COST

Incremental cost per installed fan is $43.50 for quiet, efficient fans[384].

### LOADSHAPE

Loadshape R11 - Residential Ventilation

### COINCIDENCE FACTOR

The summer Peak Coincidence Factor is assumed to be 100% because the fan runs continuously.

---

[382] Bi-level controls may be used by efficient fans larger than 50 CFM

[383] Conservative estimate based upon GDS Associates Measure Life Report "Residential and C&I Lighting and HVAC measures" 25 years for whole-house fans, and 19 for thermostatically-controlled attic fans.

[384] VEIC analysis using cost data collected from wholesale vendor.

**Algorithm**

## CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

$$\Delta kWh = (CFM * (1/\eta_{,BASELINE} - 1/\eta_{EFFICIENT})/1000) * Hours$$

Where:

CFM = Nominal Capacity of the exhaust fan

= Actual or use defaults provided below

= Assume 50CFM for continuous ventilation[385]

$\eta_{BASELINE}$ = Average efficacy for baseline fan (CFM/watts)

= See table below

$\eta_{EFFCIENT}$ = Average efficacy for efficient fan (CFM/watts)

= Actual or use defaults provided below

Hours = assumed annual run hours,

= 1089 for standard usage[386]

= 8766 for continuous ventilation.

Defaults provided below[387]:

| | | | | | ENERGY STAR | | ENERGY STAR Most Efficient | |
|---|---|---|---|---|---|---|---|---|
| Application | Min CFM | Max CFM | Average CFM | Base CFM/Watts | CFM/Watts | ΔkWh Savings | CFM/Watts | ΔkWh Savings |
| Standard usage | 10 | 89 | 70.6 | 1.7 | 4.9 | 28.9 | 12.0 | 38.2 |
| | 90 | 200 | 116.1 | 2.6 | 5.6 | 25.3 | 13.9 | 38.7 |
| | Unknown | | 92.4 | 2.2 | 5.3 | 27.4 | 12.9 | 38.6 |
| Continuous usage | N/A | | 50 | 1.7 | 5.1 | 170.7 | 11.2 | 216.9 |

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = (CFM * (1/\eta_{BASELINE} - 1/_{EFFICIENT})/1000) * CF$$

Where:

CF = Summer Peak Coincidence Factor

= 0.135 for standard usage

= 1.0 for continuous operation

Other variables as defined above

385 50CFM is the closest available fan size to ASHRAE 62.2 Section 4.1 Whole House Ventilation rates based upon typical square footage and bedrooms.

386 Assumed to be consistent with Residential Indoor Lighting hours of use.

387 Based on review of Bathroom Exhaust Fan product available on CEC Appliance Database, accessed 6/18/2018. See 'CEC Bath Fan.xls' for more information.

| Application | Min CFM | Max CFM | Average CFM | ENERGY STAR ΔkW Savings | ENERGY STAR Most Efficient ΔkW Savings |
|---|---|---|---|---|---|
| Standard usage | 10 | 89 | 70.6 | 0.0036 | 0.0047 |
| | 90 | 200 | 116.1 | 0.0031 | 0.0048 |
| | Unknown | | 92.4 | 0.0034 | 0.0048 |
| Continuous usage | N/A | | 50 | 0.0195 | 0.0247 |

**NATURAL GAS SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-HVC-BAFA-V02-190101**

**REVIEW DEADLINE: 1/1/2024**

## 5.3.10 HVAC Tune Up (Central Air Conditioning or Air Source Heat Pump)

### Description

This measure involves the measurement of refrigerant charge levels and airflow over the central air conditioning or heat pump unit coil, correction of any problems found and post-treatment re-measurement. Measurements must be performed with standard industry tools and the results tracked by the efficiency program.

Savings from this measure are developed using a reputable Wisconsin study. It is recommended that future evaluation be conducted in Illinois to generate a more locally appropriate characterization.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

N/A

### Definition of Baseline Equipment

This measure assumes that the existing unit being maintained is either a residential central air conditioning unit or an air source heat pump that has not been serviced for at least 3 years.

### Deemed Lifetime of Efficient Equipment

The measure life is assumed to be 2 years[388].

### Deemed Measure Cost

If the implementation mechanism involves delivering and paying for the tune up service, the actual cost should be used. If however the customer is provided a rebate and the program relies on private contractors performing the work, the measure cost should be assumed to be $175[389].

### Loadshape

Loadshape R08 - Residential Cooling

### Coincidence Factor

The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the *average* savings over the defined summer peak period, and is presented so that savings can be bid into PJM's Forward Capacity Market.

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Central A/C (during utility peak hour)

= 68%[390]

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

= 72%%[391]

---

388 Based on VEIC professional judgment.

389 Based on personal communication with HVAC efficiency program consultant Buck Taylor or Roltay Inc., 6/21/10, who estimated the cost of tune up at $125 to $225, depending on the market and the implementation details.

390 Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

391 Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC's 2010 system peak; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period)

= 46.6%[392]

**Algorithm**

## CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

$\Delta kWh_{Central\ AC}$ = (FLHcool * Capacity_cooling* (1/$SEER_{CAC}$))/1000 * MFe

$\Delta kWh_{Air\ Source\ Heat\ Pump}$ = ((FLHcool * Capacity_cooling * (1/$SEER_{ASHP}$))/1000 * MFe) + (FLHheat * Capacity_heating * (1/$HSPF_{ASHP}$))/1000 * MFe)

Where:

FLHcool = Full load cooling hours

Dependent on location as below:[393]

| Climate Zone (City based upon) | FLHcool Single Family | FLHcool Multifamily |
|---|---|---|
| 1 (Rockford) | 512 | 467 |
| 2 (Chicago) | 570 | 506 |
| 3 (Springfield) | 730 | 663 |
| 4 (Belleville) | 1,035 | 940 |
| 5 (Marion) | 903 | 820 |
| Weighted Average[394] | 629 | 564 |

Use Multifamily if: Building has shared HVAC or meets utility's definition for multifamily

Capacity_cooling = Cooling cpacity of equipment in Btu/hr (note 1 ton = 12,000 Btu/hr)

= Actual

$SEER_{CAC}$ = SEER Efficiency of existing central air conditioning unit receiving maintenence

= Actual. If unknown assume 10 SEER [395]

MFe = Maintenance energy savings factor

= 0.05[396]

$SEER_{ASHP}$ = SEER Efficiency of existing air source heat pump unit receiving maintenence

= Actual. If unknown assume 10 SEER [397]

FLHheat = Full load heating hours

[392] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.
[393] Based on Full Load Hours from ENERGY STAR with adjustments made in a Navigant Evaluation, other cities were scaled using those results and CDD. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.
[394] Weighted based on number of occupied residential housing units in each zone.
[395] Use actual SEER rating where it is possible to measure or reasonably estimate. Unknown default of 10 SEER is a VEIC estimate of existing unit efficiency, based on minimum federal standard between the years of 1992 and 2006.
[396] Energy Center of Wisconsin, May 2008; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research."
[397] Use actual SEER rating where it is possible to measure or reasonably estimate. Unknown default of 10 SEER is a VEIC estimate of existing unit efficiency, based on minimum federal standard between the years of 1992 and 2006.

Dependent on location:[398]

| Climate Zone (City based upon) | FLHheat |
|---|---|
| 1 (Rockford) | 2208 |
| 2 (Chicago) | 2064 |
| 3 (Springfield) | 1967 |
| 4 (Belleville) | 1420 |
| 5 (Marion) | 1445 |
| Weighted Average[399] | 1821 |

Capacity_heating = Heating cpacity of equipment in Btu/hr (note 1 ton = 12,000 Btu/hr)

= Actual

$HSPF_{ASHP}$ = Heating Season Performance Factor of existing air source heat pump unit receiving maintenence

= Actual. If unknown assume 6.8 HSPF [400]

For example, maintenance of a 3-ton, SEER 10 air conditioning unit in a single family house in Springfield:

$\Delta kWh_{CAC}$ = (730 * 36,000 * (1/10))/1000 * 0.05

= 131 kWh

For example, maintenance of a 3-ton, SEER 10, HSPF 6.8 air source heat pump unit in a single family house in Springfield:

$\Delta kWh_{ASHP}$ = ((730 * 36,000 * (1/10))/1000 * 0.05) + (1967 * 36,000 * (1/6.8))/1000 * 0.05)

= 652 kWh

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = Capacity_cooling * (1/EER)/1000 * MFd * CF

Where:

EER = EER Efficiency of existing unit receiving maintenance in Btu/H/Watts

= Calculate using Actual SEER

$= - 0.02*SEER^2 + 1.12*SEER$ [401]

398 Full load heating hours for heat pumps are provided for Rockford, Chicago and Springfield in the ENERGY STARCalculator. Estimates for the other locations were calculated based on the FLH to Heating Degree Day (from NCDC) ratio. VEIC consider ENERGY STARestimates to be high due to oversizing not being adequately addressed. Using average Illinois billing data (from Illinois Commerce Commission) VEIC estimated the average gas heating load and used this to estimate the average home heating output (using 83% average gas heat efficiency). Dividing this by a typical 36,000 Btu/hr ASHP gives an estimate of average ASHP FLH_heat of 1821 hours. We used the ratio of this value to the average of the locations using the ENERGY STAR data (1994 hours) to scale down the ENERGY STAR estimates. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

399 Weighted based on number of occupied residential housing units in each zone.

400 Use actual HSPF rating where it is possible to measure or reasonably estimate. Unknown default of 6.8 HSPF is a VEIC estimate based on minimum Federal Standard between 1992 and 2006.

401 Based on Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder. Note this is appropriate for single speed units only.

MFd = Maintenance demand savings factor

= 0.02 [402]

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)

= 68%[403]

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

= 72%%[404]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Central A/C and Heat Pumps (average during peak period)

= 46.6%[405]

For example, maintenance of 3-ton, SEER 10 (equals EER 9.2) CAC unit:

$\Delta kW_{SSP}$ = 36,000 * 1/(9.2)/1000 * 0.02 * 0.68

= 0.0532 kW

$\Delta kW_{PJM}$ = 36,000 * 1/(9.2)/1000 * 0.02 * 0.466

= 0.0365 kW

### NATURAL GAS SAVINGS

N/A

### WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

### DEEMED O&M COST ADJUSTMENT CALCULATION

Conservatively not included.

### MEASURE CODE: RS-HVC-TUNE-V04-190101

### REVIEW DEADLINE: 1/1/2021

[402] Based on June 2010 personal conversation with Scott Pigg, author of Energy Center of Wisconsin, May 2008; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research" suggesting the average WI unit system draw of 2.8kW under peak conditions, and average peak savings of 50W.

[403] Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

[404] Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC's 2010 system peak; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.

[405] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.

## 5.3.11 Programmable Thermostats

### DESCRIPTION

This measure characterizes the household energy savings from the installation of a new or reprogramming of an existing Programmable Thermostat for reduced heating energy consumption through temperature set-back during unoccupied or reduced demand times. Because a literature review was not conclusive in providing a defensible source of prescriptive cooling savings from programmable thermostats, cooling savings from programmable thermostats are assumed to be zero for this version of the measure. It is not appropriate to assume a similar pattern of savings from setting a thermostat down during the heating season and up during the cooling season. Note that the EPA's EnergyStar program is developing a new specification for this project category, and if/when evaluation results demonstrate consistent cooling savings, subsequent versions of this measure will revisit this assumption[406]. Energy savings are applicable at the household level; all thermostats controlling household heat should be programmable and installation of multiple programmable thermostats per home does not accrue additional savings.

This measure was developed to be applicable to the following program types: TOS, NC, RF, DI.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

The criteria for this measure are established by replacement of a manual-only temperature control, with one that has the capability to adjust temperature setpoints according to a schedule without manual intervention. This category of equipment is broad and rapidly advancing in regards to the capability, and usability of the controls and their sophistication in setpoint adjustment and information display, but for the purposes of this characterization, eligibility is perhaps most simply defined by what it isn't: a manual only temperature control.

For the thermostat reprogramming measure, the auditor consults with the homeowner to determine an appropriate set back schedule, reprograms the thermostat and educates the homeowner on its appropriate use.

### DEFINITION OF BASELINE EQUIPMENT

For new thermostats the baseline is a non-programmable thermostat requiring manual intervention to change temperature setpoint.

For the purpose of thermostat reprogramming, an existing programmable thermostat that an auditor determines is being used in override mode or otherwise effectively being operated like a manual thermostat.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life of a programmable thermostat is assumed to be 8 years[407]. For reprogramming, this is reduced further to give a measure life of 2 years.

### DEEMED MEASURE COST

Actual material and labor costs should be used if the implementation method allows. If unknown (e.g. through a retail program) the capital cost for the new installation measure is assumed to be $30[408]. The cost for reprogramming is assumed to be $10 to account for the auditor's time to reprogram and educate the homeowner.

---

406 The ENERGY STAR program discontinued its support for this measure category effective 12/31/09, and is presently developing a new specification for 'Residential Climate Controls'.

**407** 8 years is based upon ASHRAE Applications (2003), Section 36, Table 3 estimate of 16 years for the equipment life, reduced by 50% to account for persistence issues.

**408** Market prices vary significantly in this category, generally increasing with thermostat capability and sophistication. The basic functions required by this measure's eligibility criteria are available on units readily available in the market for the listed price.

**LOADSHAPE**

Loadshape R09 - Residential Electric Space Heat

**COINCIDENCE FACTOR**

N/A due to no savings attributable to cooling during the summer peak period.

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

ΔkWh[409] = %ElectricHeat * Elec_Heating_Consumption * Heating_Reduction * HF * Eff_ISR + (ΔTherms * $F_e$ * 29.3)

Where:

%ElectricHeat = Percentage of heating savings assumed to be electric

| Heating fuel | %ElectricHeat |
|---|---|
| Electric | 100% |
| Natural Gas | 0% |
| Unknown | 6.5%[410] |

Elec_Heating_ Consumption

= Estimate of annual household heating consumption for electrically heated homes[411]. If location and heating type is unknown, assume 15,683 kWh[412]

| Climate Zone (City based upon) | Electric Resistance Elec_Heating_ Consumption (kWh) | Electric Heat Pump Elec_Heating_ Consumption (kWh) |
|---|---|---|
| 1 (Rockford) | 21,748 | 12,793 |
| 2 (Chicago) | 20,777 | 12,222 |
| 3 (Springfield) | 17,794 | 10,467 |
| 4 (Belleville) | 13,726 | 8,074 |
| 5 (Marion) | 13,970 | 8,218 |
| Average | 19,749 | 11,617 |

[409] Note the second part of the algorithm relates to furnace fan savings if the heating system is Natural Gas.

[410] Assumes that half of the electric heat in the state is a heat pump able to be controlled by an advanced thermostat (consistent with Potential Study results from the state). Average value of 13% electric space heating from 2010 Residential Energy Consumption Survey for Illinois. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.

[411] Values in table are based on converting an average household heating load (834 therms) for Chicago based on 'Table E-1, Energy Efficiency/Demand Response Nicor Gas Plan Year 1: Research Report: Furnace Metering Study, Draft, Navigant, August 1 2013 to an electric heat load (divide by 0.03412) to electric resistance and ASHP heat load (resistance load reduced by 15% to account for distribution losses that occur in furnace heating but not in electric resistance while ASHP heat is assumed to suffer from similar distribution losses) and then to electric consumption assuming efficiencies of 100% for resistance and 200% for HP (see 'Household Heating Load Summary Calculations_08222018.xls'). Finally these values were adjusted to a statewide average using relative HDD assumptions to adjust for the evaluation results focus on northern region. Values for individual cities are then calculated by comparing average HDD to the individual city's HDD.

[412] Assumption that 1/2 of electrically heated homes have electric resistance and 1/2 have Heat Pump, based on 2010 Residential Energy Consumption Survey for Illinois.

Heating_Reduction = Assumed percentage reduction in total household heating energy consumption due to programmable thermostat

= 6.2%[413]

HF = Household factor, to adjust heating consumption for non-single-family households.

| Household Type | HF |
|---|---|
| Single-Family | 100% |
| Mobile home | 83%[414] |
| Multifamily | 65%[415] |
| Unknown | 89%[416] |
| Actual | Custom[417] |

Use Multifamily if: Building has shared HVAC or meets utility's definition for multifamily

Eff_ISR = Effective In-Service Rate, the percentage of thermostats installed and programmed effectively

| Program Delivery | Eff_ISR |
|---|---|
| Direct Install | 100% |
| Other, or unknown | 56%[418] |

ΔTherms = Therm savings if Natural Gas heating system

= See calculation in Natural Gas section below

$F_e$ = Furnace Fan energy consumption as a percentage of annual fuel consumption

= 3.14%[419]

29.3 = kWh per therm

413 The savings from programmable thermostats are highly susceptible to many factors best addressed, so far for this category, by a study that controlled for the most significant issues with a very large sample size. To the extent that the treatment group is representative of the program participants for IL, this value is suitable. Higher and lower values would be justified based upon clear dissimilarities due to program and product attributes. Future evaluation work should assess program specific impacts associated with penetration rates, baseline levels, persistence, and other factors which this value represents.

414 Since mobile homes are similar to Multifamily homes with respect to conditioned floor area but to single-family homes with respect to exposure (i.e., all four wall orientations are adjacent to the outside), this factor is estimated as an average of the single family and multifamily household factors.

415 Multifamily household heating consumption relative to single-family households is affected by overall household square footage and exposure to the exterior. This 65% factor is applied to MF homes based on professional judgment that average household size, and heat loads of MF households are smaller than single-family homes

416 Unknown is based on statewide weighted average of 69% single family and 31% multifamily, based on IL data from 2009 RECS Table HC2.9 Structural and Geographic Characteristics of Homes in Midwest Region, Divisions and States, 2009.

417 Program-specific household factors may be utilized on the basis of sufficiently validated program evaluations.

418 "Programmable Thermostats. Report to KeySpan Energy Delivery on Energy Savings and Cost Effectiveness," GDS Associates, Marietta, GA. 2002GDS

419 $F_e$ is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR version 3 criteria for 2% $F_e$. See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference.

For example, a programmable thermostat directly installed in an electric resistance heated, single-family home in Springfield:

ΔkWH = 1 * 17,794 * 0.062 * 100% * 100% + (0 * 0.0314 * 29.3)

= 1,103 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

N/A due to no savings from cooling during the summer peak period.

**NATURAL GAS ENERGY SAVINGS**

ΔTherms = %FossilHeat * Gas_Heating_Consumption * Heating_Reduction * HF * Eff_ISR

Where:

%FossilHeat = Percentage of heating savings assumed to be Natural Gas

| Heating fuel | %FossilHeat |
|---|---|
| Electric | 0% |
| Natural Gas | 100% |
| Unknown | 93.5%[420] |

Gas_Heating_Consumption

= Estimate of annual household heating consumption for gas heated single-family homes. If location is unknown, assume the average below[421].

| Climate Zone (City based upon) | Gas_Heating_ Consumption (therms) |
|---|---|
| 1 (Rockford) | 1,052 |
| 2 (Chicago) | 1,005 |
| 3 (Springfield) | 861 |
| 4 (Belleville) | 664 |
| 5 (Marion) | 676 |
| Average | 955 |

For example, a programmable thermostat directly-installed in a gas heated single-family home in Chicago:

ΔTherms = 1.0 * 1005 * 0.062 * 100% * 100%

= 62.3 therms

[420] Assumes that half of the electric heat in the state is a heat pump able to be controlled by an advanced thermostat. Data from 2010 Residential Energy Consumption Survey for Illinois. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.

[421] Values are based on adjusting the average household heating load (834 therms) for Chicago based on 'Table E-1, Energy Efficiency / Demand Response Nicor Gas Plan Year 1, Research Report: Furnace Metering Study', divided by standard assumption of existing unit efficiency of 83% (estimate based on 24% of furnaces purchased in Illinois were condensing in 2000 (based on data from GAMA, provided to Department of Energy), assuming typical efficiencies: (0.24*0.92) + (0.76*0.8) = 0.83) to give 1005 therms. This Chicago value was then adjusted to a statewide average using relative HDD assumptions to adjust for the evaluation results focus on northern region. Values for individual cities are then calculated by comparing average HDD to the individual city's HDD.

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-HVC-PROG-V05-190101**

**REVIEW DEADLINE: 1/1/2021**

## 5.3.12 Ductless Heat Pumps

### DESCRIPTION

This measure is designed to calculate electric savings for the installation of a ductless mini-split heat pump (DMSHP). DMSHPs save energy in heating mode because they provide heat more efficiently than electric resistance heat and central ASHP systems. Additionally, DMSHPs use less fan energy to move heat and don't incur heat loss through a duct distribution system.

For cooling, the proposed savings calculations are aligned with those of typical replacement systems. DMSHPs save energy in cooling mode because they provide cooling capacity more efficiently than other types of unitary cooling equipment. A DMSHP installed in a home with a central ASHP system will save energy by offsetting some of the cooling energy of the ASHP. In order for this measure to apply, the control strategy for the heat pump is assumed to be chosen to maximize savings per installer recommendation.[422]

This measure characterizes the following scenarios:

d) New Construction:
   a. The installation of a new DMSHP meeting efficiency standards required by the program in a new home.
   b. Note the baseline in this case should be determined via EM&V and the algorithms are provided to allow savings to be calculated from any baseline condition.

e) Time of Sale:
   a. The planned installation of a new DMSHP meeting efficiency standards required by the program to replace an existing system(s) that does not meet the criteria for early replacement described in section c below.
   b. Note the baseline in this case is an equivalent replacement system to that which exists currently in the home. The calculation of savings is dependent on whether an incentive for the installation has been provided by both a gas and electric utility, just an electric utility or just a gas utility.

f) Early Replacement/Retrofit:
   a. The early removal or displacement of functioning either electric or gas space heating and/or cooling systems from service, prior to the natural end of life, and replacement with a new DMSHP.
   b. Note the baseline in this case is the existing equipment being replaced/displaced. The calculation of savings is dependent on whether an incentive for the installation has been provided by both a gas and electric utility, just an electric utility or just a gas utility.
   c. Early Replacement determination will be based on meeting the following conditions:
      - The existing unit is operational when replaced/displaced, or
      - The existing unit requires minor repairs, defined as costing less than[423]:

| Existing System | Maximum repair cost |
|---|---|
| Air Source Heat Pump | $276 per ton |
| Central Air Conditioner | $190 per ton |

[422] The whole purpose of installing ductless heat pumps is to conserve energy, so the installer can be assumed to be capable of recommending an appropriate controls strategy. For most applications, the heating setpoint for the ductless heat pump should be at least 2F higher than any remaining existing system and the cooling setpoint for the ductless heat pump should be at least 2F cooler than the existing system (this should apply to all periods of a programmable schedule, if applicable). This helps ensure that the ductless heat pump will be used to meet as much of the load as possible before the existing system operates to meet the remaining load. Ideally, the new ductless heat pump controls should be set to the current comfort settings, while the existing system setpoints should be adjusted down (heating) and up (cooling) to capture savings.

[423] The Technical Advisory Committee agreed that if the cost of repair is less than 20% of the new baseline replacement cost it can be considered early replacement.

| Existing System | Maximum repair cost |
|---|---|
| Boiler | $709 |
| Furnace | $528 |
| Ground Source Heat Pump | <$249 per ton |

- All other conditions will be considered Time of Sale.

d. The Baseline efficiency of the existing unit replaced:
   - If the efficiency of the existing unit is less than the maximum shown below, the Baseline efficiency is the actual efficiency value of the unit replaced. If the efficiency is greater than the maximum, the Baseline efficiency is shown in the "New Baseline" column below:

| Existing System | Maximum efficiency for Actual | New Baseline[424] |
|---|---|---|
| Air Source Heat Pump | 10 SEER | 14 SEER |
| Central Air Conditioner | 10 SEER | 13 SEER |
| Boiler | 75% AFUE | 82% AFUE |
| Furnace | 75% AFUE | 80% AFUE |
| Ground Source Heat Pump | 10 SEER | 13 SEER |

   - If the efficiency of the existing unit is unknown, use assumptions in variable list below (SEER, HSPF or AFUE exist).
   - If the operational status or repair cost of the existing unit is unknown use time of sale assumptions.

This measure was developed to be applicable to the following program types: RF, TOS, NC, EREP.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the new equipment must be a high-efficiency, variable-capacity (typically "inverter-driven" DC motor) ductless heat pump system that exceeds the program minimum efficiency requirements.

### DEFINITION OF BASELINE EQUIPMENT

For these products, baseline equipment includes Air Conditioning and Space Heating:

New Construction:

To calculate savings with an electric baseline, the baseline equipment is assumed to be an Air Source Heat Pump meeting the Federal Standard efficiency level; 14 SEER, 8.2 HSPF and 11.8[425] EER.

To calculate savings with a furnace/central AC baseline, the baseline equipment is assumed to be an 80% AFUE Furnace and central AC meeting the Federal Standard efficiency level; 13 SEER, 11 EER.

Time of Sale: The baseline for this measure is a new replacement unit of the same system type as the existing unit, meeting the baselines provided below.

| Unit Type | Efficiency Standard |
|---|---|
| ASHP | 14 SEER, 11.8 EER, 8.2 HSPF |
| Gas Furnace | 80% AFUE |

[424] Based on relevant Federal Standards.

[425] The Federal Standard does not include an EER requirement, so it is approximated with this formula: $(-0.02 * SEER^2) + (1.12 * SEER)$ Wassmer, M. (2003). 'A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations' Masters Thesis, University of Colorado at Boulder.

| Unit Type | Efficiency Standard |
|---|---|
| Gas Boiler | 82% AFUE |
| Central AC | 13 SEER, 11 EER |

Early replacement / Retrofit: The baseline for this measure is the efficiency of the *existing* heating and cooling equipment for the assumed remaining useful life of the existing unit and a new baseline heating and cooling system for the remainder of the measure life (as provided in table above except for Gas Furnace where new baseline assumption is 90% due to pending standard change). Note that in order to claim cooling savings, there must be an existing air conditioning system.

For multifamily buildings, each residence must have existing individual heating equipment. Multifamily residences with central heating do not qualify for this characterization.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years[426].

For early replacement, the remaining life of existing equipment is assumed to be 6 years[427].

### DEEMED MEASURE COST

New Construction and Time of Sale: The actual installed cost of the DMSHP should be used (defaults are provided below), minus the assumed installation cost of the baseline equipment ($1,381 per ton for ASHP[428] or $2,011 for a new baseline 80% AFUE furnace or $3,543 for a new 82% AFUE boiler[429] and $952 per ton[430] for new baseline Central AC replacement).

Default full cost of the DMSHP is provided below. Note, for smaller units a minimum cost of $2,000 should be applied[431]:

| Unit Size | Full Install Cost ($/ton)[432] |
|---|---|
| 9-9.9 | $1,443 |
| 10-10.9 | $1,605 |
| 11-12.9 | $1,715 |
| 13+ | $2,041 |

The incremental cost of the DSMHP compared to a baseline minimum efficiency DSMHP is provided in the table below[433].

[426] Based on 2016 DOE Rulemaking Technical Support Document, as recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.
[427] Assumed to be one third of effective useful life
[428] Baseline cost per ton derived from DEER 2008 Database Technology and Measure Cost Data. See 'ASHP_Revised DEER Measure Cost Summary.xls' for calculation.
[429] Furnace and boiler costs are based on data provided in Appendix E of the Appliance Standards Technical Support Documents including equipment cost and installation labor. Where efficiency ratings are not provided, the values are interpolated from those that are.
[430] Based on 3 ton initial cost estimate for a conventional unit from ENERGY STAR Central AC calculator
[431] The cost per ton table provides reasonable estimates for installation costs of DMSHP, which can vary significantly due to requirements of the home. It is estimated that all units, even those 1 ton or less will be at least $2000 to install.
[432] Full costs based upon full install cost of an ASHP plus incremental costs provided in Memo from Opinion Dynamics Evaluation Team, Ductless Mini-Split Heat Pumps: Incremental Cost Analysis, April 27, 2017.
[433] Memo from Opinion Dynamics Evaluation Team, Ductless Mini-Split Heat Pumps: Incremental Cost Analysis, April 27, 2017

| Efficiency (HSPF) | Incremental Cost ($/ton) over an HSPF 8.0 DHP |
|---|---|
| 9-9.9 | $62 |
| 10-10.9 | $224 |
| 11-12.9 | $334 |
| 13+ | $660 |

Early Replacement/retrofit (replacing existing equipment): The full installation cost of the DMSHP should be used (default provided above). The assumed deferred cost (after 8 years) of replacing existing equipment with a new baseline unit is assumed to be $1,518 per ton for a new baseline Air Source Heat Pump, or $2,903 for a new baseline 90% AFUE furnace or $4,045 for a new 82% AFUE boiler and $1,047 per ton for new baseline Central AC replacement[434]. This future cost should be discounted to present value using the nominal societal discount rate.

Where the DMSHP is a supplemental HVAC system, the full installation cost of the DMSHP should be used (default provided above) without a deferred replacement cost.

**LOADSHAPE**

Loadshape R10 - Residential Electric Heating and Cooling (if replacing gas heat and central AC)435

Loadshape R09 - Residential Electric Space Heat (if replacing electric heat with no cooling)

Loadshape R10 - Residential Electric Heating and Cooling (if replacing ASHP)

Note for purpose of cost effectiveness screening a fuel switch scenario, the heating kWh increase and cooling kWh decrease should be calculated separately such that the appropriate loadshape (i.e. Loadshape R09 - Residential Electric Space Heat and Loadshape R08 – Residential Cooling respectively) can be applied.

**COINCIDENCE FACTOR**

The summer peak coincidence factor for cooling is provided in four different ways below. The first two relate to the use of DMSHP to supplement existing cooling or provide limited zonal cooling, the second two relate to use of the DMSHP to provide whole house cooling. In each pair, the first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the *average* savings over the defined summer peak period, and is presented so that savings can be bid into PJM's Forward Capacity Market. Both values provided are based on metering data for 40 DMSHPs in Ameren Illinois service territory[436].

For supplemental or limited zonal cooling:

$CF_{SSP}$ = Summer System Peak Coincidence Factor for DMSHP (during utility peak hour)

= 43.1%%[437]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for DMSHP (average during PJM peak period)

= 28.0%[438]

For whole house cooling:

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Heat Pumps (during utility peak hour)

---

434 All baseline replacement costs are consistent with their respective measures and include inflation rate of 1.91%.
435 The baseline for calculating electric savings is an Air Source Heat Pump.
436 All-Electric Homes PY6 Metering Results: Multifamily HVAC Systems, Cadmus, October 2015
437 Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC's 2010 system peak; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.
438 Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.

= 72%%[439]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Heat Pumps (average during PJM peak period)

= 46.6%[440]

## Algorithms

### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

New Construction and Time of Sale (non-fuel switch only):

ΔkWh = [Heating Savings] + [Cooling Savings]

$= [(Elecheat * Capacity_{heat} * EFLH_{heat} * (1/HSPF_{Base} - 1/HSPF_{ee})) / 1000] + [(Capacity_{cool} * EFLH_{cool} * (1/SEER_{Base} - 1/SEER_{ee})) / 1000]$

New Construction and Time of Sale (fuel switch only):

If measure is supported by gas utility only, ΔkWH = 0

If measure is supported by gas and electric utility or electric utility only, electric utility claim savings calculated below:

ΔkWh = [Heating Savings from base ASHP to DMSHP] + [Cooling Savings]

$= [(Capacity_{heat} * EFLH_{heat} * (1/HSPF_{ASHP} - 1/HSPF_{ee})) / 1000] + [(Capacity_{cool} * EFLH_{cool} * (1/SEER_{Base} - 1/SEER_{ee})) / 1000]$

Early replacement (non-fuel switch only)[441]:

ΔkWH for remaining life of existing unit (1st 6 years):

ΔkWh = [Heating Savings] + [Cooling Savings]

$= [(Elecheat * Capacity_{heat} * EFLH_{heat} * (1/HSPF_{Exist} - 1/HSPF_{ee})) / 1000] + [(Capacity_{cool} * EFLH_{cool} * (1/SEER_{Exist} - 1/SEER_{ee})) / 1000]$

ΔkWH for remaining measure life (next 12 years):

ΔkWh = [Heating Savings] + [Cooling Savings]

$= [(Elecheat * Capacity_{heat} * EFLH_{heat} * (1/HSPF_{Base} - 1/HSPF_{ee})) / 1000] + [(Capacity_{cool} * EFLH_{cool} * (1/SEER_{Base} - 1/SEER_{ee})) / 1000]$

Early replacement - fuel switch only :

If measure is supported by gas utility only, ΔkWH = 0

If measure is supported by gas and electric utility or electric utility only, electric utility claim savings calculated below:

[439] Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC's 2010 system peak; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.
[440] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.
[441] The two equations are provided to show how savings are determined during the initial phase of the measure (existing to efficient) and the remaining phase (new baseline to efficient). In practice, the screening tools used may either require a First Year savings (using the first equation) and then a "number of years to adjustment" and "savings adjustment" input which would be the (new base to efficient savings)/(existing to efficient savings).

ΔkWh for remaining life of existing unit (1st 6 years):

ΔkWh = [Heating Savings from base ASHP to DMSHP] + [Cooling Savings]

$= [(Capacity_{heat} * EFLH_{heat} * (1/HSPF_{ASHP} - 1/HSPF_{ee})) / 1000] + [(Capacity_{cool} * EFLH_{cool} * (1/SEER_{Exist} - 1/SEER_{ee})) / 1000]$

ΔkWh for remaining measure life (next 12 years):

ΔkWh = [Heating Savings from base ASHP to DMSHP] + [Cooling Savings]

$= [(Capacity_{heat} * EFLH_{heat} * (1/HSPF_{ASHP} - 1/HSPF_{ee})) / 1000] + [(Capacity_{cool} * EFLH_{cool} * (1/SEER_{Base} - 1/SEER_{ee})) / 1000]$

Where:

ElecHeat = 1 if existing building is electrically heated

= 0 if existing building is not electrically heated

$Capacity_{heat}$ = Heating capacity of the ductless heat pump unit in Btu/hr

= Actual

$EFLH_{heat}$ = Equivalent Full Load Hours for heating. Depends on location. See table below

| Climate Zone (City based upon) | $EFLH_{heat}$ [442] |
|---|---|
| 1 (Rockford) | 1,520 |
| 2 (Chicago) | 1,421 |
| 3 (Springfield) | 1,347 |
| 4 (Belleville) | 977 |
| 5 (Marion) | 994 |
| Weighted Average | 1,406 |

$HSPF_{base}$ =Heating System Performance Factor of new replacement baseline heating system (kBtu/kWh)

| Existing Heating System | HSPF_base |
|---|---|
| Air Source Heat Pump | 8.2 |
| Electric Resistance | 3.41[443] |

$HSPF_{exist}$ = HSPF rating of existing equipment (kbtu/kwh)

= Use actual HSPF rating where it is possible to measure or reasonably estimate. If unknown assume default:

| Existing Equipment Type | $HSPF_{exist}$ |
|---|---|
| Electric resistance heating | 3.412[444] |
| Air Source Heat Pump | 5.54[445] |

[442] *All-Electric Homes PY6 Metering Results: Multifamily HVAC Systems*, Cadmus, October 2015. FLH values are based on metering of Multifamily units that were used as the primary heating source to the whole home, and in buildings that had received weatherization improvements. A DMSHP installed in a single-family home may be used more sporadically, especially if the DMSHP serves only a room, and buildings that have not been weatherized may require longer hours. Additional evaluation is recommended to refine the EFLH assumptions for the general population.
[443] Electric resistance has a COP of 1.0 which equals 1/0.293 = 3.41 HSPF.
[444] Electric resistance has a COP of 1.0 which equals 1/0.293 = 3.41 HSPF.
[445] Based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering

$HSPF_{ASHP}$ =Heating Season Performance Factor for new ASHP baseline unit (for fuel switch)

=8.2 [446]

$HSPF_{ee}$ = HSPF rating of new equipment (kbtu/kwh)

= Actual installed

$Capacity_{cool}$ = the cooling capacity of the ductless heat pump unit in Btu/hr[447].

= Actual installed

SEERbase = SEER Efficiency of new replacement baseline unit

| Existing Cooling System | SEERbase |
|---|---|
| Air Source Heat Pump | 14[448] |
| Central AC | 13[449] |
| No central cooling | 13[450] |

$SEER_{ee}$ = SEER rating of new equipment (kbtu/kwh)

= Actual installed[451]

$SEER_{exist}$ = SEER rating of existing equipment (kbtu/kwh)

= Use actual value. If unknown, see table below

| Existing Cooling System | SEER_exist |
|---|---|
| Air Source Heat Pump | 9.3 |
| Central AC | |
| Room AC | 8.0[453] |
| No existing cooling[454] | Make '1/SEER_exist' = 0 |

$EFLH_{cool}$ = Equivalent Full Load Hours for cooling. Depends on location. See table below[455].

Study Memo FINAL 2_28_2018'.

446 Minimum Federal Standard as of 1/1/2015

447 1 Ton = 12 kBtu/hr

448 Minimum Federal Standard as of 1/1/2015

449 Minimum Federal Standard; Federal Register, Vol. 66, No. 14, Monday, January 22, 2001/Rules and Regulations, p. 7170-7200.

450 Assumes that the decision to replace existing systems includes desire to add cooling.

451 Note that if only an EER rating is available, use the following conversion equation; EER_base = (-0.02 * SEER_base$^2$) + (1.12 * SEER). From Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder.

452 Based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study Memo FINAL 2_28_2018'

453 Estimated by converting the EER assumption using the conversion equation; EER_base = (-0.02 * SEER_base$^2$) + (1.12 * SEER). From Wassmer, M. (2003). 'A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations', Masters Thesis, University of Colorado at Boulder.

454 If there is no existing cooling in place but the incentive encourages installation of a new DMSHP with cooling, the added cooling load should be subtracted from any heating benefit.

455 *All-Electric Homes PY6 Metering Results: Multifamily HVAC Systems*, Cadmus, October 2015. FLH values are based on metering of Multifamily units, and in buildings that had received weatherization improvements. Additional evaluation is recommended to refine the EFLH assumptions for the general population.

| Climate Zone (City based upon) | $EFLH_{cool}$ |
|---|---|
| 1 (Rockford) | 323 |
| 2 (Chicago) | 308 |
| 3 (Springfield) | 468 |
| 4 (Belleville) | 629 |
| 5 (Marion) | 549 |
| Weighted Average[456] | 364 |

For example, installing a 1.5-ton (heating and cooling capacity) ductless heat pump unit rated at 8 HSPF and 14 SEER in a single-family home in Chicago to displace electric baseboard heat and replace a window air conditioner of unknown efficiency, savings are:

$\Delta kWh_{heat}$ = (18000 * 1421 * (1/3.412 – 1/8))/1000 = 4,299 kWh

$\Delta kWh_{cool}$ = (18000 * 308 *(1/8.0 – 1/14)) /1000 = 297 kWh

ΔkWh = 4,299 + 297 = 4,596 kWh

### Summer Coincident Peak Demand Savings

New Construction and Time of Sale:

$\Delta kW = (Capacity_{cool} * (1/EER_{base} - 1/EER_{ee})) / 1000) * CF$

Early replacement:

ΔkW for remaining life of existing unit (1st 6 years):

$\Delta kW = (Capacity_{cool} * (1/EER_{exist} - 1/EER_{ee})) / 1000) * CF$

ΔkW for remaining measure life (next 12 years):

$\Delta kW = (Capacity_{cool} * (1/EER_{base} - 1/EER_{ee})) / 1000) * CF$

Where:

EERbase = EER Efficiency of new replacement unit

| Existing Cooling System | EER_base |
|---|---|
| Air Source Heat Pump | 11.8[457] |
| Central AC | 11 [458] |
| No central cooling | 11[459] |

$EER_{exist}$ = Energy Efficiency Ratio of existing cooling system (kBtu/hr / kW)

= Use actual EER rating where it is possible to measure or reasonably estimate. If EER unknown but SEER available convert using the equation:

$EERexist = (-0.02 * SEERexist^2) + (1.12 * SEERexist)$ [460]

---

[456] Weighted based on number of residential occupied housing units in each zone.

[457] The Federal Standard does not include an EER requirement, so it is approximated with the conversion formula from Wassmer, M. 2003 thesis referenced below.

[458] Minimum Federal Standard; Federal Register, Vol. 66, No. 14, Monday, January 22, 2001/Rules and Regulations, p. 7170-7200.

[459] Assumes that the decision to replace existing systems includes desire to add cooling.

[460] From Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations.

If SEER rating unavailable use:

| Existing Cooling System | EER_exist |
|---|---|
| Air Source Heat Pump | 7.5[461] |
| Central AC | 7.5 |
| Room AC | 7.7[462] |
| No existing cooling[463] | Make '1/EER_exist' = 0 |

EER_ee = Energy Efficiency Ratio of new ductless Air Source Heat Pump (kBtu/hr / kW)

= Actual, If not provided convert SEER to EER using this formula: [464]

= $(-0.02 * SEER^2) + (1.12 * SEER)$

For supplemental or limited zonal cooling:

$CF_{SSP}$ = Summer System Peak Coincidence Factor for DMSHP (during utility peak hour)

= 43.1%[465]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for DMSHP (average during PJM peak period)

= 28.0%[466]

For whole house cooling:

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Heat Pumps (during utility peak hour)

= 72%[467]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Heat Pumps (average during PJM peak period)

= 46.6%[468]

**NATURAL GAS SAVINGS**

New Construction and Time of Sale with baseline gas heat:

If measure is supported by gas utility only, gas utility claim savings calculated below:

ΔTherms = [Heating Savings]

= [Replaced gas consumption – therm equivalent of DMSHP source kWh]

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEbase) – (kWhtoTherm * $Capacity_{heat}$ *

Masters Thesis, University of Colorado at Boulder.

461 Based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study Memo FINAL 2_28_2018'.

462 Same EER as Window AC recycling. Based on Nexus Market Research Inc, RLW Analytics, December 2005; "Impact, Process, and Market Study of the Connecticut Appliance Retirement Program: Overall Report."

463 If there is no central cooling in place but the incentive encourages installation of a new DMSHP with cooling, the added cooling load should be subtracted from any heating benefit.

464 Based on Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder. Note this is appropriate for single speed units only.

465 Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC's 2010 system peak; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.

466 Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.

467 Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC's 2010 system peak; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.

468 Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.

$EFLH_{heat}$ * 1/$HSPF_{ee}$)/1000)]

If measure is supported by electric utility only, ΔTherms = 0

If measure is supported by gas and electric utility, gas utility claim savings calculated below, (electric savings is provided in Electric Energy Savings section):

ΔTherms = [Heating Savings]

= [Replaced gas consumption – therm equivalent of base ASHP source kWh]

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEbase) – (kWhtoTherm * $Capacity_{heat}$ * $EFLH_{heat}$ * 1/$HSPF_{ASHP}$)/1000)]

Early replacement for homes with existing gas heat:

If measure is supported by gas utility only, gas utility claim savings calculated below:

ΔTherms for remaining life of existing unit (1st 6 years):

= [Heating Savings]

= [Replaced gas consumption – therm equivalent of DMSHP source kWh]

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEexist) – (kWhtoTherm * $Capacity_{heat}$ * $EFLH_{heat}$ * 1/$HSPF_{ee}$)/1000)]

ΔTherms for remaining measure life (next 12 years):

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEbaseER) – (kWhtoTherm * $Capacity_{heat}$ * $EFLH_{heat}$ * 1/$HSPF_{ee}$)/1000)]

If measure is supported by electric utility only, ΔTherms = 0

If measure is supported by gas and electric utility, gas utility claim savings calculated below:

ΔTherms for remaining life of existing unit (1st 6 years):

ΔTherms = [Heating Savings]

= [Replaced gas consumption – therm equivalent of base ASHP source kWh]

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEexist) – (kWhtoTherm * $Capacity_{heat}$ * $EFLH_{heat}$ * 1/$HSPF_{ASHP}$)/1000)]

ΔTherms for remaining measure life (next 12 years):

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEbaseER) – (kWhtoTherm * $Capacity_{heat}$ * $EFLH_{heat}$ * 1/$HSPF_{ASHP}$)/1000)]

Where:

ElecHeat = 1 if existing building is electrically heated

= 0 if existing building is not electrically heated

Gas_Heating_Load

= Estimate of annual household heating load [469] for gas furnace heated single-family homes. If location is unknown, assume the average below.

= Actual if informed by site-specific load calculations, ACCA Manual J or equivalent[470].

[469] Heating load is used to describe the household heating need, which is equal to (gas consumption * AFUE )

[470] The Air Conditioning Contractors of America Manual J, Residential Load Calculation 8th Edition produces equipment sizing loads for Single Family, Multi-single, and Condominiums using input characteristics of the home. A best practice for equipment

| Climate Zone (City based upon) | Gas_Heating_Load if Furnace (therms) [471] | Gas_Heating_Load if Boiler (therms) [472] |
|---|---|---|
| 1 (Rockford) | 873 | 1275 |
| 2 (Chicago) | 834 | 1218 |
| 3 (Springfield) | 714 | 1043 |
| 4 (Belleville) | 551 | 805 |
| 5 (Marion) | 561 | 819 |
| Average | 793 | 1158 |

AFUEbase = Baseline Annual Fuel Utilization Efficiency Rating

= 80% if furnace and 82% if boiler.

AFUEexist = Existing Annual Fuel Utilization Efficiency Rating

= Use actual AFUE rating where it is possible to measure or reasonably estimate.

If unknown, assume 64.4% if furnace and 61.6% [473] if boiler.

AFUEbaseER = Baseline Annual Fuel Utilization Efficiency Rating for early replacement measure

= 90%[474] if furnace and 82% if boiler.

kWhtoTherm = Converts source kWh to Therms

= $H_{grid}$ / 100000

$H_{grid}$ = Heat rate of the grid in btu/kWh based on the average fossil heat rate for the EPA eGRID subregion and includes a factor that takes into account T&D losses.

For systems operating less than 6,500 hrs per year:

Use the Non-baseload heat rate provided by EPA eGRID for RFC West region for ComEd territory (including independent providers connected to RFC West), and SERC Midwest region for Ameren territory (including independent providers connected to SERC Midwest)[475]. Also include any line losses.

selection and installation of Heating and Air Conditioning, load calculations are commonly completed by contractors during the selection process and may be readily available for program data purposes.

[471] Values are based on household heating consumption values and inferred average AFUE results from Table 2-1, *Energy Efficiency / Demand Response Nicor Gas Plan Year 1 (6/1/2011-5/31/2012) Research Report: Furnace Metering Study* (August 1, 2013) (prepared by Navigant Consulting, Inc.) and adjusting to a statewide average using relative HDD values to adjust for the evaluation results focus on northern region. Values for individual cities are then calculated by comparing average HDD to the individual city's HDD.

[472] Boiler consumption values are informed by an evaluation which did not identify any fraction of heating load due to domestic hot water (DHW) provided by the boiler. Thus these values are an average of both homes with boilers only providing heat, and homes with boilers that also provide DHW. Values are based on household heating consumption values and inferred average AFUE results from Table 3-4, Program Sample Analysis, *Nicor R29 Res Rebate Evaluation Report 092611_REV FINAL to Nicor*). Adjusting to a statewide average using relative HDD values to adjust for the evaluation results focus on northern region. Values for individual cities are then calculated by comparing average HDD to the individual city's HDD.

[473] Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren PY3-PY4.

[474] Assumes that Federal Standard will have been increased to 90% by the time the existing unit would have to have been replaced.

[475] Refer to the latest EPA eGRID data. Current values, based on eGrid 2016 are:

- Non-Baseload RFC West: 10,539 Btu/kWh * (1 + Line Losses)
- Non-Baseload SERC Midwest: 9,968 Btu/kWh * (1 + Line Losses)
- All Fossil Average RFC West: 9,962 Btu/kWh * (1 + Line Losses)
- All Fossil Average SERC Midwest: 9,996 Btu/kWh * (1 + Line Losses)

For systems operating more than 6,500 hrs per year:

Use the All Fossil Average heat rate provided by EPA eGRID for RFC West region for ComEd territory, and SERC Midwest region for Ameren territory. Also include any line losses.

All other variables provided above

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**COST EFFECTIVENESS SCREENING AND LOAD REDUCTION FORECASTING WHEN FUEL SWITCHING**

This measure can involve fuel switching from gas to electric.

For the purposes of forecasting load reductions due to fuel switch DMSHP projects per Section 16-111.5B, changes in site energy use at the customer's meter (using ΔkWh algorithm below) adjusted for utility line losses (at-the-busbar savings), customer switching estimates, NTG, and any other adjustment factors deemed appropriate, should be used.

The inputs to cost effectiveness screening should reflect the actual impacts on the electric and fuel consumption at the customer meter and, for fuel switching measures, this will not match the output of the calculation/allocation methodology presented in the "Electric Energy Savings" and "Natural Gas Savings" sections above. Therefore in addition to the calculation of savings claimed, the following values should be used to assess the cost effectiveness of the measure.

ΔTherms = [Heating Consumption Replaced[476]]

= [(1 – ElecHeat) * ((Gas_Heating_Load/AFUEbase)]

ΔkWh = - [DMSHP heating consumption] + [Cooling savings[477]]

$= - [(Capacity_{heat} * EFLH_{heat} * 1/HSPFee)/1000] + [(Capacity_{cool} * EFLH_{cool} * (1/SEER_{Base} - 1/SEER_{ee})) / 1000]$

**MEASURE CODE: RS-HVC-DHP-V06-190101**

**REVIEW DEADLINE: 1/1/2021**

[476] Note AFUEbase in the algorithm should be replaced with AFUEexist for early replacement measures.
[477] Note SEERbase in the algorithm should be replaced with SEERexist for early replacement measures.

## 5.3.13 Residential Furnace Tune-Up

#### DESCRIPTION

This measure is for a natural gas Residential furnace that provides space heating. The tune-up will improve furnace performance by inspecting, cleaning and adjusting the furnace and appurtenances for correct and efficient operation. Additional savings maybe realized through a complete system tune-up.

Two savings algorithms are provided for tune-up programs: through the HVAC SAVE program and for other tune-up programs, the difference being how relative efficiencies are measured.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

#### DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure an approved technician must complete the tune-up requirements[478] listed below:

- Measure combustion efficiency using an electronic flue gas analyzer
- Check and clean blower assembly and components per manufacturer’s recommendations
- Where applicable Lubricate motor and inspect and replace fan belt if required
- Inspect for gas leaks
- Clean burner per manufacturer’s recommendations and adjust as needed
- Check ignition system and safety systems and clean and adjust as needed
- Check and clean heat exchanger per manufacturer’s recommendations
- Inspect exhaust/flue for proper attachment and operation
- Inspect control box, wiring and controls for proper connections and performance
- Check air filter and clean or replace per manufacturer’s
- Inspect duct work connected to furnace for leaks or blockages
- Measure temperature rise and adjust flow as needed
- Check for correct line and load volts/amps
- Check thermostat operation is per manufacturer’s recommendations(if adjustments made, refer to ‘Residential Programmable Thermostat’ measure for savings estimate)
- Perform Carbon Monoxide test and adjust heating system until results are within standard industry acceptable limits

Verified Quality Maintenance:

This approach uses in-field measurement and interpretation of static pressures, identification and plotting of airflow, airflow measurement, temperature measurement and diagnostics, pressure measurements and duct design, and BTU measurement to ensure that existing equipment is operating according to manufacturers’ published potential performance. Installed equipment operating efficiency is largely dependent on the efficiency rating of the equipment, the skill of the installation contractor, the degree to which the equipment has aged or drifted from initial settings, and the system level constraints. When one or more of these key dependencies are operating sub-optimally, the overall efficiency of the equipment is degraded. A Verified Quality Maintenance identifies sub-optimal performance and prescribes a solution during furnace tune ups.

The HVAC SAVE program has its own certifications and requirements. In addition to the maintenance described above, the following are key activities that are provided through an HVAC SAVE Verified Quality Maintenance visit[479]:

- Measure pressure drops at return, filter, coil and supply.
- Determine equipment air flow using OEM blower data or measuring.
- Measure temperature rise across heat exchanger.

[478] American Standard Maintenance for Indoor Units (see ‘HVAC Maintenance American Standard’)

[479] As provided in ANSI approved ACCA 4 specification for Quality Maintenance

- Determine on-rate for a furnace by clocking the gas meter.
- Record outdoor temperature & elevation, and complete test-in.
- Clean evaporator coil to OEM pressure drop specification.
- Clean/replace/modify air filter to OEM pressure drop specification.
- Reset air flow based on up design parameter and updated pressure conditions.
- Adjust/modify gas pressure and venting to OEM specifications.
- Complete final test-out, compare before and after

### DEFINITION OF BASELINE EQUIPMENT

The baseline is furnace assumed not to have had a tune-up in the past 2 years.

HVAC SAVE tune-ups are a one-time measure and cannot be performed more than once on the same piece of equipment.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life for the clean and check tune up is 2 years.[480]

An HVAC SAVE tune-up lasts the remaining life of the equipment because they come from adjustments to fans and ducts that remain effective through normal operation of the equipment. Assume 10 years. This measure cannot be performed more than once on the same piece of equipment. However subsequent clean and check tune-ups can be performed.

### DEEMED MEASURE COST

The incremental cost for this measure should be the actual cost of tune up.

### DEEMED O&M COST ADJUSTMENTS

There are no expected O&M savings associated with this measure.

### LOADSHAPE

Loadshape R09 - Residential Electric Space Heat

### COINCIDENCE FACTOR

N/A

## Algorithms

### CALCULATION OF ENERGY SAVINGS

### ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \Delta Therms * F_e * 29.3$$

Where:

ΔTherms = as calculated below

$F_e$ = Furnace Fan energy consumption as a percentage of annual fuel consumption

= 3.14%[481]

[480] Act on Energy Commercial Technical Reference Manual No. 2010-4, 9.2.3 Gas Forced-Air Furnace Tune-up.

[481] $F_e$ is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a

29.3 = kWh per therm

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

N/A

**NATURAL GAS SAVINGS**

1. Verified Quality Maintenance:

The HVAC SAVE protocol results in a number of outputs including the measured output capacity of the unit (btuh), and the adjusted input capacity (btuh) by recording the gas meter.

The following algorithm utilizes these outputs to adjust the EFLH of the post tune-up condition to calculate a site specific savings estimate. There are two limits imposed to using these outputs directly:

1. The post efficiency (i.e. measured output/adjusted input) must not exceed the rated efficiency of the unit. Where the test results indicates an efficiency greater than the rated efficiency, the measured output should be adjusted to equal the value at the rated efficiency,
2. A limit of 15% savings of pre tune-up consumption is applied. Where outputs indicate savings higher than 15%, the program should claim savings at 15%, unless a higher level of independent review is able to justify the higher level of savings.

$$\Delta Therms = ConsumptionPre - ConsumptionPost$$

$$\Delta Therms = \frac{\left((CAPInput_{Pre} * EFLH) - \left(CAPInput_{Post} * \ EFLH * \left(\frac{CAPOutput_{Pre}}{CAPOutput_{Post}}\right)\right)\right)}{100{,}000}$$

Note, if a program prefers, a deemed savings percentage can be applied and this is provided as an alternative below:

$$\Delta Therms = \ (CAPInput_{Pre} * EFLH \ * \ \left(\frac{1}{AFUE \ * \ (1 \ - \ Derating_{Pre})} - \frac{1}{AFUE \ * \ (1 \ - \ Derating_{Post})}\right)$$

Where:

$CAPInput_{Pre}$ = Gas Furnace input capacity pre tune-up (Btuh)

= Measured input capacity from HVAC SAVE

$CAPInput_{Post}$ = Gas Furnace input capacity post tune-up (Btuh)

= Measured input capacity from HVAC SAVE

EFLH = Equivalent Full Load Hours for heating

| Climate Zone (City based upon) | EFLH[482] |
|---|---|
| 1 (Rockford) | 1022 |
| 2 (Chicago) | 976 |

calculation based on the certified values for fuel energy (Ef in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR version 3 criteria for 2% $F_e$. See “Programmable Thermostats Furnace Fan Analysis.xlsx” for reference.

[482] Full load hours for Chicago, are based on findings in ‘Energy Efficiency / Demand Response Nicor Gas Plan Year 1 (6/1/2011-5/31/2012) Research Report: Furnace Metering Study (August 1, 2013), prepared by Navigant Consulting, Inc. Values for other cities are then calculated by comparing relative HDD at base 60F.

| Climate Zone (City based upon) | EFLH[482] |
|---|---|
| 3 (Springfield) | 836 |
| 4 (Belleville) | 645 |
| 5 (Marion) | 656 |
| Weighted Average[483] | 928 |

$CAPOutput_{Pre}$ = Measured Output Capacity before HVAC SAVE tune-up (btuh)

$CATOutput_{Post}$ = Measured Output Capacity after HVAC SAVE tune-up (btuh)

AFUE = Furnace Annual Fuel Utilization Efficiency Rating

= Actual

$Derating_{pre}$ = Furnace AFUE Derating before HVAC SAVE tune-up

= 6.4%[484]

$Derating_{post}$ = Furnace AFUE Derating after HVAC SAVE tune-up

= 0%

2. Other Tune-Up Programs:

$$\Delta Therms = (CAPInput_{Pre} * EFLH * (1/ Effbefore – 1/ (Effbefore + Ei)))$$

Where:

Effbefore = Efficiency of the furnace before the tune-up

= Actual

*Note: Contractors should select a mid-level firing rate that appropriately represents the average building operating condition over the course of the heating season and take readings at a consistent firing rate for pre and post tune-up.*

EI = Efficiency Improvement of the furnace tune-up measure

= Actual

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-HVC-FTUN-V04-190101**

**REVIEW DEADLINE: 1/1/2021**

483 Weighted based on number of occupied residential housing units in each zone.

484 Based on findings from Building America, US Department of Energy, Brand, Yee and Baker "Improving Gas Furnace Performance: A Field and Laboratory Study at End of Life", February 2015.

## 5.3.14 Boiler Reset Controls

**DESCRIPTION**

This measure relates to improving system efficiency by adding controls to residential heating boilers to vary the boiler entering water temperature relative to heating load as a function of the outdoor air temperature to save energy. The water can be run a little cooler during fall and spring, and a little hotter during the coldest parts of the winter. A boiler reset control has two temperature sensors - one outside the house and one in the boiler water. As the outdoor temperature goes up and down, the control adjusts the water temperature setting to the lowest setting that is meeting the house heating demand. There are also limits in the controls to keep a boiler from operating outside of its safe performance range.[485]

This measure was developed to be applicable to the following program types: RF.

**DEFINITION OF EFFICIENT EQUIPMENT**

Natural gas single family residential customer adding boiler reset controls capable of resetting the boiler supply water temperature in an inverse fashion with outdoor air temperature. The system must be set so that the minimum temperature is not more than 10 degrees above manufacturer's recommended minimum return temperature. This boiler reset measure is limited to existing condensing boilers serving a single family residence. Boiler reset controls for non-condensing boilers in single family residences should be implemented as a custom measure, and the cost-effectiveness should be confirmed.

**DEFINITION OF BASELINE EQUIPMENT**

Existing condensing boiler in a single family residential setting without boiler reset controls.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The life of this measure is 20 years[486]

Note a mid-life adjustment to account for replacement of HVAC equipment during the measure life should be applied after 13 years[487]. See section below for detail.

**DEEMED MEASURE COST**

The cost of this measure is $612[488]

**LOADSHAPE**

NA

**COINCIDENCE FACTOR**

N/A

---

[485] Energy Solutions Center, a consortium of natural gas utilities, equipment manufacturers and vendors, See 'Boiler Reset Control – NaturalGasEfficiency.org'.

[486] CLEAResult references the Brooklyn Union Gas Company, High Efficiency Heating and Water and Controls, Gas Energy Efficiency Program Implementation Plan.

[487] This is intentionally longer than the assumptions found in the early replacement measures as the application of this measure will occur in a variety of homes that will not be targeted for early replacement HVAC systems.

[488] Nexant. Questar DSM Market Characterization Report. August 9, 2006.

**Algorithm**

**CALCULATION OF ENERGY SAVINGS**

**ELECTRIC ENERGY SAVINGS**

N/A

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

NA

**NATURAL GAS SAVINGS**

ΔTherms = Gas_Boiler_Load * (1/AFUE) * Savings Factor

Where:

Gas_Boiler_Load[489]

= Estimate of annual household Load for gas boiler heated single-family homes. If location is unknown, assume the average below[490].

= or Actual if informed by site-specific load calculations, ACCA Manual J or equivalent[491].

| Climate Zone (City based upon) | Gas_Boiler Load (therms) |
|---|---|
| 1 (Rockford) | 1275 |
| 2 (Chicago) | 1218 |
| 3 (Springfield) | 1043 |
| 4 (Belleville) | 805 |
| 5 (Marion) | 819 |
| Average | 1158 |

AFUE = Existing Condensing Boiler Annual Fuel Utilization Efficiency Rating

= Actual.

SF = Savings Factor, 5%[492]

[489] Boiler consumption values are informed by an evaluation which did not identify any fraction of heating load due to domestic hot water (DHW) provided by the boiler. Thus these values are an average of both homes with boilers only providing heat, and homes with boilers that also provide DHW. Heating load is used to describe the household heating need, which is equal to (gas heating consumption * AFUE )

[490] Values are based on household heating consumption values and inferred average AFUE results from Table 3-4, Program Sample Analysis, *Nicor R29 Res Rebate Evaluation Report 092611_REV FINAL to Nicor*). Adjusting to a statewide average using relative HDD values to adjust for the evaluation results focus on northern region. Values for individual cities are then calculated by comparing average HDD to the individual city's HDD.

[491] The Air Conditioning Contractors of America Manual J, Residential Load Calculation 8th Edition produces equipment sizing loads for Single Family, Multi-single, and Condominiums using input characteristics of the home. A best practice for equipment selection and installation of Heating and Air Conditioning, load calculations should be completed by contractors during the selection process and may be readily available for program data purposes.

[492] Energy Solutions Center, a consortium of natural gas utilities, equipment manufacturers and vendors. See 'Boiler Reset Control – NaturalGasEfficiency.org'.

**EXAMPLE**

For example, boiler reset controls on a 92.5 AFUE boiler at a household in Rockford, IL

$\Delta$Therms = 1275 * (1/0.925) * 0.05

= 69 Therms

**Mid-Life adjustment**

In order to account for the likely replacement of existing heating equipment during the lifetime of this measure, a mid-life adjustment should be applied. To calculate the adjustment, re-calculate the savings above using the following new baseline system efficiency assumptions:

| Efficiency Assumption | System Type | New Baseline Efficiency |
|---|---|---|
| ηHeat | Boiler | 82% AFUE |

This reduced annual savings should be applied following the assumed remaining useful life of the existing equipment, estimate to be 13 years[493].

## WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

## DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

## MEASURE CODE: RS-HVC-BREC-V02-190101

## REVIEW DEADLINE: 1/1/2021

[493] This is intentionally longer than the assumption found in the early replacement measures as the application of this measure will occur in a variety of homes and will not be targeting those homes appropriate for early replacement HVAC systems.

## 5.3.15 ENERGY STAR Ceiling Fan

**DESCRIPTION**

A ceiling fan/light unit meeting the efficiency specifications of ENERGY STAR is installed in place of a model meeting the federal standard. ENERGY STAR qualified ceiling fan/light combination units are over 60% more efficient than conventional fan/light units, and use improved motors and blade designs.

Due to the savings from this measure being derived from more efficient ventilation and more efficient lighting, and the loadshape and measure life for each component being very different, the savings are split in to the component parts and should be claimed together. Lighting savings should be estimated utilizing the 5.5.1 ENERGY STAR Compact Fluorescent Lamp measure.

This measure was developed to be applicable to the following program types: TOS, NC, RF.

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

The efficient equipment is defined as an ENERGY STAR certified ceiling fan with integral CFL bulbs.

**DEFINITION OF BASELINE EQUIPMENT**

The baseline equipment is assumed to be a standard fan with efficient incandescent or halogen light bulbs. Production of 100W, standard efficacy incandescent lamps ended in 2012 followed by restrictions on 75W in 2013 and 60W and 40W in 2014, due to the Energy Independence and Security Act of 2007 (EISA). Finally, a provision in the EISA regulations requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the baseline equivalent to a current day CFL. Therefore the measure life (number of years that savings should be claimed) for the lighting portion of the savings should be reduced once the assumed lifetime of the bulb exceeds 2020. Due to expected delay in clearing retail inventory and to account for the operating life of a halogen incandescent potentially spanning over 2020, this shift is assumed not to occur until 2021.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The fan savings measure life is assumed to be 10 years.[2]

The lighting savings measure life is assumed to be 3 years for lighting savings for units installed in 2018, and then for every subsequent year should be reduced by one year[494] (see 5.5.1 ENERGY STAR Compact Fluorescent Lamp measure).

**DEEMED MEASURE COST**

Incremental cost of unit is $46.[495]

**LOADSHAPE**

R06 - Residential Indoor Lighting

R11 - Residential Ventilation

[494] Since the replacement baseline bulb from 2020 on will be equivalent to a CFL, no additional savings should be claimed from that point. Due to expected delay in clearing stock from retail outlets and to account for the operating life of a halogen incandescent potentially spanning over 2020, this shift is assumed not to occur until 2021.
[495] ENERGY STAR Ceiling Fan Savings Calculator.

### COINCIDENCE FACTOR

The summer peak coincidence factor for the ventilation savings is assumed to be 30%.[496]

For lighting savings, see 5.5.1 ENERGY STAR Compact Fluorescent Lamp measure.

## Algorithm

### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

$\Delta kWh = \Delta kWh_{fan} + \Delta kWh_{Light}$

$\Delta kWh_{fan} = [Days * FanHours * ((\%Low_{base} * WattsLow_{base}) + (\%Med_{base} * WattsMed_{base}) + (\%High_{base} * WattsHigh_{base}))/1000\ ] - [Days * FanHours * ((\%Low_{ES} * WattsLow_{ES}) + (\%Med_{ES} * WattsMed_{ES}) + (\%High_{ES} * WattsHigh_{ES}))/1000]$

$\Delta kWh_{light}$ = see 5.5.1 ENERGY STAR Compact Fluorescent Lamp measure.

Where[497]:

Days = Days used per year

= Actual. If unknown use 365.25 days/year

FanHours = Daily Fan “On Hours”

= Actual. If unknown use 3 hours

$\%Low_{base}$ = Percent of time spent at Low speed of baseline

= 40%

$WattsLow_{base}$ = Fan wattage at Low speed of baseline

= Actual. If unknown use 15 watts

$\%Med_{base}$ = Percent of time spent at Medium speed of baseline

= 40%

$WattsMed_{base}$ = Fan wattage at Medium speed of baseline

= Actual. If unknown use 34 watts

$\%High_{base}$ = Percent of time spent at High speed of baseline

= 20%

$WattsHigh_{base}$ = Fan wattage at High speed of baseline

= Actual. If unknown use 67 watts

%LowES = Percent of time spent at Low speed of ENERGY STAR

= 40%

$WattsLow_{ES}$ = Fan wattage at Low speed of ENERGY STAR

= Actual. If unknown use 6 watts

[496] Assuming that the CF same as a Room AC. Consistent with coincidence factors found in: RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008.

[497] All fan default assumptions are based upon assumptions provided in the ENERGY STAR Ceiling Fan Savings Calculator.

$\%Med_{ES}$ = Percent of time spent at Medium speed of ENERGY STAR

= 40%

$WattsMed_{ES}$ = Fan wattage at Medium speed of ENERGY STAR

= Actual. If unknown use 23 watts

$\%High_{ES}$ = Percent of time spent at High speed of ENERGY STAR

= 20%

$WattsHigh_{ES}$ = Fan wattage at High speed of ENERGY STAR

= Actual. If unknown use 56 watts

For ease of reference, the fan assumptions are provided below in table form:

| | Low Speed | Medium Speed | High Speed |
|---|---|---|---|
| Percent of Time at Given Speed | 40% | 40% | 20% |
| Conventional Unit Wattage | 15 | 34 | 67 |
| ENERGY STAR Unit Wattage | 6 | 23 | 56 |
| ΔW | 9 | 11 | 11 |

If the lighting WattsBase and WattsEE is unknown, assume the following

WattsBase = 3 x 43 = 129 W

WattsEE = 1 x 42 = 42 W

**Example**

For example, a ceiling fan with three 43W bulb light fixtures, replaced with an ES ceiling fan with one 42W bulb light fixture, the savings are:

$\Delta kWh_{fan}$ = [365.25*3*((0.4*15)+(0.4*34)+(0.2*67))/1000] – [365.25*3*((0.4*6)+(0.4*23)+(0.2*56))/1000]

= 36.2 – 25.0 = 11.2 kWh

$\Delta kWh_{light}$ =((129 – 42)/1000) *759 * 1.06

= 70.0 kWh

ΔkWh = 11.2 + 70

=81.2 kWh

Using the default assumptions provided above, the deemed savings is 81.2 kWh.

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$\Delta kW = \Delta kW_{Fan} + \Delta kW_{light}$

$\Delta kW_{Fan} = ((WattsHigh_{base} - WattsHigh_{ES})/1000) * CF_{fan}$

$\Delta kW_{Light}$ = see 5.5.1 ENERGY STAR Compact Fluorescent Lamp measure.

Where:

$CF_{fan}$ = Summer Peak coincidence factor for ventilation savings

= 30%[498]

[498] Assuming that the CF same as a Room AC. Consistent with coincidence factors found in: RLW Report: Final Report

$CF_{light}$ = Summer Peak coincidence factor for lighting savings

= 7.1%[499]

**Example**

For example a ceiling fan with three 43W bulb light fixtures, replaced with an ES ceiling fan with one 42W bulb light fixture, the savings are:

$\Delta kW_{fan}$ = ((67-56)/1000) * 0.3

=0.0033 kW

$\Delta kW_{light}$ =((129 – 42)/1000) * 1.11 * 0.071

= 0.0068 kW

$\Delta kW$ = 0.0033 + 0.0068

= 0.010 kW

Using the default assumptions provided above, the deemed savings is 0.010kW.

### NATURAL GAS SAVINGS

N/A

### WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

### DEEMED O&M COST ADJUSTMENT CALCULATION

See 5.5.1 ENERGY STAR Compact Fluorescent Lamp measure for bulb replacement costs.

### MEASURE CODE: RS-HVC-CFAN-V02-180101

### REVIEW DEADLINE: 1/1/2022

Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008.

[499] Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

## 5.3.16 Advanced Thermostats

### DESCRIPTION

This measure characterizes the household energy savings from the installation of a new thermostat(s) for reduced heating and cooling consumption through a configurable schedule of temperature setpoints (like a programmable thermostat) *and* automatic variations to that schedule to better match HVAC system runtimes to meet occupant comfort needs. These schedules may be defaults, established through user interaction, and be changed manually at the device or remotely through a web or mobile app. Automatic variations to that schedule could be driven by local sensors and software algorithms, and/or through connectivity to an internet software service. Data triggers to automatic schedule changes might include, for example: occupancy/activity detection, arrival & departure of conditioned spaces, optimization based on historical or population-specific trends, weather data and forecasts.[500] This class of products and services are relatively new, diverse, and rapidly changing. Generally, the savings expected for this measure aren't yet established at the level of individual features, but rather at the system level and how it performs overall. Like programmable thermostats, it is not suitable to assume that heating and cooling savings follow a similar pattern of usage and savings opportunity, and so here too this measure treats these savings independently. Note that this is an active area of ongoing work to better map features to savings value, and establish standards of performance measurement based on field data so that a standard of efficiency can be developed.[501] Energy savings are applicable at the household level; all thermostats controlling household heat should be programmable and installation of multiple advanced thermostats per home does not accrue additional savings.

Note that though these devices and service could potentially be used as part of a demand response program, the costs, delivery, impacts, and other aspects of DR-specific program delivery are not included in this characterization at this time, though they could be added in the future.

This measure was developed to be applicable to the following program types: TOS, NC, RF, DI.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

The criteria for this measure are established by replacement of a manual-only or programmable thermostat, with one that has the default enabled capability—or the capability to automatically—establish a schedule of temperature setpoints according to driving device inputs above and beyond basic time and temperature data of conventional programmable thermostats. As summarized in the description, this category of products and services is broad and rapidly advancing in regards to their capability, usability, and sophistication, but at a minimum must be capable of two-way communication[502] and exceed the typical performance of manual and conventional programmable thermostats through the automatic or default capabilities described above.

### DEFINITION OF BASELINE EQUIPMENT

The baseline is either the actual type (manual or programmable) if it is known,[503] or an assumed mix of these two types based upon information available from evaluations or surveys that represent the population of program

[500] For example, the capabilities of products and added services that use ultrasound, infrared, or geofencing sensor systems, automatically develop individual models of home's thermal properties through user interaction, and optimize system operation based on equipment type and performance traits based on weather forecasts demonstrate the type of automatic schedule change functionality that apply to this measure characterization.

[501] The ENERGY STAR program released version 1.0 of its Connected Thermostats Specification in 2017. Details and active discussion can be found on ENERGY STAR website; 'Connected Thermostats Specifications v1.0'.

[502] This measure recognizes that field data may be available, through this 2-way communication capability, to better inform characterization of efficiency criteria and savings calculations. It is recommended that program implementations incorporate this data into their planning and operation activities to improve understanding of the measure to manage risks and enhance savings results.

[503] If the actual thermostat is programmable and it is found to be used in override mode or otherwise effectively being operated like a manual thermostat, then the baseline may be considered to be a manual thermostat

participants. This mix may vary by program, but as a default, 51% programmed programmable and 49% manual or non-programmed programmable thermostats may be assumed[504].

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected measure life for advanced thermostats is assumed to be 11 years[505].

**DEEMED MEASURE COST**

For DI and other programs for which installation services are provided, the actual material, labor, and other costs should be used. For retail, Bring Your Own Thermostat (BYOT) programs[506], or other program types actual costs are still preferable[507] but if unknown then the average incremental cost for the new installation measure is assumed to be $125[508].

**LOADSHAPE**

$\Delta kWh$ → Loadshape R10 - Residential Electric Heating and Cooling
$\Delta kWh_{heating}$ → Loadshape R09 - Residential Electric Space Heat
$\Delta kWh_{cooling}$ → Loadshape R08 - Residential Cooling

**COINCIDENCE FACTOR**

In the absence of conclusive results from empirical studies on peak savings, the TAC agreed to a temporary assumption of 50% of the cooling coincidence factor, acknowledging that while the savings from the advanced Thermostat will track with the cooling load, the impact during peak periods may be lower. This is an assumption that could use future evaluation to improve these estimates.

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)
= 34%[509]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period)
= 23.3%[510]

---

[504] Based on Opinion Dynamics Corporation, "ComEd Residential Saturation/End Use, Market Penetration & Behavioral Study", Appendix 3: Detailed Mail Survey Results, p34, April 2013.

[505] Based on 2017 Residential Smart Thermostat Workpaper, prepared by SCE and Nest for SCE (Work Paper SCE17HC054, Revision #0). Estimate ability of smart systems to continue providing savings after disconnection and conduct statistical survival analysis which yields 9.2-13.8 year range.

[506] In contrast to program designs that utilize program affiliated contractors or other trade ally partners that support customer participation through thermostat distribution, installation and other services , BYOT programs enroll customers *after* the time of purchase through online rebate and program integration sign-ups.

[507] Including any one-time software integration or annual software maintenance, and or individual device energy feature fees.

**[508]** Market prices vary considerably in this category, generally increasing with thermostat capability and sophistication. The core suite of functions required by this measure's eligibility criteria are available on units readily available in the market roughly in the range of $150 and $250, excluding the availability of time or market-limited wholesale or volume pricing. The assumed incremental cost is based on the middle of this range ($175) minus a cost of $50 for the baseline equipment blend of manual and programmable thermostats. Note that any add-on energy service costs, which may include one-time setup and/or annual per device costs are not included in this assumption.

[509] Assumes 50% of the cooling coincidence factor (based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory).

[510] Assumes 50% of the cooling coincidence factor (based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.)

**Algorithm**

## CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

ΔkWh[511] = $\Delta kWh_{heating} + \Delta kWh_{cooling}$

$\Delta kWh_{heating}$ = %ElectricHeat * Elec_Heating_Consumption * Heating_Reduction * HF * Eff_ISR + (ΔTherms * $F_e$ * 29.3)

$\Delta kWh_{cool}$ = %AC * ((FLH * Capacity * 1/SEER)/1000) * Cooling_Reduction * Eff_ISR

Where:

%ElectricHeat = Percentage of heating savings assumed to be electric

| Heating fuel | %ElectricHeat |
|---|---|
| Electric | 100% |
| Natural Gas | 0% |
| Unknown | 3%[512] |

Elec_Heating_Consumption

= Estimate of annual household heating consumption for electrically heated homes[513]. If location and heating type is unknown, assume 15,683 kWh[514]

| Climate Zone (City based upon) | Electric Resistance Elec_Heating_ Consumption (kWh) | Electric Heat Pump Elec_Heating_ Consumption (kWh) |
|---|---|---|
| 1 (Rockford) | 21,748 | 12,793 |
| 2 (Chicago) | 20,778 | 12,222 |
| 3 (Springfield) | 17,794 | 10,467 |
| 4 (Belleville) | 13,726 | 8,074 |
| 5 (Marion) | 13,970 | 8,218 |
| Average | 19,749 | 11,617 |

Heating_Reduction = Assumed percentage reduction in total household heating energy consumption due to advanced thermostat

---

[511] Electrical savings are a function of both heating and cooling energy usage reductions. For heating this is a function of the percent of electric heat (heat pumps) and fan savings in the case of a natural gas furnace.

[512] Value used is based on known PY8 percent of electric heat provided by Navigant as part of the ongoing evaluation work source: "Slide 21: May 22, 2018, Second Addendum IL TRM Advanced Thermostat Cooling Savings Evaluation"

[513] Values in table are based on converting an average household heating load (834 therms) for Chicago based on 'Table E-1, Energy Efficiency/Demand Response Nicor Gas Plan Year 1: Research Report: Furnace Metering Study, Draft, Navigant, August 1 2013 to an electric heat load (divide by 0.03412) to electric resistance and ASHP heat load (resistance load reduced by 15% to account for distribution losses that occur in furnace heating but not in electric resistance while ASHP heat is assumed to suffer from similar distribution losses) and then to electric consumption assuming efficiencies of 100% for resistance and 200% for HP (see 'Household Heating Load Summary Calculations_08222018.xls'). Finally these values were adjusted to a statewide average using relative HDD assumptions to adjust for the evaluation results focus on northern region. Values for individual cities are then calculated by comparing average HDD to the individual city's HDD.

[514] Assumption that 1/2 of electrically heated homes have electric resistance and 1/2 have Heat Pump, based on 2010 Residential Energy Consumption Survey for Illinois.

| Existing Thermostat Type | Heating_Reduction[515] |
|---|---|
| Manual | 8.8% |
| Programmable | 5.6% |
| Unknown (Blended) | 7.0% |

HF = Household factor, to adjust heating consumption for non-single-family households.

| Household Type | HF |
|---|---|
| Single-Family | 100% |
| Mobile home | 83%[516] |
| Multifamily | 65%[517] |
| Actual | Custom[518] |
| Unknown | 96.5%[519] |

Use Multifamily if: Building has shared HVAC or meets utility's definition for multifamily

Eff_ISR = Effective In-Service Rate, the percentage of thermostats installed and configured effectively for 2-way communication. Note that retrospective adjustments should be made during evaluation verification activities through the use of a realization rate if the program design does not ensure that each advanced thermostat is actually installed and/or if the evaluation determines that the advanced thermostat is not actually installed in the Program Administrator's service territory.

| Program Delivery | Eff_ISR |
|---|---|
| Direct Install | 100% |
| Other | 100%[520] |

ΔTherms = Therm savings if Natural Gas heating system

= See calculation in Natural Gas section below

$F_e$ = Furnace Fan energy consumption as a percentage of annual fuel consumption

= 3.14%[521]

---

[515] These values represent adjusted baseline savings values (8.8% for manual, and 5.6% for programmable thermostats) as presented in Navigant's PowerPoint on Impact Analysis from Preliminary Gas savings findings (slide 28 of 'IL SAG Smart Thermostat Preliminary Gas Impact Findings 2015-12-08 to IL SAG.ppt'). These values are used as the basis for the weighted average savings value when the type of existing thermostat is not known. Using weightings updated from PY8 data, based upon baseline type, and allocating programmability into manual and programmable based upon programmed status yields a weighted new blend of 43% manual (or non-programmed programmable) and 57% programmed. The 7.0% savings value is equal to the sum of proportional savings for manual (including non-programmed programmable)and programmable thermostats: 8.8% * 0.43 + 5.6% * 0.57. Further evaluation and regular review of this key assumption is encouraged.

[516] Since mobile homes are similar to Multifamily homes with respect to conditioned floor area but to single-family homes with respect to exposure (i.e., all four wall orientations are adjacent to the outside), this factor is estimated as an average of the single family and multifamily household factors.

[517] Multifamily household heating consumption relative to single-family households is affected by overall household square footage and exposure to the exterior. This 65% reduction factor is applied to MF homes, based on professional judgment that average household size, and heat loads of MF households are smaller than single-family homes

[518] Program-specific household factors may be utilized on the basis of sufficiently validated program evaluations.

[519] When Household type is unknown, a value of 96.5% may be used as a weighted average of 90% SF and 10% MF (96.5% = 100%*90% + 65%*10%) based on the PY8 split communicated by Navigant as part of the current evaluation.

[520] As a function of the method for determining savings impact of these devices, in-service rate effects are already incorporated into the savings value for heating_reduction above.

[521] $F_e$ is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a

29.3 = kWh per therm

%AC = Fraction of customers with thermostat-controlled air-conditioning

| Thermostat control of air conditioning? | %AC[522] |
|---|---|
| Yes | 100% |
| No | 0% |
| Unknown (AC-targeted program) | 99% |
| Unknown (general program) | 82.5% |

FLH = Estimate of annual household full load cooling hours for air conditioning equipment based on location and home type. If location and cooling type are unknown, assume the weighted average.

| Climate zone (city based upon) | FLH (single family) [523] | FLH (general multifamily) [524] | FLH_cooling (weatherized multi family) [525] |
|---|---|---|---|
| 1 (Rockford) | 512 | 467 | 243 |
| 2 (Chicago) | 570 | 506 | 263 |
| 3 (Springfield) | 730 | 663 | 345 |
| 4 (Belleville) | 1035 | 940 | 489 |
| 5 (Marion) | 903 | 820 | 426 |
| Weighted average[526] | 629 | 564 | 293 |

Use Multifamily if: Building has shared HVAC or meets utility's definition for multifamily

Capacity = Size of AC unit[527]. (Note: One refrigeration ton is equal to 12,000 Btu/hr)

= Use actual when program delivery allows size of AC unit to be known. If unknown assume 33,600 Btu/hr for single family homes, 28,000 Btu/hr for multifamily or 24,000

calculation based on the certified values for fuel energy (Ef in MMBTU/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STARversion 3 criteria for 2% $F_e$. See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference.

522 99% of ComEd PY8 program participants (AC targeted programs) have Central AC per communication with Navigant's ongoing 2017/2018 cooling savings evaluation. Non-targeted programs are still expected to have participation with %AC above general population rates. 82.5% is an average of the 99% program participation rate, and the 66% of homes in Illinois having central cooling ("Table HC7.9 Air Conditioning in Homes in Midwest Region, Divisions, and States, 2009 from Energy Information Administration", 2009 Residential Energy Consumption Survey ;

523 Full load hours for Chicago, Moline and Rockford are provided in "Final Evaluation Report: Central Air Conditioning Efficiency Services (CACES), 2010, Navigant Consulting", p.33. An average FLH/Cooling Degree Day (from NCDC) ratio was calculated for these locations and applied to the CDD of the other locations in order to estimate FLH. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

524 Ibid.

525 *All-Electric Homes PY6 Metering Results: Multifamily HVAC Systems*, Cadmus, October 2015

526 Weighted based on number of residential occupied housing units in each zone.

527 Actual unit size required for Multifamily building, no size assumption provided because the unit size and resulting savings can vary greatly depending on the number of units.

Btu/hr for mobile homes[528]. If building type is unknown, assume 31,864Btu/hr[529].

SEER = the cooling equipment's Seasonal Energy Efficiency Ratio rating (kBtu/kWh)

= Use actual SEER rating where it is possible to measure or reasonably estimate.

| Cooling System | SEER[530] |
|---|---|
| Air Source Heat Pump | 9.3 |
| Central AC | |

1/1000 = kBtu per Btu

Cooling_Reduction = Assumed average percentage reduction in total household cooling energy consumption due to installation of advanced thermostat[531]:

= 8%[532]

For example, an advanced thermostat replacing a programmable thermostat directly installed in an electric heat pump heated, single-family home in Springfield with advanced thermostat-controlled air conditioning of a system of unknown size and seasonal efficiency rating:

$\Delta kWH = \Delta kWh_{heating} + \Delta kWh_{cooling}$

$= 1 * 10{,}464 * 5.6\% * 100\% * 100\% + (0 * 0.0314 * 29.3) + 100\% * ((730 * 33{,}600 * (1/9.3))/1000) * 6.3\% * 100\%$

= 586kWh + 166 kWh

= 752 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$\Delta kW = \%AC * (Cooling\_Reduction * Btu/hr * (1/EER)/1000) * EFF\_ISR * CF$

Where:

EER = Energy Efficiency Ratio of existing cooling system (kBtu/hr / kW)

= Use actual EER rating where it is possible to measure or reasonably estimate. If EER unknown but SEER available convert using the equation:

[528] Single family cooling capacity based on Final Evaluation Report: Central Air Conditioning Efficiency Services (CACES), October 19, 2010, ComEd, Navigant Consulting. Multifamily capacity based on weighted average of PY9 Ameren and ComEd MF cooling capacities. Mobile home capacity based on ENERGY STAR's Manufactured Home Cooling Equipment Sizing Guidelines which vary by climate zone and home size. The average size of a mobile home in the East North Central region (1,120 square feet) from the 2015 RECS data is used to calculated appropriate size.

[529] Unknown is based on statewide weighted average of 69% single family and 31% multifamily, based on IL data from 2009 RECS Table HC2.9 Structural and Geographic Characteristics of Homes in Midwest Region, Divisions and States, 2009.

[530] Based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study Memo FINAL 2_28_2018'

[531] Note that "Cooling_Reduction" percentage is the savings expected from reduced cooling use, and is not the same as % cooling savings that are based on total kWh saved (including fan and heating kWh savings) as a percent of total kWh used for cooling.

[532] Note: In an effort to resolve potential disputes, without the need for litigation regarding the cooling reduction value in the IL-TRM for advanced thermostats, Stakeholders have reached through negotiation a separate stipulation that retains the 8% cooling reduction value in the 2019 IL-TRM Version 7.0, pending completion of a statewide advanced thermostat evaluation utilizing participant AMI data, and consistent with a Stipulation reached among stakeholders and the Program Administrators. Specifically, the parties have agreed to work collaboratively to develop an Illinois-specific advanced thermostat evaluation framework that utilizes AMI data, for consideration in updating the IL-TRM as soon as feasible, but no later than completing the evaluation in time for the 2021 IL-TRM Version 9.0, if practicable and, for Ameren Illinois, in a manner consistent with the timing of its AMI installation schedule.

$EER = (-0.02 * SEER\_exist^2) + (1.12 * SEER\_exist)$ [533]

If SEER or EER rating unavailable use:

| Cooling System | EER[534] |
|---|---|
| Air Source Heat Pump | 7.5 |
| Central AC | |

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)
= 34%[535]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period)
= 23.3%[536]

For example, an advanced thermostat replacing a programmable thermostat directly installed in an electric resistance heated, single-family home in Springfield with advanced thermostat-controlled air conditioning of a system of unknown size and seasonal efficiency rating:

$\Delta kW_{SSP}$ = 100% *( 6.3% * 33,600 * (1/7.5)/1000) * 100% * 34%
= 0.096 kW

$\Delta kW_{PJM}$ = 100% * (6.3% * 33,600 * (1/7.5)/1000) * 100% * 23.3%
= 0.066 kW

**NATURAL GAS ENERGY SAVINGS**

ΔTherms = %FossilHeat * Gas_Heating_Consumption * Heating_Reduction * HF * Eff_ISR

Where:

%FossilHeat = Percentage of heating savings assumed to be Natural Gas

| Heating fuel | %FossilHeat |
|---|---|
| Electric | 0% |
| Natural Gas | 100% |
| Unknown | 97%[537] |

Gas_Heating_Consumption

= Estimate of annual household heating consumption for gas heated single-family homes. If location is unknown, assume the average below[538].

533 From Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder.

534 Based on Opinion Dynamics and Cadmus metering study of Ameren HVAC program participants; See 'AIC HVAC Metering Study Memo FINAL 2_28_2018'.

535 Assumes 50% of the cooling coincidence factor (based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.)

536 Assumes 50% of the cooling coincidence factor (based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.)

537 Value used is based on known PY8 percent of electric heat provided by Navigant as part of the ongoing evaluation work source: "Slide 21: May 22, 2018, Second Addendum IL TRM Advanced Thermostat Cooling Savings Evaluation"

538 Values are based on adjusting the average household heating consumption (849 therms) for Chicago based on 'Table 3-4, Program Sample Analysis, Nicor R29 Res Rebate Evaluation Report 092611_REV FINAL to Nicor', calculating inferred heating load by dividing by average efficiency of new in program units in the study (94.4%) and then applying standard assumption of existing unit efficiency of 83% (estimate based on 24% of furnaces purchased in Illinois were condensing in 2000 (based on data from GAMA, provided to Department of Energy), assuming typical efficiencies: (0.24*0.92) + (0.76*0.8) = 0.83). This Chicago

| Climate Zone (City based upon) | Gas_Heating_ Consumption (therms) |
|---|---|
| 1 (Rockford) | 1,052 |
| 2 (Chicago) | 1,005 |
| 3 (Springfield) | 861 |
| 4 (Belleville) | 664 |
| 5 (Marion) | 676 |
| Average | 955 |

Other variables as provided above

For example, an advanced thermostat replacing a programmable thermostat directly-installed in a gas heated single-family home in Chicago:

ΔTherms = 1.0 * 1005 * 5.6% * 100% * 100%

= 56.28 therms

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-HVC-ADTH-V03-190101**

**REVIEW DEADLINE: 1/1/2020**

value was then adjusted to a statewide average using relative HDD assumptions to adjust for the evaluation results focus on northern region. Values for individual cities are then calculated by comparing average HDD to the individual city's HDD.

## 5.3.17 Gas High Efficiency Combination Boiler

### Description

Space heating boilers are pressure vessels that transfer heat to water for use in space heating. Boilers either heat water using a heat exchanger that works like an instantaneous water heater or by adding/connecting a separate tank with an internal heat exchanger to the boiler. A combination boiler contains a separate heat exchanger that heats water for domestic hot water use. Qualifying combination boilers must be whole-house units used for both space heating and domestic water heating with one appliance and energy source. Only participants who have a natural gas account with a participating natural gas utility are eligible for this rebate.

This measure was developed to be applicable to the following program types: TOS. If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

The efficient condition is a condensing combination boiler unit with boiler AFUE of 90% or greater. The combination boiler must have a sealed combustion unit and be capable of modulating the firing rate and must be accompanied by a programmed outdoor reset control.[539] Measures that do not qualify for this incentive include boilers with a storage tank and redundant or backup boilers.

### Definition of Baseline Equipment

The baseline condition is a boiler with the federal minimum of 82% AFUE and a residential, natural gas-fueled, 0.5803 UEF storage water heater.

In 2021, the federal minimum residential boiler efficiency is scheduled to increase to 84% AFUE.

### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 21.5 years.[540]

### Deemed Measure Cost

The incremental measure cost is assumed to be $3,522[541]

### Loadshape

N/A

### Coincidence Factor

N/A

[539] In a 2015 study, the Cadmus Group team conducted an analysis of optimal outdoor reset curves and discovered that "a boiler in Massachusetts with well-programmed outdoor reset controls could see an operating efficiency improvement of up to 3 to 4 percentage points from the average efficiency of 88.4% observed".

[540] US Department of Energy, Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Furnaces." February 10, 2015. Table 8.2.1, p. 8-23. The document's definition of furnaces includes hot water boilers with firing rates of less than 300,000 Btu/h.

[541] Northeast Energy Efficiency Partnerships. Incremental Cost Study Report. September 23, 2011. Incremental measure cost of $2,791.00 for a combination boiler and $2,461.00 for a high efficiency boiler sized at 110 Mbh. The percentage increase is applied to the current boiler incremental cost to provide a combination boiler cost of $3,521.72.

**Algorithm**

## CALCULATION OF ENERGY SAVINGS

### ELECTRIC ENERGY SAVINGS

N/A

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

### NATURAL GAS SAVINGS

$$\Delta Therms = \Delta Therm_{Boiler} + \Delta Therm_{WH}$$

$$\Delta Therms_{Boiler} = (EFLH * CAPInput * (AFUE(eff) / AFUE(base) - 1)) / 100000$$

$$\Delta Therms_{WH} = (1/UEF_{Base} - 1/UEF_{Eff}) * (GPD * Household * 365.25 * \gamma_{Water} * (T_{OUT} - T_{IN}) * 1.0)/100,000$$

Where:

CAPInput = Gas Furnace input capacity (Btuh)

= Actual

EFLH = Equivalent Full Load Hours for gas heating

| Climate Zone (City based upon) | EFLH[542] |
|---|---|
| 1 (Rockford) | 1022 |
| 2 (Chicago) | 976 |
| 3 (Springfield) | 836 |
| 4 (Belleville) | 645 |
| 5 (Marion) | 656 |
| Weighted Average[543] | 928 |

$AFUE_{Exist}$ = Existing boiler annual fuel utilization efficiency rating

= Use actual AFUE rating where it is possible to measure or reasonably estimate.

If unknown, assume 61.6 AFUE%.[544]

$AFUE_{Base}$ = Baseline boiler annual fuel utilization efficiency rating

= 82%

$AFUE_{Eff}$ = Efficent boiler annual fuel utilization efficiency rating

= Actual. If unknown, use defaults dependent[545] on tier as listed below:

[542] Full load hours for Chicago, are based on findings in 'Energy Efficiency / Demand Response Nicor Gas Plan Year 1 (6/1/2011-5/31/2012) Research Report: Furnace Metering Study (August 1, 2013), prepared by Navigant Consulting, Inc. Values for other cities are then calculated by comparing relative HDD at base 60F.
[543] Weighted based on number of occupied residential housing units in each zone.
[544] Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren PY3-PY4.
[545] Default values per tier selected based upon the average AFUE value for the tier range except for the top tier where the minimum is used due to proximity to the maximum possible.

| Measure Type | $AFUE_{Eff}$ |
|---|---|
| AFUE ≥ 90% | 92.5% |
| AFUE ≥ 95% | 95% |

$UEF_{Base}$ = Uniform Energy Factor rating for baseline equipment

= For ≤55 gallons: 0.6483 – (0.0017 * storage capacity in gallons)

= For >55 gallons: 0.7897 − (0.0004 × storage capacity in gallons)

= If tank size unknown for SF assume 40 gallons and $UEF_{Base}$ of 0.58

= If tank size unknown for MF assume 30 gallons and $UEF_{Base}$ of 0.54

Use Multifamily if: Building meets utility's definition for multifamily

$UEF_{Eff}$ =Uniform Energy Factor rating for efficient combination boiler. This is assumed consistent with a condensing instantaneous gas-fired water heater.

= 0.933[546]

GPD = Gallons per day of hot water use per person

= 45.5 gallons hot water per day per household/2.59 people per household[547]

= 17.6

Household = Average number of people per household

| Household Unit Type | Household |
|---|---|
| Single-Family - Deemed | 2.56[548] |
| Multifamily - Deemed | 2.1[549] |
| Custom | Actual Occupancy or Number of Bedrooms[550] |

Use Multifamily if: Building meets utility's definition for multifamily

365.25 = Days per year, on average

$\gamma_{Water}$ = Specific weight of water

= 8.33 pounds per gallon

$T_{OUT}$ = Tank temperature

= 125°F

$T_{IN}$ = Incoming water temperature from well or municipal system

= 54°F[551]

---

546 Average Uniform Energy Factor from DOE CCMS of condensing instantaneous gas-fired water heaters. The water heater portion of a gas high efficiency combination boiler is essentially a tankless water heater.

547 Deoreo, B., and P. Mayer. Residential End Uses of Water Study Update. Forthcoming. ©2015 Water Research Foundation. Reprinted With Permission.

548 ComEd Energy Efficiency/ Demand Response Plan: Plan Year 2 (6/1/2009-5/31/2010) Evaluation Report: All Electric Single Family Home Energy Performance Tune-Up Program citing 2006-2008 American Community Survey data from the US Census Bureau for Illinois cited on p. 17 of the PY2 Evaluation report. 2.75 * 93% evaluation adjustment

549 Navigant, ComEd PY3 Multifamily Home Energy Savings Program Evaluation Report Final, May 16, 2012.

550 Bedrooms are suitable proxies for household occupancy, and may be preferable to actual occupancy due to turnover rates in residency and non-adult population impacts.

551 US DOE Building America Program. Building America Analysis Spreadsheet.

1.0 = Heat capacity of water (1 Btu/lb*°F)

For example, a Rockford single-family home installing a 80,000 Btuh condensing combination boiler unit with boiler AFUE of 95%:

$\Delta Therms_{Boiler}$ = (1022 * 80,000 * (0.95/0.82 - 1))/100000

$\Delta Therms_{WH}$ = (1/0.5803 – 1/0.933) * (17.6 * 2.56 * 365.25 * 8.33 * (125-54) *1.0 )/100,000

ΔTherms = 129.6 + 63.4

= 193.0 Therms

**WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-HVC-COMB-V01-190101**

**REVIEW DEADLINE: 1/1/2023**

# 5.4 Hot Water End Use

## 5.4.1 Domestic Hot Water Pipe Insulation

**DESCRIPTION**

This measure describes adding insulation to un-insulated domestic hot water pipes. The measure assumes the pipe wrap is installed to the first length of both the hot and cold pipe up to the first elbow. This is the most cost effective section to insulate since the water pipes act as an extension of the hot water tank up to the first elbow which acts as a heat trap. Insulating this length therefore helps reduce standby losses. Default savings are provided per 3ft length and are appropriate up to 6ft of the hot water pipe and 3ft of the cold.

This measure was developed to be applicable to the following program types: TOS, NC, RF.

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

The efficient case is installing pipe wrap insulation to a length of hot water pipe.

**DEFINITION OF BASELINE EQUIPMENT**

The baseline is an un-insulated hot water pipe.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The measure life is assumed to be 15 years[552].

**DEEMED MEASURE COST**

The measure cost including material and installation is assumed to be $3 per linear foot[553].

**LOADSHAPE**

Loadshape C53 - Flat

**COINCIDENCE FACTOR**

This measure assumes a flat loadshape since savings relate to reducing standby losses and as such the coincidence factor is 1.

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

For electric DHW systems:

$$\Delta kWh = ((C_{exist} / R_{exist} - C_{new} / R_{new})) * L * \Delta T * 8{,}766) / \eta DHW / 3412$$

Where:

Rexist = Pipe heat loss coefficient of uninsulated pipe (existing) [(hr-°F-ft)/Btu]

[552] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
[553] Consistent with DEER 2008 Database Technology and Measure Cost Data (www.deeresources.com).

= 1.0[554]

Rnew = Pipe heat loss coefficient of insulated pipe (new) [(hr-°F-ft)/Btu]

= Actual (1.0 + R value of insulation)

L = Length of pipe from water heating source covered by pipe wrap (ft)

= Actual

$C_{exist}$ = Circumference of pipe (ft) (Diameter (in) * π/12)

= Actual (0.5” pipe = 0.131ft, 0.75” pipe = 0.196ft)

$C_{new}$ = Circumference of pipe (ft) (Diameter (in) * π/12)

= Actual (0.5” pipe and 3/8” foam ((0.5 + 3/8 + 3/8) * π/12) = .327 ft)

ΔT = Average temperature difference between supplied water and outside air temperature (°F)

= 60°F [555]

8,766 = Hours per year

ηDHW = Recovery efficiency of electric hot water heater

= 0.98 [556]

3412 = Conversion from Btu to kWh

For example, insulating 5 feet of 0.75” pipe with R-5 wrap:

$$\Delta kWh = ((C_{exist} / R_{exist} - C_{new} / R_{new}) * L * \Delta T * 8{,}766) / \eta DHW / 3412$$

$$= ((0.196/1 - 0.327/5) * 5 * 60 * 8766) / 0.98 / 3412$$

$$= 106 \text{ kWh}$$

If inputs above are not available the following default per 3ft R-5 length can be used for up to 6 ft length on the hot pipe and 3 ft on the cold pipe.

$$\Delta kWh = ((C_{exist} / R_{exist} - C_{new} / R_{new}) * L * \Delta T * 8{,}766) / \eta DHW / 3412$$

$$= ((0.196/1 - 0.327/5) * 3 * 60 * 8766) / 0.98 / 3412$$

$$= 64 \text{kWh per 3ft length}$$

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$$\Delta kW = \Delta kWh / 8766$$

Where:

ΔkWh = kWh savings from pipe wrap installation

8766 = Number of hours in a year (since savings are assumed to be constant over year).

[554] Navigant Consulting Inc., April 2009; “Measures and Assumptions for Demand Side Management (DSM) Planning; Appendix C Substantiation Sheets”, p77.

[555] Assumes 125°F water leaving the hot water tank and average temperature of basement of 65°F.

[556] Electric water heaters have recovery efficiency of 98%.

For example, insulating 5 feet of 0.75" pipe with R-5 wrap:

$\Delta kW = 106/8766$

$= 0.0121 kW$

If inputs above are not available the following default per 3ft R-4 length can be used for up to 6 ft length on the hot pipe and 3 ft on the cold pipe.

$\Delta kW = 64/8766$

$= 0.0073\ kW$

**NATURAL GAS SAVINGS**

For Natural Gas DHW systems:

$$\Delta Therm = ((C_{exist} / R_{exist} - C_{new} / R_{new}) * L * \Delta T * 8{,}766) / \eta DHW / 100{,}000$$

Where:

ηDHW = Recovery efficiency of gas hot water heater

= 0.78 [557]

Other variables as defined above

For example, insulating 5 feet of 0.75" pipe with R-5 wrap:

$\Delta Therm = ((0.196/1 - 0.327/5) * 5 * 60 * 8766) / 0.78 / 100{,}000$

$= 4.40$ therms

If inputs above are not available the following default per 3ft R-4 length can be used for up to 6ft length on the hot pipe and 3ft on the cold pipe.

$$\Delta Therm = ((C_{exist} / R_{exist} - C_{new} / R_{new}) * L * \Delta T * 8{,}766) / \eta DHW / 100{,}000$$

$$= ((0.196/1 - 0.327/5) * 3 * 60 * 8766) / 0.78 / 100{,}000$$

$= 2.64$ therms per 3ft length

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-HWE-PINS-V03-190101**

**REVIEW DEADLINE: 1/1/2022**

[557] Review of AHRI Directory suggests range of recovery efficiency ratings for new Gas DHW units of 70-87%. Average of existing units is estimated at 78%

## 5.4.2 Gas Water Heater

**DESCRIPTION**

This measure characterizes:

a) Time of sale or new construction:
The purchase and installation of a new efficient gas-fired water heater, in place of a Federal Standard unit in a residential setting. Savings are provided for power-vented, condensing storage, and whole-house tankless units meeting specific Uniform Energy Factor (UEF) criteria.

b) Early replacement:
The early removal of an existing functioning natural gas water heater from service, prior to its natural end of life, and replacement with a new high efficiency unit. Savings are calculated between existing unit and efficient unit consumption during the remaining life of the existing unit, and between new baseline unit and efficient unit consumption for the remainder of the measure life.

This measure was developed to be applicable to the following program types: TOS, NC, EREP.

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

To qualify for this measure, the installed equipment must be a residential gas-fired storage water heater or tankless water heater meeting ENERGY STAR criteria.[558]

| Water Heater Type | Water Heater Volume (gallons) | Minimum Uniform Energy Factor |
|---|---|---|
| Gas Storage | ≤ 55 | ≥ 0.64 |
| | > 55 | ≥ 0.78 |
| Gas Instantaneous | All | ≥ 0.87 |

**DEFINITION OF BASELINE EQUIPMENT**

Time of Sale or New Construction: The baseline equipment is assumed to be a new, gas-fired storage residential water heater meeting minimum Federal efficiency standards. For storage water heaters with a storage capacity equal to or less than 55 gallons, the Federal energy factor requirement is calculated as 0.6483 – (0.0017 * storage capacity in gallons) and 0.7897 − (0.0004 × storage capacity in gallons) for greater than 55 gallon storage water heaters.[559] For a 40-gallon storage water heater this would be 0.58 UEF.

Early Replacement: The baseline is the efficiency of the existing gas water heater for the remaining useful life of the unit and the efficiency of a new gas water heater of the same type meeting minimum Federal efficiency standards for the remainder of the measure life.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected measure life is assumed to be 13 years.[560]

---

[558] ENERGY STAR Product Specification for Residential Water Heaters, Version 3.2, effective April 16, 2015

[559] Minimum Federal standard as of 4/16/2015.

[560] DOE, 2010 Residential Heating Products Final Rule Technical Support Document, Table 8.2.14. Note: This source is used to support this category in aggregate. For all water heaters, life expectancy will depend on local variables such as water chemistry and homeowner maintenance. Some categories, including condensing storage and tankless water heaters do not yet have sufficient field data to support separate values. Preliminary data show lifetimes may exceed 20 years, though this has yet to be sufficiently demonstrated.

For early replacement: Remaining life of existing equipment is assumed to be 4 years[561].

### DEEMED MEASURE COST

Time of Sale or New Construction:

The incremental capital cost for this measure is dependent on the type of water heater as listed below[562].

Early Replacement: The full installed cost is provided in the table below. The assumed deferred cost (after 4 years) of replacing existing equipment with a new baseline unit is assumed to be $650[563]. This cost should be discounted to present value using the nominal discount rate.

| Water heater Type | Incremental Cost | Full Install Cost |
|---|---|---|
| Gas Storage | $400 | $1014 |
| Condensing gas storage | $685 | $1299 |
| Tankless whole-house unit | $605 | $1219 |

### LOADSHAPE

N/A

### COINCIDENCE FACTOR

N/A

## Algorithm

### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

N/A

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

### NATURAL GAS ENERGY SAVINGS

Time of Sale or New Construction:

$$\Delta Therms = (1/\ UEF_{BASE} - 1/UEF_{EFFICIENT}) * (GPD * Household * 365.25 * \gamma Water * (T_{OUT} - T_{IN}) * 1.0\ )/100{,}000$$

Early replacement[564]:

ΔTherms for remaining life of existing unit (1st 3.7 years for gas storage unit and 1st 6.7 years for gas tankless unit):

$$= (1/\ UEF_{EXISTING} - 1/UEF_{EFFICIENT}) * (GPD * Household * 365.25 * \gamma Water * (T_{OUT} - T_{IN}) * 1.0\ )/100{,}000$$

---

561 Assumed to be one third of effective useful life

562 Source for cost info; DOE, 2010 Residential Heating Products Final Rule Technical Support Document, Table 8.2.14.

563 The deemed install cost of a Gas Storage heater is based upon DCEO Efficient Living Program Data for a sample size of 157 gas water heaters, and applying inflation rate of 1.91%.

564 The two equations are provided to show how savings are determined during the initial phase of the measure (existing to efficient) and the remaining phase (new baseline to efficient). In practice, the screening tools used may either require a First Year savings (using the first equation) and then a “number of years to adjustment” and “savings adjustment” input which would be the (new base to efficient savings)/(existing to efficient savings).

ΔTherms for remaining measure life (next 7.3 years for gas storage unit and next 13.3 years for gas tankless unit):

$$= (1/ UEF_{BASE} - 1/UEF_{EFFICIENT}) * (GPD * Household * 365.25 * \gamma Water * (T_{OUT} – T_{IN}) * 1.0 )/100,000$$

Where:

UEF_Baseline = Uniform Energy Factor rating of standard storage water heater according to federal standards[565]

= For gas storage water heaters ≤55 gallons: 0.6483 – (0.0017 * storage capacity in gallons)

= For gas storage water heaters >55 gallons: 0.7897 − (0.0004 × storage capacity in gallons)

= If tank size is unknown, assume 0.563 for a gas storage water heater with a 50-gallon storage capacity

UEF_Efficient = Uniform Energy Factor Rating for efficient equipment

= Actual. If Tankless whole-house multiply rated efficiency by 0.91[566]. If unknown assume 0.64 for gas storage water heaters ≤55 gallons, 0.78 for gas storage water heaters >55 gallons, and 0.79 for gas tankless water heaters[567]

UEF_Existing = Uniform Energy Factor rating for existing equipment

= Use actual UEF rating where it is possible to measure or reasonably estimate.

= if unknown assume 0.52 [568]

GPD = Gallons Per Day of hot water use per person

= 45.5 gallons hot water per day per household/2.59 people per household[569]

= 17.6

Household = Average number of people per household

| Household Unit Type | Household |
|---|---|
| Single-Family - Deemed | 2.56[570] |
| Multifamily - Deemed | 2.1[571] |
| Custom | Actual Occupancy or Number of Bedrooms[572] |

[565] Minimum Federal standard as of 4/16/2015

[566] The disconnect between rated energy factor and in-situ energy consumption is markedly different for tankless units due to significantly higher contributions to overall household hot water usage from short draws. In tankless units the large burner and unit heat exchanger must fire and heat up for each draw. The additional energy losses incurred when the mass of the unit cools to the surrounding space in-between shorter draws was found to be 9% in a study prepared for Lawrence Berkeley National Laboratory by Davis Energy Group, 2006. "Field and Laboratory Testing of Tankless Gas Water Heater Performance" Due to the similarity (storage) between the other categories and the baseline, this derating factor is applied only to the tankless category.

[567] ENERGY STAR Product Specification for Residential Water Heaters, Version 3.2, effective April 16, 2015.

[568] Based on DCEO Efficient Living Program Data for a sample size of 157 gas water heaters.

[569] Deoreo, B., and P. Mayer. Residential End Uses of Water Study Update. Forthcoming. ©2015 Water Research Foundation. Reprinted With Permission.

[570] ComEd Energy Efficiency/ Demand Response Plan: Plan Year 2 (6/1/2009-5/31/2010) Evaluation Report: All Electric Single Family Home Energy Performance Tune-Up Program citing 2006-2008 American Community Survey data from the US Census Bureau for Illinois cited on p. 17 of the PY2 Evaluation report. 2.75 * 93% evaluation adjustment

[571] Navigant, ComEd PY3 Multifamily Home Energy Savings Program Evaluation Report Final, May 16, 2012.

[572] Bedrooms are suitable proxies for household occupancy, and may be preferable to actual occupancy due to turnover rates in residency and non-adult population impacts.

| | |
|---|---|
| | Use Multifamily if: Building meets utility's definition for multifamily |
| 365.25 | = Days per year, on average |
| γWater | = Specific Weight of water |
| | = 8.33 pounds per gallon |
| $T_{OUT}$ | = Tank temperature |
| | = 125°F |
| $T_{IN}$ | = Incoming water temperature from well or municipal system |
| | = 54°F[573] |
| 1.0 | = Heat Capacity of water (1 Btu/lb*°F) |

For example, a 40 gallon condensing gas storage water heater, with a uniform energy factor of 0.80 in a single family house:

ΔTherms = (1/0.58 - 1/0.80) * (17.6 * 2.56 * 365.25* 8.33 * (125 – 54) * 1) / 100,000

= 46.15 therms

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-HWE-GWHT-V08-190101**

**REVIEW DEADLINE: 1/1/2022**

[573] US DOE Building America Program. Building America Analysis Spreadsheet.

## 5.4.3 Heat Pump Water Heaters

### DESCRIPTION

The installation of a heat pump domestic hot water heater in place of a standard electric water heater in a home. Savings are presented dependent on the heating system installed in the home due to the impact of the heat pump water heater on the heating loads.

This measure was developed to be applicable to the following program types: TOS, NC, RF.
If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed equipment must be an ENERGY STAR Heat Pump domestic water heater[574].

### DEFINITION OF BASELINE EQUIPMENT

The baseline condition is a new electric water heater meeting federal minimum efficiency standards[575], dependent on the storage volume (in gallons) of the water heater.

For units ≤55 gallons – resistance storage unit with efficiency: 0.9307 – (0.0002 * rated volume in gallons)

For units >55 gallons – assume a 50 gallon resistance tank baseline[576] i.e. 0.9207 UEF.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years.[577]

Note a mid-life adjustment to account for replacement of HVAC equipment during the measure life should be applied after 10 years or 13 years for boilers[578]. See section below for detail.

### DEEMED MEASURE COST

For Time of Sale or New Construction the incremental installation cost (including labor) should be used. Defaults are provided below[579]. Actual efficient costs can also be used although care should be taken as installation costs can vary significantly due to complexities of a particular site.

For retrofit costs, the actual full installation cost should be used (default provided below if unknown).

| Capacity | Efficiency Range | Baseline Installed Cost | Efficient Installed Cost | Incremental Installed Cost |
|---|---|---|---|---|
| ≤55 gallons | <2.6 UEF | $1,032 | $2,062 | $1,030 |
| | ≥2.6 UEF | $1,032 | $2,231 | $1,199 |
| >55 gallons | <2.6 UEF | $1,319 | $2,432 | $1,113 |

574 If the water heater does not have a UEF rating, but a EF rating, revert to using the previous version of this measure.
575 Minimum Federal Standard as of 4/1/2015, and updated in a Supplemental Notice of Proposed Rulemaking in 2016 assuming medium draw pattern.
576 A 50 gallon volume tank for the baseline is assumed to capture market practice of using larger heat pump water heaters to achieve greater efficiency of the heat pump cycle and preventing the unit from going in electric resistance mode.
577 As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.
578 This is intentionally longer than the assumptions found in the early replacement measures as the application of this measure will occur in a variety of homes that will not be targeted for early replacement HVAC systems.
579 Costs for <2.6 UEF are based upon averages from the NEEP Phase 3 Incremental Cost Study. The assumption for higher efficiency tanks is based upon averaged from NEEP Phase 4 Incremental Cost Study. See 'HPWH Cost Estimation.xls' for more information.

| Capacity | Efficiency Range | Baseline Installed Cost | Efficient Installed Cost | Incremental Installed Cost |
|---|---|---|---|---|
| | ≥2.6 UEF | $1,319 | $3,116 | $1,797 |

**LOADSHAPE**

Loadshape R03 - Residential Electric DHW

**COINCIDENCE FACTOR**

The summer Peak Coincidence Factor is assumed to be 12%.[580]

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

$\Delta kWh = (((1/UEF_{BASE} - 1/UEF_{EFFICIENT}) * GPD * Household * 365.25 * \gamma Water * (T_{OUT} - T_{IN}) * 1.0) / 3412) + kWh\_cooling - kWh\_heating$

Where:

$UEF_{BASE}$ = Uniform Energy Factor (efficiency) of standard electric water heater according to federal standards[581]:

For <=55 gallons: 0.96 – (0.0003 * rated volume in gallons)

For >55 gallons: 2.057 – (0.00113 * rated volume in gallons)

= If unknown volume, use 0.945 for a 50 gallon tank, the most common size for HPWH

$UEF_{EFFICIENT}$ = Uniform Energy Factor (efficiency) of Heat Pump water heater

= Actual

GPD = Gallons Per Day of hot water use per person

= 45.5 gallons hot water per day per household/2.59 people per household[582]

= 17.6

Household = Average number of people per household

| Household Unit Type | Household |
|---|---|
| Single-Family - Deemed | 2.56[583] |
| Multifamily - Deemed | 2.1[584] |
| Custom | Actual Occupancy or |

[580] Calculated from Figure 8 "Combined six-unit summer weekday average electrical demand" in FEMP study; 'Field Testing of Pre-Production Prototype Residential Heat Pump Water Heaters' as (average kW usage during peak period * hours in peak period) / [(annual kWh savings / FLH) * hours in peak period] = (0.1 kW * 5 hours) / [(2100 kWh (default assumptions) / 2533 hours) * 5 hours] = 0.12
[581] Minimum Federal Standard as of 1/1/2015.
[582] Deoreo, B., and P. Mayer. Residential End Uses of Water Study Update. Forthcoming. ©2015 Water Research Foundation. Reprinted With Permission.
[583] ComEd Energy Efficiency/ Demand Response Plan: Plan Year 2 (6/1/2009-5/31/2010) Evaluation Report: All Electric Single Family Home Energy Performance Tune-Up Program citing 2006-2008 American Community Survey data from the US Census Bureau for Illinois cited on p. 17 of the PY2 Evaluation report. 2.75 * 93% evaluation adjustment
[584] Navigant, ComEd PY3 Multifamily Home Energy Savings Program Evaluation Report Final, May 16, 2012.

| Household Unit Type | Household |
|---|---|
| | Number of Bedrooms[585] |

Use Multifamily if: Building meets utility's definition for multifamily

365.25 = Days per year

γWater = Specific weight of water

= 8.33 pounds per gallon

$T_{OUT}$ = Tank temperature

= 125°F

$T_{IN}$ = Incoming water temperature from well or municiple system

= 54°F[586]

1.0 = Heat Capacity of water (1 Btu/lb*°F)

3412 = Conversion from Btu to kWh

kWh_cooling[587] = Cooling savings from conversion of heat in home to water heat

$$=(((((GPD * Household * 365.25 * \gamma Water * (T_{OUT} - T_{IN}) * 1.0) / 3412) - ((1/ UEF_{NEW} * GPD * Household * 365.25 * \gamma Water * (T_{OUT} - T_{IN}) * 1.0) / 3412)) * LF * 27\%) / COP_{COOL}) * LM$$

Where:

LF = Location Factor

= 1.0 for HPWH installation in a conditioned space

= 0.5 for HPWH installation in an unknown location

= 0.0 for installation in an unconditioned space

27% = Portion of reduced waste heat that results in cooling savings[588]

$COP_{COOL}$ = COP of central air conditioning

= Actual, if unknown, assume 2.8 [589]

LM = Latent multiplier to account for latent cooling demand

= 1.33 [590]

kWh_heating = Heating cost from conversion of heat in home to water heat (dependent on heating fuel)

---

[585] Bedrooms are suitable proxies for household occupancy, and may be preferable to actual occupancy due to turnover rates in residency and non-adult population impacts.

[586] US DOE Building America Program. Building America Analysis Spreadsheet.

[587] This algorithm calculates the heat removed from the air by subtracting the HPWH electric consumption from the total water heating energy delivered. This is then adjusted to account for location of the HP unit and the coincidence of the waste heat with cooling requirements, the efficiency of the central cooling and latent cooling demands.

[588] REMRate determined percentage (27%) of lighting savings that result in reduced cooling loads (lighting is used as a proxy for hot water heating since load shapes suggest their seasonal usage patterns are similar).

[589] Starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm (-0.02 * SEER2) + (1.12 * SEER) (from Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), converted to COP = EER/3.412 = 2.8COP.

[590] A sensible heat ratio (SHR) of 0.75 corresponds to a latent multiplier of 4/3 or 1.33. SHR of 0.75 for typical split system from page 10 of "Controlling Indoor Humidity Using Variable-Speed Compressors and Blowers" by M. A. Andrade and C. W. Bullard, 1999.

$= (((((GPD * Household * 365.25 * \gamma Water * (T_{OUT} – T_{IN}) * 1.0) / 3412) –$

$((1/ UEF_{NEW} * GPD * Household * 365.25 * \gamma Water * (T_{OUT} – T_{IN}) * 1.0) / 3412)) * LF * 49\%) / COP_{HEAT}) * (1 - \%NaturalGas)$

Where:

49% = Portion of reduced waste heat that results in increased heating load[591]

$COP_{HEAT}$ = COP of electric heating system

= actual. If not available use[592]:

| System Type | Age of Equipment | HSPF Estimate | $COP_{HEAT}$ (COP Estimate) = (HSPF/3.413)*0.85 |
|---|---|---|---|
| Heat Pump | Before 2006 | 6.8 | 1.7 |
| | After 2006 - 2014 | 7.7 | 1.92 |
| | 2015 on | 8.2 | 2.04 |
| Resistance | N/A | N/A | 1.00 |
| Unknown[593] | N/A | N/A | 1.28 |

For example, a 2.0 UEF heat pump water heater, in a conditioned space in a single family home with gas space heat and central air conditioning (SEER 10.5) in Belleville:

ΔkWh = [(1 / 0.945 – 1 / 2.0) * 17.6 * 2.56 * 365.25* 8.33 * (125 – 54)] / 3412 + 188.9 - 0

= 1781kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = ΔkWh / Hours * CF

Where:

Hours = Full load hours of water heater

= 2533 [594]

CF = Summer Peak Coincidence Factor for measure

= 0.12 [595]

591 REMRate determined percentage (49%) of lighting savings that result in increased heating loads (lighting is used as a proxy for hot water heating since load shapes suggest their seasonal usage patterns are similar).

592 These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate. Note efficiency should include duct losses. Defaults provided assume 15% duct loss for heat pumps.

593 Calculation assumes 35% Heat Pump and 65% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see "HC6.9 Space Heating in Midwest Region.xls", using average for East North Central Region. Average efficiency of heat pump is based on assumption that 50% are units from before 2006 and 50% from 2006-2014. Program or evaluation data should be used to improve this assumption if available.

594 Full load hours assumption based on Efficiency Vermont analysis of Itron eShapes.

595 Calculated from Figure 8 "Combined six-unit summer weekday average electrical demand" in FEMP study; 'Field Testing of Pre-Production Prototype Residential Heat Pump Water Heaters' as (average kW usage during peak period * hours in peak period) / [(annual kWh savings / FLH) * hours in peak period] = (0.1 kW * 5 hours) / [(2100 kWh / 2533 hours) * 5 hours] = 0.12

For example, a 2.0 UEF heat pump water heater, in a conditioned space in a single family home with gas space heat and central air conditioning in Belleville:

kW = 1838 / 2533 * 0.12

= 0.087kW

**NATURAL GAS SAVINGS**

ΔTherms = - ((((GPD * Household * 365.25 * γWater * ($T_{OUT}$ – $T_{IN}$) * 1.0) / 3412) – (((GPD * Household * 365.25 * γWater * ($T_{OUT}$ – $T_{IN}$) * 1.0) / 3412) / $UEF_{EFFICIENT}$)) * LF * 49% * 0.03412) / ηHeat) * %NaturalGas

Where:

ΔTherms = Heating cost from conversion of heat in home to water heat for homes with Natural Gas heat.[596]

0.03412 = conversion factor (therms per kWh)

ηHeat = Efficiency of heating system

= Actual.[597] If not available use 70%.[598]

%NaturalGas = Factor dependent on heating fuel:

| Heating System | %NaturalGas |
|---|---|
| Electric resistance or heat pump | 0% |
| Natural Gas | 100% |
| Unknown heating fuel[599] | 87% |

Other factors as defined above

For example, a 2.0 COP heat pump water heater in conditioned space, in a single family home with gas space heat (70% system efficiency):

ΔTherms = -((((17.6 * 2.56 * 365.25* 8.33 * (125 – 54) * 1.0) / 3412) – (17.6 * 2.56 * 365.25* 8.33 * (125 – 54) * 1.0 / 3412 / 2.0)) * 1 * 0.49 * 0.03412) / (0.7 * 1)

= - 34.1 therms

[596] This is the additional energy consumption required to replace the heat removed from the home during the heating season by the heat pump water heater. kWh_heating (electric resistance) is that additional heating energy for a home with electric resistance heat (COP 1.0). This formula converts the additional heating kWh for an electric resistance home to the MMBtu required in a Natural Gas heated home, applying the relative efficiencies.

[597] Ideally, the System Efficiency should be obtained either by recording the AFUE of the unit, or performing a steady state efficiency test. The Distribution Efficiency can be estimated via a visual inspection and by referring to a look up table such as that provided by the Building Performance Institute: (see 'DistributionEfficiencyTable-BlueSheet.pdf') or by performing duct blaster testing.

[598] This has been estimated assuming that natural gas central furnace heating is typical for Illinois residences (66% of Illinois homes have a Natural Gas Furnace (based on Energy Information Administration, 2009 Residential Energy Consumption Survey). In 2000, 24% of furnaces purchased in Illinois were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 10 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows:

(0.24*0.92) + (0.76*0.8) * (1-0.15) = 0.70

[599] 2010 American Community Survey.

**Mid-Life adjustment**

In order to account for the likely replacement of existing heating and cooling equipment during the lifetime of this measure, a mid-life adjustment should be applied. To calculate the adjustment, re-calculate the savings above using the following new baseline system efficiency assumptions:

| Efficiency Assumption | System Type | New Baseline Efficiency |
|---|---|---|
| ηCool | Central AC | 13 SEER |
| | Heat Pump | 14 SEER |
| ηHeat | Electric Resistance | 1.0 COP |
| | Heat Pump<br>(8.2HSPF/3.413)*0.85 | 2.04 COP |
| | Furnace<br>90% AFUE * 0.85 | 76.5% AFUE |
| | Boiler | 82% AFUE |

This reduced annual savings should be applied following the assumed remaining useful life of the existing equipment, estimate to be 10 years or 13 years for boilers[600].

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-HWE-HPWH-V07-190101**

**REVIEW DEADLINE: 1/1/2022**

[600] This is intentionally longer than the assumption found in the early replacement measures as the application of this measure will occur in a variety of homes and will not be targeting those homes appropriate for early replacement HVAC systems.

## 5.4.4 Low Flow Faucet Aerators

### Description

This measure relates to the installation of a low flow faucet aerator in a household kitchen or bath faucet fixture.

This measure may be used for units provided through Efficiency Kits however the in service rate for such measures should be derived through evaluation results specifically for this implementation methodology.

This measure was developed to be applicable to the following program types: TOS, NC, RF, DI, KITS.

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

To qualify for this measure the installed equipment must be a low flow faucet aerator, for bathrooms rated at 1.5 gallons per minute (GPM) or less, or for kitchens rated at 2.2 GPM or less. Savings are calculated on an average savings per faucet fixture basis.

### Definition of Baseline Equipment

The baseline condition is assumed to be a standard bathroom faucet aerator rated at 2.2 GPM or greater, or a standard kitchen faucet aerator rated at 2.2 GPM or greater.

Average measured flow rates are used in the algorithm and are lower, reflecting the penetration of previously installed low flow fixtures (and therefore the freerider rate for this measure should be 0), use of the faucet at less than full flow, debris buildup, and lower water system pressure than fixtures are rated at.

### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 10 years.[601]

### Deemed Measure Cost

For time of sale or new construction the incremental cost for this measure is $3[602] or program actual.

For faucet aerators provided through Direct Install or within Efficiency Kits, the actual program delivery costs (including labor if applicable) should be utilized. If unknown assume $8[603] for Direct Install and $3 for Efficiency Kits.

### Loadshape

Loadshape R03 - Residential Electric DHW

### Coincidence Factor

The coincidence factor for this measure is assumed to be 2.2%.[604]

---

[601] As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.

[602] 2011, Market research average of $3.

[603] Includes assess and install labor time of $5 (20min @ $15/hr)

[604] Calculated as follows: Assume 18% aerator use takes place during peak hours (based on: Oreo et al, "The end uses of hot water in single family homes from flow trace analysis", 2001.) There are 65 days in the summer peak period, so the percentage of total annual aerator use in peak period is 0.18*65/365 = 3.21%. The number of hours of recovery during peak periods is therefore assumed to be 3.21% *180 = 5.8 hours of recovery during peak period where 180 equals the average annual electric DHW recovery hours for faucet use including SF and MF homes. There are 260 hours in the peak period so the probability you will see savings during the peak period is 5.8/260 = 0.022

**Algorithm**

### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

Note these savings are *per* faucet retrofitted[605] (unless faucet type is unknown, then it is per household).

ΔkWh = %ElectricDHW * ((GPM_base * L_base - GPM_low * L_low) * Household * 365.25 *DF / FPH) * EPG_electric * ISR

Where:

%ElectricDHW = proportion of water heating supplied by electric resistance heating

| DHW fuel | %ElectricDHW |
|---|---|
| Electric | 100% |
| Natural Gas | 0% |
| Unknown | 16%[606] |

GPM_base = Average flow rate, in gallons per minute, of the baseline faucet "as-used." This includes the effect of existing low flow fixtures and therefore the freerider rate for this measure should be 0.

= If unknown assume values in table below, or custom based on metering studies[607], or if measured during DI:

= Measured full throttle flow * 0.83 throttling factor[608]

| Faucet Type | GPM[609] |
|---|---|
| Kitchen | 1.63 |
| Bathroom | 1.53 |
| If faucet location unknown | 1.58 |

GPM_low = Average flow rate, in gallons per minute, of the low-flow faucet aerator "as-used"

[605] This algorithm calculates the amount of energy saved per aerator by determining the fraction of water consumption savings for the upgraded fixture.

[606] Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IL. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used

[607] Measurement should be based on actual average flow consumed over a period of time rather than a onetime spot measurement for maximum flow. Studies have shown maximum flow rates do not correspond well to average flow rate due to occupant behavior which does not always use maximum flow.

[608] 2008, Schultdt, Marc, and Debra Tachibana. Energy related Water Fixture Measurements: Securing the Baseline for Northwest Single Family Homes. 2008 ACEEE Summer Study on Energy Efficiency in Buildings. Page 1-265. www.seattle.gov/light/Conserve/Reports/paper_10.pdf

[609] Based on flow meter bag testing conducted from June 2013 to January 2014 by Franklin Energy. Over 300 residential sites in the Chicago area were tested.

= 0.94[610] or custom based on metering studies[611] or if measured during DI:

= Rated full throttle flow * 0.95 throttling factor[612]

L_base = Average baseline daily length faucet use per capita for faucet of interest in minutes

= if available custom based on metering studies, if not use:

| Faucet Type | L_base (min/person/day) |
|---|---|
| Kitchen | 4.5[613] |
| Bathroom | 1.6[614] |
| If faucet location unknown (total for household): Single-Family except mobile homes | 9.0[615] |
| If location unknown (total for household): Multifamily and mobile homes | 6.9[616] |
| If faucet location and building type unknown (total for household) | 8.3[617] |

L_low = Average retrofit daily length faucet use per capita for faucet of interest in minutes

= if available custom based on metering studies, if not use:

| Faucet Type | L_low (min/person/day) |
|---|---|
| Kitchen | 4.5[618] |
| Bathroom | 1.6[619] |
| If faucet location unknown (total for household): Single-Family except mobile homes | 9.0[620] |
| If faucet location unknown (total for household): | 6.9[621] |

[610] Average retrofit flow rate for kitchen and bathroom faucet aerators from sources 2, 4, 5, and 7(see source table at end of characterization). This accounts for all throttling and differences from rated flow rates. Assumes all kitchen aerators at 2.2 gpm or less and all bathroom aerators at 1.5 gpm or less. The most comprehensive available studies did not disaggregate kitchen use from bathroom use, but instead looked at total flow and length of use for all faucets. This makes it difficult to reliably separate kitchen water use from bathroom water use. It is possible that programs installing low flow aerators lower than the 2.2 gpm for kitchens and 1.5 gpm for bathrooms will see a lower overall average retrofit flow rate.

[611] Measurement should be based on actual average flow consumed over a period of time rather than a onetime spot measurement for maximum flow. Studies have shown maximum flow rates do not correspond well to average flow rate due to occupant behavior which does not always use maximum flow.

[612] 2008, Schultdt, Marc, and Debra Tachibana. Energy related Water Fixture Measurements: Securing the Baseline for Northwest Single Family Homes. 2008 ACEEE Summer Study on Energy Efficiency in Buildings. Page 1-265.

[613] Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group. This study of 135 single and Multifamily homes in Michigan metered energy parameters for efficient showerhead and faucet aerators.

[614] Ibid.

[615] One kitchen faucet plus 2.83 bathroom faucets. Based on findings from a 2009 ComEd residential survey of 140 sites, provided by Cadmus.

[616] One kitchen faucet plus 1.5 bathroom faucets. Based on findings from a 2009 ComEd residential survey of 140 sites, provided by Cadmus.

[617] Unknown is based on statewide weighted average of 69% single family and 31% multifamily, based on IL data from 2009 RECS Table HC2.9 Structural and Geographic Characteristics of Homes in Midwest Region, Divisions and States, 2009.

[618] Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.

[619] Ibid.

[620] One kitchen faucet plus 2.83 bathroom faucets. Based on findings from a 2009 ComEd residential survey of 140 sites, provided by Cadmus.

[621] One kitchen faucet plus 1.5 bathroom faucets. Based on findings from a 2009 ComEd residential survey of 140 sites, provided by Cadmus.

| Faucet Type | L_low (min/person/day) |
|---|---|
| Multifamily | |
| If faucet location and building type unknown (total for household) | 8.3[622] |

Household = Average number of people per household

| Household Unit Type | Household |
|---|---|
| Single-Family - Deemed | 2.56[623] |
| Multi-Family - Deemed | 2.1[624] |
| Household type unknown | 2.42[625] |
| Custom | Actual Occupancy or Number of Bedrooms[626] |

Use Multifamily if: Building meets utility's definition for multifamily

365.25 = Days in a year, on average.

DF = Drain Factor

| Faucet Type | Drain Factor[627] |
|---|---|
| Kitchen | 75% |
| Bath | 90% |
| Unknown | 79.5% |

FPH = Faucets Per Household

| Faucet Type | FPH |
|---|---|
| Kitchen Faucets Per Home (KFPH) | 1 |
| Bathroom Faucets Per Home (BFPH): Single-Family except mobile homes | 2.83[628] |
| Bathroom Faucets Per Home (BFPH): Multifamily and mobile homes | 1.5[629] |
| If faucet location unknown (total for household): Single-Family except mobile homes | 3.83 |
| If faucet location unknown (total for household): Multifamily and mobile homes | 2.5 |

[622] Unknown is based on statewide weighted average of 69% single family and 31% multifamily, based on IL data from 2009 RECS Table HC2.9 Structural and Geographic Characteristics of Homes in Midwest Region, Divisions and States, 2009.
[623] ComEd Energy Efficiency/ Demand Response Plan: Plan Year 2 (6/1/2009-5/31/2010) Evaluation Report: All Electric Single Family Home Energy Performance Tune-Up Program citing 2006-2008 American Community Survey data from the US Census Bureau for Illinois cited on p. 17 of the PY2 Evaluation report. 2.75 * 93% evaluation adjustment
[624] Navigant, ComEd PY3 Multifamily Home Energy Savings Program Evaluation Report Final, May 16, 2012.
[625] Unknown is based on statewide weighted average of 69% single family and 31% multifamily, based on IL data from 2009 RECS Table HC2.9 Structural and Geographic Characteristics of Homes in Midwest Region, Divisions and States, 2009.
[626] Bedrooms are suitable proxies for household occupancy, and may be preferable to actual occupancy due to turnover rates in residency and non-adult population impacts.
[627] Because faucet usages are at times dictated by volume, only usage of the sort that would go straight down the drain will provide savings. VEIC is unaware of any metering study that has determined this specific factor and so through consensus with the Illinois Technical Advisory Group have deemed these values to be 75% for the kitchen and 90% for the bathroom. If the aerator location is unknown an average of 79.5% should be used which is based on the assumption that 70% of household water runs through the kitchen faucet and 30% through the bathroom (0.7*0.75)+(0.3*0.9)=0.795.
[628] Based on findings from a 2009 ComEd residential survey of 140 sites, provided by Cadmus.
[629] Ibid.

| Faucet Type | FPH |
|---|---|
| If faucet location and building type unknown (total for household) | 3.42[630] |

EPG_electric = Energy per gallon of water used by faucet supplied by electric water heater

= (8.33 * 1.0 * (WaterTemp - SupplyTemp)) / (RE_electric * 3412)

= (8.33 * 1.0 * (86 – 54.1)) / (0.98 * 3412)

= 0.0795 kWh/gal (Bath), 0.0969 kWh/gal (Kitchen), 0.0919 kWh/gal (Unknown)

8.33 = Specific weight of water (lbs/gallon)

1.0 = Heat Capacity of water (btu/lb-°F)

WaterTemp = Assumed temperature of mixed water

= 86F for Bath, 93F for Kitchen 91F for Unknown[631]

SupplyTemp = Assumed temperature of water entering house

= 54.1F [632]

RE_electric = Recovery efficiency of electric water heater

= 98% [633]

3412 = Converts Btu to kWh (btu/kWh)

ISR = In service rate of faucet aerators dependant on install method as listed in table below

---

[630] Unknown is based on statewide weighted average of 69% single family and 31% multifamily, based on IL data from 2009 RECS Table HC2.9 Structural and Geographic Characteristics of Homes in Midwest Region, Divisions and States, 2009.

[631] Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group. If the aerator location is unknown an average of 91% should be used which is based on the assumption that 70% of household water runs through the kitchen faucet and 30% through the bathroom (0.7*93)+(0.3*86)=0.91.

[632] US DOE Building America Program. Building America Analysis Spreadsheet.

[633] Electric water heaters have recovery efficiency of 98%.http://www.ahridirectory.org/ahridirectory/pages/home.aspx

| Selection | ISR |
|---|---|
| Direct Install - Single Family | 0.95[634] |
| Direct Install –Multifamily Kitchen | 0.91[635] |
| Direct Install –Multifamily Bathroom | 0.95[636] |
| Efficiency Kit Bathroom Aerator | 0.61[637] |
| Efficiency Kit Kitchen Aerator | 0.58[638] |
| Distributed School Efficiency Kit Bathroom Aerator | 0.30[639] |
| Distributed School Efficiency Kit Kitchen Aerator | 0.31[640] |

Use Multifamily if: Building meets utility's definition for multifamily

For example, a direct installed kitchen low flow faucet aerator in an individual electric DHW home:

ΔkWh = 1.0 * (((1.63 * 4.5 – 0.94 * 4.5) * 2.56 * 365.25 *0.75) / 1) * 0.0969 * 0.95

= 200 kWh

For example, a direct installed bath low flow faucet aerator in a shared electric DHW home:

ΔkWh = 1.0 * (((1.53 * 1.6 – 0.94 * 1.6) * 2.1 * 365.25 * 0.90) /1.5) * 0.0795 * 0.95

= 33.0 kWh

For example, a direct installed low flow faucet aerator in unknown faucet in an individual electric DHW home:

ΔkWh = 1.0 * (((1.58 * 9.0 – 0.94 * 9.0) * 2.56 * 365.25 * 0.795) /3.83) * 0.0919 * 0.95

= 97.6 kWh

Secondary kWh Savings for Water Supply and Wastewater Treatment

The following savings should be included in the total savings for this measure, but should not be included in TRC tests to avoid double counting the economic benefit of water savings.

$$\Delta kWh_{water} = \Delta Water\ (gallons) / 1{,}000{,}000 * E_{water\ total}$$

Where

$E_{water\ total}$ = IL Total Water Energy Factor (kWh/Million Gallons)

=5010[641]

[634] ComEd Energy Efficiency/ Demand Response Plan: Plan Year 2 (6/1/2009-5/31/2010) Evaluation Report: All Electric Single Family Home Energy Performance Tune-Up Program Table 3-8

[635] Navigant, ComEd-Nicor Gas EPY4/GPY1 Multifamily Home Energy Savings Program Evaluation Report DRAFT 2013-01-28

[636] Ibid.

[637] A weighted ISR was found by weighting Nicor and Ameren efficiency kit program uptake and their previously found ISRs. This analysis can be found in Faucet Aerators and Showerheads Weighted Average ISR IL TRM.xlsx.

[638] A weighted ISR was found by weighting Nicor and Ameren efficiency kit program uptake and their previously found ISRs. This analysis can be found in Faucet Aerators and Showerheads Weighted Average ISR IL TRM.xlsx.

[639] Opinion Dynamics and Cadmus. Ameren Illinois Company Transition Period Impact Evaluation Report. Volume 1 – Impact Evaluation Results. April 30, 2018. School Kits Program.

[640] ibid

[641] This factor includes 2571 kWh/MG for water supply based on Illinois energy intensity data from a 2012 ISAWWA study and 2439 kWh/MG for wastewater treatment based on national energy intensity use estimates. For more information please review Elevate Energy's 'IL TRM: Energy per Gallon Factor, May 2018 paper'.

For example, a direct installed kitchen low flow aerator in an single family home

ΔWater (gallons) = (((1.63 * 4.5 – 0.94 * 4.5) * 2.56 * 365.25 *0.75) / 1) * 0.95

= 2068 gallons

$\Delta kWh_{water}$ = 2068/1000000 * 5010

=10.4 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = ΔkWh / Hours * CF

Where:

ΔkWh = calculated value above.

Hours = Annual electric DHW recovery hours for faucet use per faucet

= ((GPM_base * L_base) * Household/FPH * 365.25 * DF ) * 0.545[642] / GPH

| Building Type | Faucet location | Calculation | Hours per faucet |
|---|---|---|---|
| Single Family | Kitchen | ((1.63 * 4.5) * 2.56/1 * 365.25 * 0.75) * 0.545 / 27.4 | 102 |
| | Bathroom | ((1. 53 * 1.6) * 2.56/2.83 * 365.25 * 0.9) * 0.545 / 27.4 | 14 |
| | Unknown | ((1. 58* 9.0) * 2.56/3.83 * 365.25 * 0.795) * 0.545 / 27.4 | 55 |
| Multifamily | Kitchen | ((1. 63 * 4.5) * 2.1/1 * 365.25 * 0.75) * 0.545 / 27.4 | 84 |
| | Bathroom | ((1. 53* 1.6) * 2.1/1.5 * 365.25 * 0.9) * 0.545 / 27.4 | 22 |
| | Unknown | ((1. 58 * 6.9) * 2.1/2.5 * 365.25 * 0.795) * 0.545 / 27.4 | 53 |

GPH = Gallons per hour recovery of electric water heater calculated for 70.9F temp rise (125-54.1), 98% recovery efficiency, and typical 4.5kW electric resistance storage tank.

= 27.4

CF = Coincidence Factor for electric load reduction

= 0.022[643]

For example, a direct installed kitchen low flow faucet aerator in a single family electric DHW home:

ΔkW =200/110 * 0.022

= 0.04 kW

**NATURAL GAS SAVINGS**

ΔTherms = %FossilDHW * ((GPM_base * L_base - GPM_low * L_low) * Household * 365.25 *DF / FPH) * EPG_gas * ISR

Where:

[642] 54.5% is the proportion of hot 120F water mixed with 54.1F supply water to give 90F mixed faucet water.

[643] Calculated as follows: Assume 18% aerator use takes place during peak hours (based on: Oreo et al, "The end uses of hot water in single family homes from flow trace analysis", 2001.) There are 65 days in the summer peak period, so the percentage of total annual aerator use in peak period is 0.18*65/365 = 3.21%. The number of hours of recovery during peak periods is therefore assumed to be 3.21% *180 = 5.8 hours of recovery during peak period where 180 equals the average annual electric DHW recovery hours for faucet use including SF and MF homes. There are 260 hours in the peak period so the probability you will see savings during the peak period is 5.8/260 = 0.022

%FossilDHW = proportion of water heating supplied by Natural Gas heating

| DHW fuel | %Fossil_DHW |
|---|---|
| Electric | 0% |
| Natural Gas | 100% |
| Unknown | 84%[644] |

EPG_gas = Energy per gallon of Hot water supplied by gas

= (8.33 * 1.0 * (WaterTemp - SupplyTemp)) / (RE_gas * 100,000)

= 0.00341 Therm/gal for SF homes (Bath), 0.00415 Therm/gal for SF homes (Kitchen), 0.00394 Therm/gal for SF homes (Unknown)

= 0.00397 Therm/gal for MF homes (Bath), 0.00484 Therm/gal for MF homes (Kitchen), 0.00459 Therm/gal for MF homes (Unknown)

RE_gas = Recovery efficiency of gas water heater

= 78% For individual water heater[645]

= 67% For shared water heater[646]

If unknown, use individual water heater value for single family, use shared water heater value for multifamily. Use multifamily if building meets utility's definition for multifamily.

100,000 = Converts Btus to Therms (btu/Therm)

Other variables as defined above.

For example, a direct-installed kitchen low flow faucet aerator in a fuel DHW single-family home:

ΔTherms = 1.0 * (((1.63 * 4.5 – 0.94 * 4.5) * 2.56 * 365.25 *0.75) / 1) * 0.00415 * 0.95

= 8.58 Therms

For example, a direct installed bath low flow faucet aerator in a fuel DHW multi-family home:

ΔTherms = 1.0 * (((1.53 * 1.6 – 0.94 * 1.6) * 2.1 * 365.25 * 0.90) /1.5) * 0.003974 * 0.95

= 1.64 Therms

For example, a direct installed low flow faucet aerator in unknown faucet in a fuel DHW single-family home:

ΔTherms = 1.0 * (((1.58 * 9.0 – 0.94 * 9.0) * 2.56 * 365.25 * 0.795) /3.83) * 0.00394 * 0.95

= 4.18 Therms

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

ΔWater (gallons) = ((GPM_base * L_base - GPM_low * L_low) * Household * 365.25 *DF / FPH) * ISR

Variables as defined above

[644] Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IL. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used

[645] DOE Final Rule discusses Recovery Efficiency with an average around 0.76 for Gas Fired Storage Water heaters and 0.78 for standard efficiency gas fired tankless water heaters up to 0.95 for the highest efficiency gas fired condensing tankless water heaters. These numbers represent the range of new units however, not the range of existing units in stock. Review of AHRI Directory suggests range of recovery efficiency ratings for new Gas DHW units of 70-87%. Average of existing units is estimated at 78%.

[646] Water heating in Multifamily buildings is often provided by a larger central boiler. This suggests that the average recovery efficiency is somewhere between a typical central boiler efficiency of 0.59 and the 0.75 for single family homes. An average efficiency of 0.67 is used for this analysis as a default for Multifamily buildings.

For example, a direct-installed kitchen low flow aerator in a single family home

ΔWater (gallons) = (((1.63 * 4.5 – 0.94 * 4.5) * 2.56 * 365.25 *0.75) / 1) * 0.95

= 2068 gallons

For example, a direct installed bath low flow faucet aerator in a multi-family home:

ΔWater (gallons) = (((1.53 * 1.6 – 0.94 * 1.6) * 2.1 * 365.25 * 0.90) /1.5) * 0.95

= 413 gallons

For example, a direct installed low flow faucet aerator in unknown faucet in a single family home:

ΔWater (gallons) = (((1.58 * 9.0 – 0.94 * 9.0) * 2.56 * 365.25 * 0.795) /3.83) * 0.95

= 1062 gallons

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**SOURCES**

| Source ID | Reference |
|---|---|
| 1 | 2011, DeOreo, William. California Single Family Water Use Efficiency Study. April 20, 2011. |
| 2 | 2000, Mayer, Peter, William DeOreo, and David Lewis. Seattle Home Water Conservation Study. December 2000. |
| 3 | 1999, Mayer, Peter, William DeOreo. Residential End Uses of Water. Published by AWWA Research Foundation and American Water Works Association. 1999. |
| 4 | 2003, Mayer, Peter, William DeOreo. Residential Indoor Water Conservation Study. Aquacraft, Inc. Water Engineering and Management. Prepared for East Bay Municipal Utility District and the US EPA. July 2003. |
| 5 | 2011, DeOreo, William. Analysis of Water Use in New Single Family Homes. By Aquacraft. For Salt Lake City Corporation and US EPA. July 20, 2011. |
| 6 | 2011, Aquacraft. Albuquerque Single Family Water Use Efficiency and Retrofit Study. For Albuquerque Bernalillo County Water Utility Authority. December 1, 2011. |
| 7 | 2008, Schultdt, Marc, and Debra Tachibana. Energy related Water Fixture Measurements: Securing the Baseline for Northwest Single Family Homes. 2008 ACEEE Summer Study on Energy Efficiency in Buildings. |

**MEASURE CODE: RS-HWE-LFFA-V07-190101**

**REVIEW DEADLINE: 1/1/2022**

## 5.4.5 Low Flow Showerheads

### DESCRIPTION

This measure relates to the installation of a low flow showerhead in a single or multi-family household.

This measure may be used for units provided through Efficiency Kits; however the in service rate for such measures should be derived through evaluation results specifically for this implementation methodology.

This measure was developed to be applicable to the following program types: TOS, RF, NC, DI, KITS.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed equipment must be a low flow showerhead rated at least 0.5 gallons per minute (GPM) less than the existing showerhead. Savings are calculated on a per showerhead fixture basis.

### DEFINITION OF BASELINE EQUIPMENT

For Direct install programs, the baseline condition is assumed to be a standard showerhead rated at 2.0 GPM or greater.

For retrofit and time-of-sale programs, the baseline condition is assumed to be a representative average of existing showerhead flow rates of participating customers including a range of low flow showerheads, standard-flow showerheads, and high-flow showerheads.

Average measured flow rates are used in the algorithm and are lower, reflecting the penetration of previously installed low flow fixtures (and therefore the freerider rate for this measure should be 0), use of the shower at less than full flow, debris buildup, and lower water system pressure than fixtures are rated at.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 10 years.[647]

### DEEMED MEASURE COST

For time of sale or new construction the incremental cost for this measure is $7[648] or program actual.

For low flow showerheads provided through Direct Install or within Efficiency Kits, the actual program delivery costs (including labor if applicable) should be utilized. If unknown assume $12[649] for Direct Install and $7 for Efficiency Kits.

### LOADSHAPE

Loadshape R03 - Residential Electric DHW

### COINCIDENCE FACTOR

The coincidence factor for this measure is assumed to be 2.78%.[650]

---

[647] Table C-6, Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. Evaluations indicate that consumer dissatisfaction may lead to reductions in persistence, particularly in Multifamily.
[648] Market research average of $7.
[649] Includes assess and install labor time of $5 (20min @ $15/hr)
[650] Calculated as follows: Assume 11% showers take place during peak hours (based on: Oreo et al, "The end uses of hot water in single family homes from flow trace analysis", 2001.). There are 65 days in the summer peak period, so the percentage of total annual aerator use in peak period is 0.11*65/365 = 1.96%. The number of hours of recovery during peak periods is

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

Note these savings are per showerhead fixture

ΔkWh = %ElectricDHW * ((GPM_base * L_base - GPM_low * L_low) * Household * SPCD * 365.25 / SPH) * EPG_electric * ISR

Where:

%ElectricDHW = proportion of water heating supplied by electric resistance heating

| DHW fuel | %ElectricDHW |
|---|---|
| Electric | 100% |
| Natural Gas | 0% |
| Unknown | 16%[651] |

GPM_base = Average flow rate, in gallons per minute, of the baseline faucet "as-used." This includes the effect of existing low flow fixtures and therefore the freerider rate for this measure should be 0.

| Program | GPM_base |
|---|---|
| Direct-install | 2.24[652] |
| Retrofit, Efficiency Kits, NC or TOS | 2.35[653] |

GPM_low = As-used flow rate of the low-flow showerhead, which may, as a result of measurements of program evaulations deviate from rated flows, see table below:

| Rated Flow |
|---|
| 2.0 GPM |
| 1.75 GPM |
| 1.5 GPM |
| Custom or Actual[654] |

L_base = Shower length in minutes with baseline showerhead

therefore assumed to be 1.96% * 369 = 7.23 hours of recovery during peak period, where 369 equals the average annual electric DHW recovery hours for showerhead use including SF and MF homes with Direct Install and Retrofit/TOS measures. There are 260 hours in the peak period so the probability you will see savings during the peak period is 7.23/260 = 0.0278

[651] Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IL. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used

[652] Based on measurements conducted from June 2013 to January 2014 by Franklin Energy. Over 300 residential sites in the Chicago area were tested.

[653] Representative value from sources 1, 2, 4, 5, 6 and 7 (See Source Table at end of measure section) adjusted slightly upward to account for program participation which is expected to target customers with existing higher flow devices rather than those with existing low flow devices.

[654] Note that actual values may be either a) program-specific minimum flow rate, or b) program-specific evaluation-based value of actual effective flow-rate due to increased duration or temperatures. The latter increases in likelihood as the rated flow drops and may become significant at or below rated flows of 1.5 GPM. The impact can be viewed as the inverse of the throttling described in the footnote for baseline flowrate.

= 7.8 min[655]

L_low = Shower length in minutes with low-flow showerhead

= 7.8 min[656]

Household = Average number of people per household

| Household Unit Type[657] | Household |
|---|---|
| Single-Family - Deemed | 2.56[658] |
| Multi-Family - Deemed | 2.1[659] |
| Household type unknown | 2.42[660] |
| Custom | Actual Occupancy or Number of Bedrooms[661] |

Use Multifamily if: Building meets utility's definition for multifamily

SPCD = Showers Per Capita Per Day

= 0.6[662]

365.25 = Days per year, on average.

SPH = Showerheads Per Household so that per-showerhead savings fractions can be determined

| Household Type | SPH |
|---|---|
| Single-Family except mobile homes | 1.79[663] |
| Multifamily and mobile homes | 1.3[664] |
| Household type unknown | 1.64[665] |
| Custom | Actual |

Use Multifamily if: Building meets utility's definition for multifamily

EPG_electric = Energy per gallon of hot water supplied by electric

= (8.33 * 1.0 * (ShowerTemp - SupplyTemp)) / (RE_electric * 3412)

= (8.33 * 1.0 * (101 – 54.1)) / (0.98 * 3412)

---

[655] Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group. This study of 135 single and Multifamily homes in Michigan metered energy parameters for efficient showerhead and faucet aerators.

[656] Ibid.

[657] If household type is unknown, as may be the case for time of sale measures, then single family deemed value shall be used.

[658] ComEd Energy Efficiency/ Demand Response Plan: Plan Year 2 (6/1/2009-5/31/2010) Evaluation Report: All Electric Single Family Home Energy Performance Tune-Up Program citing 2006-2008 American Community Survey data from the US Census Bureau for Illinois cited on p. 17 of the PY2 Evaluation report. 2.75 * 93% evaluation adjustment

[659] ComEd PY3 Multifamily Evaluation Report REVISED DRAFT v5 2011-12-08.docx

[660] Unknown is based on statewide weighted average of 69% single family and 31% multifamily, based on IL data from 2009 RECS Table HC2.9 Structural and Geographic Characteristics of Homes in Midwest Region, Divisions and States, 2009.

[661] Bedrooms are suitable proxies for household occupancy, and may be preferable to actual occupancy due to turnover rates in residency and non-adult population impacts.

[662] Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.

[663] Based on findings from a 2009 ComEd residential survey of 140 sites, provided by Cadmus.

[664] Ibid.

[665] Unknown is based on statewide weighted average of 69% single family and 31% multifamily, based on IL data from 2009 RECS Table HC2.9 Structural and Geographic Characteristics of Homes in Midwest Region, Divisions and States, 2009.

= 0.117 kWh/gal

8.33 = Specific weight of water (lbs/gallon)

1.0 = Heat Capacity of water (btu/lb-°)

ShowerTemp = Assumed temperature of water

= 101F[666]

SupplyTemp = Assumed temperature of water entering house

= 54.1F[667]

RE_electric = Recovery efficiency of electric water heater

= 98%[668]

3412 = Converts Btu to kWh (btu/kWh)

ISR = In service rate of showerhead

= Dependant on program delivery method as listed in table below

| Selection | ISR |
|---|---|
| Direct Install - Single Family | 0.98[669] |
| Direct Install –Multifamily | 0.95[670] |
| Efficiency Kits--One showerhead kit | 0.62[671] |
| Efficiency Kits—Two showerhead kit | 0.67[672] |
| Distributed School Efficiency Kit showerhead | 0.28[673] |

Use Multifamily if: Building meets utility's definition for multifamily

For example, a direct-installed 1.5 GPM low flow showerhead in a single family home with electric DHW where the number of showers is not known:

$$\Delta kWh = 1.0 * ((2.24 * 7.8 – 1.5 * 7.8) * 2.56 * 0.6 * 365.25 / 1.79) * 0.117 * 0.98$$

$$= 207 \text{ kWh}$$

Secondary kWh Savings for Water Supply and Wastewater Treatment

The following savings should be included in the total savings for this measure, but should not be included in TRC tests to avoid double counting the economic benefit of water savings.

$$\Delta kWh_{water} = \Delta Water \text{ (gallons)} / 1{,}000{,}000 * E_{water\ total}$$

666 Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.

667 US DOE Building America Program. Building America Analysis Spreadsheet.

668 Electric water heaters have recovery efficiency of 98%.

669 Deemed values are from ComEd Energy Efficiency/ Demand Response Plan: Plan Year 2 (6/1/2009-5/31/2010) Evaluation Report: All Electric Single Family Home Energy Performance Tune-Up Program Table 3-8. Alternative ISRs may be developed for program delivery methods based on evaluation results.

670 Navigant, ComEd-Nicor Gas EPY4/GPY1 Multifamily Home Energy Savings Program Evaluation Report FINAL 2013-06-05

671 A weighted ISR was found by weighting Nicor and Ameren efficiency kit program uptake and their previously found ISRs. This analysis can be found in Faucet Aerators and Showerheads Weighted Average ISR IL TRM.xlsx.

672 A weighted ISR was found by weighting Nicor and Ameren efficiency kit program uptake and their previously found ISRs. This analysis can be found in Faucet Aerators and Showerheads Weighted Average ISR IL TRM.xlsx.

673 Opinion Dynamics and Cadmus. Ameren Illinois Company Transition Period Impact Evaluation Report. Volume 1 – Impact Evaluation Results. April 30, 2018. School Kits Program.

Where

$E_{water\ total}$ = IL Total Water Energy Factor (kWh/Million Gallons)

=5010[674]

For example, a direct installed 1.5 GPM low flow showerhead in a single family where the number of showers is not known:

ΔWater (gallons) = ((2.24 * 7.8 – 1.5 * 7.8) * 2.56 * 0.6 * 365.25 / 1.79) * 0.98

= 1773 gallons

$\Delta kWh_{water}$ = 1773/1,000,000 * 5010

= 8.9 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = ΔkWh/Hours * CF

Where:

ΔkWh = calculated value above. Note do not include the secondary savings in this calculation.

Hours = Annual electric DHW recovery hours for showerhead use

= ((GPM_base * L_base) * Household * SPCD * 365.25 ) * 0.712[675] / GPH

= 255 for SF Direct Install; 208 for MF Direct Install

= 267 for SF Retrofit, Efficiency Kits, NC and TOS; 219 for MF Retrofit, Efficiency Kits, NC and TOS

Use Multifamily if: Building meets utility's definition for multifamily

GPH = Gallons per hour recovery of electric water heater calculated for 65.9F temp rise (120-54.1), 98% recovery efficiency, and typical 4.5kW electric resistance storage tank.

= 27.4

CF = Coincidence Factor for electric load reduction

= 0.0278[676]

For example, a direct installed 1.5 GPM low flow showerhead in a single family home with electric DHW where the number of showers is not known:

ΔkW = 207/255 * 0.0278

= .022 kW

**NATURAL GAS SAVINGS**

ΔTherms = %FossilDHW * ((GPM_base * L_base - GPM_low * L_low) * Household * SPCD

[674] This factor includes 2571 kWh/MG for water supply based on Illinois energy intensity data from a 2012 ISAWWA study and 2439 kWh/MG for wastewater treatment based on national energy intensity use estimates. For more information please review Elevate Energy's 'IL TRM: Energy per Gallon Factor, May 2018 paper'.

[675] 71.2% is the proportion of hot 120F water mixed with 54.1F supply water to give 101F shower water.

[676] Calculated as follows: Assume 11% showers take place during peak hours (based on: Oreo et al, "The end uses of hot water in single family homes from flow trace analysis", 2001.). There are 65 days in the summer peak period, so the percentage of total annual aerator use in peak period is 0.11*65/365 = 1.96%. The number of hours of recovery during peak periods is therefore assumed to be 1.96% * 369 = 7.23 hours of recovery during peak period where 369 equals the average annual electric DHW recovery hours for showerhead use including SF and MF homes with Direct Install and Retrofit/TOS measures. There are 260 hours in the peak period so the probability you will see savings during the peak period is 7.23/260 = 0.0278

* 365.25 / SPH) * EPG_gas * ISR

Where:

%FossilDHW = proportion of water heating supplied by Natural Gas heating

| DHW fuel | %Fossil_DHW |
|---|---|
| Electric | 0% |
| Natural Gas | 100% |
| Unknown | 84%[677] |

EPG_gas = Energy per gallon of Hot water supplied by gas

= (8.33 * 1.0 * (ShowerTemp - SupplyTemp)) / (RE_gas * 100,000)

= 0.00501 Therm/gal for SF homes

= 0.00583 Therm/gal for MF homes

RE_gas = Recovery efficiency of gas water heater

= 78% For individual water heater[678]

= 67% For shared water heater[679]

If unknown, use individual water heater value for single family, use shared water heater value for multifamily. Use multifamily if building meets utility's definition for multifamily.

100,000 = Converts Btus to Therms (btu/Therm)

Other variables as defined above.

For example, a direct installed 1.5 GPM low flow showerhead in a gas fired DHW single family home where the number of showers is not known:

ΔTherms = 1.0 * ((2.24 * 7.8 – 1.5 * 7.8) * 2.56 * 0.6 * 365.25 / 1.79) * 0.00501 * 0.98

= 8.9 therms

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

ΔWater (gallons) = ((GPM_base * L_base - GPM_low * L_low) * Household * SPCD * 365.25 / SPH) * ISR

Variables as defined above

[677] Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IL. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used

[678] DOE Final Rule discusses Recovery Efficiency with an average around 0.76 for Gas Fired Storage Water heaters and 0.78 for standard efficiency gas fired tankless water heaters up to 0.95 for the highest efficiency gas fired condensing tankless water heaters. These numbers represent the range of new units however, not the range of existing units in stock. Review of AHRI Directory suggests range of recovery efficiency ratings for new Gas DHW units of 70-87%. Average of existing units is estimated at 78%.

[679] Water heating in Multifamily buildings is often provided by a larger central boiler. This suggests that the average recovery efficiency is somewhere between a typical central boiler efficiency of 0.59 and the 0.75 for single family homes. An average efficiency of 0.67 is used for this analysis as a default for Multifamily buildings.

For example, a direct installed 1.5 GPM low flow showerhead in a single family home where the number of showers is not known:

$$\Delta Water\ (gallons) = ((2.24 * 7.8 – 1.5 * 7.8) * 2.56 * 0.6 * 365.25 / 1.79) * 0.98$$

$$= 1773\ gallons$$

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**SOURCES**

| Source ID | Reference |
|---|---|
| 1 | 2011, DeOreo, William. California Single Family Water Use Efficiency Study. April 20, 2011. |
| 2 | 2000, Mayer, Peter, William DeOreo, and David Lewis. Seattle Home Water Conservation Study. December 2000. |
| 3 | 1999, Mayer, Peter, William DeOreo. Residential End Uses of Water. Published by AWWA Research Foundation and American Water Works Association. 1999. |
| 4 | 2003, Mayer, Peter, William DeOreo. Residential Indoor Water Conservation Study. Aquacraft, Inc. Water Engineering and Management. Prepared for East Bay Municipal Utility District and the US EPA. July 2003. |
| 5 | 2011, DeOreo, William. Analysis of Water Use in New Single Family Homes. By Aquacraft. For Salt Lake City Corporation and US EPA. July 20, 2011. |
| 6 | 2011, Aquacraft. Albuquerque Single Family Water Use Efficiency and Retrofit Study. For Albuquerque Bernalillo County Water Utility Authority. December 1, 2011. |
| 7 | 2008, Schultdt, Marc, and Debra Tachibana. Energy related Water Fixture Measurements: Securing the Baseline for Northwest Single Family Homes. 2008 ACEEE Summer Study on Energy Efficiency in Buildings. |

**MEASURE CODE: RS-HWE-LFSH-V06-190101**

**REVIEW DEADLINE: 1/1/2023**

## 5.4.6 Water Heater Temperature Setback

### Description

This measure was developed to be applicable to the following program types: NC, RF, DI, KITS.

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

High efficiency is a hot water tank with the thermostat reduced to no lower than 120 degrees.

### Definition of Baseline Equipment

The baseline condition is a hot water tank with a thermostat setting that is higher than 120 degrees, typically systems with settings of 130 degrees or higher. Note if there are more than one DHW tanks in the home at or higher than 130 degrees and they are all turned down, then the savings per tank can be multiplied by the number of tanks.

### Deemed Lifetime of Efficient Equipment

The assumed lifetime of the measure is 2 years.

### Deemed Measure Cost

The incremental cost of a setback is assumed to be $5 for contractor time, or no cost if the measure is self-installed.

### Loadshape

Loadshape R03 - Residential Electric DHW

### Coincidence Factor

The summer peak coincidence factor for this measure is assumed to be 1.

## Algorithm

### Calculation of Savings

### Electric Energy Savings

For homes with electric DHW tanks:

ΔkWh[680]= (U * A * (Tpre – Tpost) * Hours * ISR) / (3412 * RE_electric)

Where:

U = Overall heat transfer coefficient of tank (Btu/Hr-°F-$ft^2$).

= Actual if known. If unknown assume R-12, U = 0.083

A = Surface area of storage tank (square feet)

= Actual if known. If unknown use table below based on capacity of tank. If capacity

[680] Note this algorithm provides savings only from reduction in standby losses. The TAC considered avoided energy from not heating the water to the higher temperature but determined that dishwashers are likely to boost the temperature within the unit (roughly canceling out any savings), faucet and shower use is likely to be at the same temperature so there would need to be more lower temperature hot water being used (cancelling any savings) and clothes washers will only see savings if the water from the tank is taken without any temperature control. It was felt the potential impact was too small to be characterized.

unknown assume 50 gal tank; A = 24.99ft$^2$

| Capacity (gal) | A (ft$^2$)[681] |
|---|---|
| 30 | 19.16 |
| 40 | 23.18 |
| 50 | 24.99 |
| 80 | 31.84 |

Tpre = Actual hot water setpoint prior to adjustment

Tpost = Actual new hot water setpoint, which may not be lower than 120 degrees

| Default Hot Water Temperature Inputs | |
|---|---|
| Tpre | 135 |
| Tpost | 120 |

Hours = Number of hours in a year (since savings are assumed to be constant over year).

= 8766

ISR = In service rate of measure

= Dependant on program delivery method as listed in table below

| Delivery method | ISR |
|---|---|
| Instructions provided in a Kit | To be determined through evaluation |
| All other | 1.0 |

3412 = Conversion from Btu to kWh

RE_electric = Recovery efficiency of electric hot water heater

= 0.98 [682]

A deemed savings assumption, where site specific assumptions are not available would be as follows:

ΔkWh = (U * A * (Tpre – Tpost) * Hours * ISR) / (3412 * RE_electric)

= (((0.083 * 24.99) * (135 – 120) * 8766 * 1.0) / (3412 * 0.98)

= 81.6 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW **=** ΔkWh / Hours * CF

Where:

Hours = 8766

CF = Summer Peak Coincidence Factor for measure

= 1

A deemed savings assumption, where site specific assumptions are not available would be as follows:

[681] Assumptions from PA TRM. Area values were calculated from average dimensions of several commercially available units, with radius values measured to the center of the insulation.

[682] Electric water heaters have recovery efficiency of 98%.

ΔkW = (81.6/ 8766) * 1

ΔkW default = 0.00931 kW

**NATURAL GAS SAVINGS**

For homes with gas water heaters:

ΔTherms = (U * A * (Tpre – Tpost) * Hours * ISR) / (100,000 * RE_gas)

Where

100,000 = Converts Btus to Therms (btu/Therm)

RE_gas = Recovery efficiency of gas water heater

= 78% For SF homes [683]

= 67% For MF homes[684]

Use Multifamily if: Building has shared DHW

A deemed savings assumption, where site specific assumptions are not available would be as follows:

For Single Family homes:

ΔTherms = (U * A * (Tpre – Tpost) * Hours * ISR) / (RE_gas)

= (((0.083 * 24.99) * (135 – 120) * 8766 * 1.0) / (100,000 * 0.78)

= 3.5 Therms

For Multi Family homes:

ΔTherms = (U * A * (Tpre – Tpost) * Hours * ISR) / (RE_gas)

= (((0.083 * 24.99) * (135 – 120) * 8766 * 1.0) / (100,000 * 0.67)

= 4.1 Therms

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-HWE-TMPS-V06-190101**

**REVIEW DEADLINE: 1/1/2022**

[683] DOE Final Rule discusses Recovery Efficiency with an average around 0.76 for Gas Fired Storage Water heaters and 0.78 for standard efficiency gas fired tankless water heaters up to 0.95 for the highest efficiency gas fired condensing tankless water heaters. These numbers represent the range of new units however, not the range of existing units in stock. Review of AHRI Directory suggests range of recovery efficiency ratings for new Gas DHW units of 70-87%. Average of existing units is estimated at 78%.

[684] Water heating in Multifamily buildings is often provided by a larger central boiler. This suggests that the average recovery efficiency is somewhere between a typical central boiler efficiency of 0.59 and the 0.75 for single family homes. An average efficiency of 0.67 is used for this analysis as a default for Multifamily buildings.

## 5.4.7 Water Heater Wrap

### Description

This measure relates to a Tank Wrap or insulation "blanket" that is wrapped around the outside of a hot water tank to reduce stand-by losses. This measure applies only for homes that have an electric water heater that is not already well insulated. Generally this can be determined based upon the appearance of the tank.[685]

This measure was developed to be applicable to the following program types: RF, DI.

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

The measure is a properly installed, R-8 or greater insulating tank wrap to reduce standby energy losses from the tank to the surrounding ambient area.

### Definition of Baseline Equipment

The baseline is a standard electric domestic hot water tank without an additional tank wrap. Gas storage water heaters are excluded due to the limitations of retrofit wrapping and the associated impacts on reduced savings and safety.

### Deemed Lifetime of Efficient Equipment

The measure life is assumed to be 5 years[686].

### Deemed Measure Cost

The incremental cost for this measure will be the actual material cost of procuring and labor cost of installing the tank wrap.

### Loadshape

Loadshape R03 - Residential Electric DHW

### Coincidence Factor

This measure assumes a flat loadshape and as such the coincidence factor is 1.

**Algorithm**

### Calculation of Savings

### Electric Energy Savings

For electric DHW systems:

$$\Delta kWh = ((A_{base} / Rbase - A_{insul} / R_{insul}) * \Delta T * Hours) / (3412 * \eta DHW)$$

Where:

$R_{base}$ = Overall thermal resistance coefficient prior to adding tank wrap (Hr-°F-ft$^2$/BTU).

[685] Visually determine whether it is insulated by foam (newer, rigid, and more effective) or fiberglass (older, gives to gently pressure, and not as effective)

[686] This estimate assumes the tank wrap is installed on an existing unit with 5 years remaining life.

$R_{insul}$ = Overall thermal resistance coefficient after addition of tank wrap (Hr-°F-ft$^2$/BTU).

$A_{base}$ = Surface area of storage tank prior to adding tank wrap (square feet)[687]

$A_{insul}$ = Surface area of storage tank after addition of tank wrap (square feet)[688]

ΔT = Average temperature difference between tank water and outside air temperature (°F)

= 60°F [689]

Hours = Number of hours in a year (since savings are assumed to be constant over year).

= 8766

3412 = Conversion from Btu to kWh

ηDHW = Recovery efficiency of electric hot water heater

= 0.98 [690]

The following table has default savings for various tank capacity and pre and post R-VALUES.

| Capacity (gal) | Rbase | Rinsul | Abase (ft2)[691] | Ainsul (ft2)[692] | ΔkWh | ΔkW |
|---|---|---|---|---|---|---|
| 30 | 8 | 16 | 19.16 | 20.94 | 171 | 0.0195 |
| 30 | 10 | 18 | 19.16 | 20.94 | 118 | 0.0135 |
| 30 | 12 | 20 | 19.16 | 20.94 | 86 | 0.0099 |
| 30 | 8 | 18 | 19.16 | 20.94 | 194 | 0.0221 |
| 30 | 10 | 20 | 19.16 | 20.94 | 137 | 0.0156 |
| 30 | 12 | 22 | 19.16 | 20.94 | 101 | 0.0116 |
| 40 | 8 | 16 | 23.18 | 25.31 | 207 | 0.0236 |
| 40 | 10 | 18 | 23.18 | 25.31 | 143 | 0.0164 |
| 40 | 12 | 20 | 23.18 | 25.31 | 105 | 0.0120 |
| 40 | 8 | 18 | 23.18 | 25.31 | 234 | 0.0268 |
| 40 | 10 | 20 | 23.18 | 25.31 | 165 | 0.0189 |
| 40 | 12 | 22 | 23.18 | 25.31 | 123 | 0.0140 |
| 50 | 8 | 16 | 24.99 | 27.06 | 225 | 0.0257 |
| 50 | 10 | 18 | 24.99 | 27.06 | 157 | 0.0179 |
| 50 | 12 | 20 | 24.99 | 27.06 | 115 | 0.0131 |
| 50 | 8 | 18 | 24.99 | 27.06 | 255 | 0.0291 |
| 50 | 10 | 20 | 24.99 | 27.06 | 180 | 0.0206 |
| 50 | 12 | 22 | 24.99 | 27.06 | 134 | 0.0153 |
| 80 | 8 | 16 | 31.84 | 34.14 | 290 | 0.0331 |
| 80 | 10 | 18 | 31.84 | 34.14 | 202 | 0.0231 |
| 80 | 12 | 20 | 31.84 | 34.14 | 149 | 0.0170 |
| 80 | 8 | 18 | 31.84 | 34.14 | 328 | 0.0374 |
| 80 | 10 | 20 | 31.84 | 34.14 | 232 | 0.0265 |
| 80 | 12 | 22 | 31.84 | 34.14 | 173 | 0.0198 |

[687] Area includes tank sides and top to account for typical wrap coverage.
[688] Ibid.
[689] Assumes 125°F water leaving the hot water tank and average temperature of basement of 65°F.
[690] Electric water heaters have recovery efficiency of 98%.
[691] Assumptions from PA TRM. Area values were calculated from average dimensions of several commercially available units, with radius values measured to the center of the insulation. Area includes tank sides and top to account for typical wrap coverage.
[692] Assumptions from PA TRM. $A_{insul}$ was calculated by assuming that the water heater wrap is a 2" thick fiberglass material.

### Summer Coincident Peak Demand Savings

$$\Delta kW = \Delta kWh / 8766 * CF$$

Where:

ΔkWh = kWh savings from tank wrap installation

8766 = Number of hours in a year (since savings are assumed to be constant over year).

CF = Summer Coincidence Factor for this measure

= 1.0

The table above has default kW savings for various tank capacity and pre and post R-values.

### Natural Gas Savings

N/A

### Water Impact Descriptions and Calculation

N/A

### Deemed O&M Cost Adjustment Calculation

N/A

### Measure Code: RS-HWE-WRAP-V02-150601

### Review Deadline: 1/1/2022

## 5.4.8 Thermostatic Restrictor Shower Valve

### DESCRIPTION

The measure is the installation of a thermostatic restrictor shower valve in a single or multi-family household. This is a valve attached to a residential showerhead which restricts hot water flow through the showerhead once the water reaches a set point (generally 95F or lower).

This measure was developed to be applicable to the following program types: RF, NC, DI. If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed equipment must be a thermostatic restrictor shower valve installed on a residential showerhead.

### DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is the residential showerhead without the restrictor valve installed.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 10 years. [693]

### DEEMED MEASURE COST

The incremental cost of the measure should be the actual program cost (including labor if applicable) or $30[694] plus $20 labor[695] if not available.

### LOADSHAPE

Loadshape R03 - Residential Electric DHW

### COINCIDENCE FACTOR

The coincidence factor for this measure is assumed to be 0.22%.[696]

**Algorithm**

### CALCULATION OF ENERGY SAVINGS

### ELECTRIC ENERGY SAVINGS

ΔkWh = %ElectricDHW * ((GPM_base_S * L_showerdevice) * Household * SPCD * 365.25 / SPH) *

[693] Assumptions based on NY TRM, Pacific Gas and Electric Company Work Paper PGECODHW113, and measure life of low-flow showerhead.
[694] Based on actual cost of the SS-1002CP-SB Ladybug Water-Saving Shower-Head adapter from Evolve showerheads.
[695] Estimate for contractor installation time.
[696] Calculated as follows: Assume 11% showers take place during peak hours (based on: Oreo et al, "The end uses of hot water in single family homes from flow trace analysis", 2001.). There are 65 days in the summer peak period, so the percentage of total annual use in peak period is 0.11*65/365 = 1.96%. The number of hours of recovery during peak periods is therefore assumed to be 1.96% * 29.5 = 0.577 hours of recovery during peak period, where 29.5 equals the average annual electric DHW recovery hours for showerhead use prevented by the device including SF and MF homes with Direct Install and Retrofit/TOS measures. There are 260 hours in the peak period so the probability you will see savings during the peak period is 0.577/260 = 0.0022

EPG_electric * ISR

Where:

%ElectricDHW = proportion of water heating supplied by electric resistance heating

| DHW fuel | %ElectricDHW |
|---|---|
| Electric | 100% |
| Natural Gas | 0% |
| Unknown | 16%[697] |

GPM_base_S = Flow rate of the basecase showerhead, or actual if available

| Program | GPM |
|---|---|
| Direct-install, device only | 2.67[698] |
| New Construction or direct install of device and low flow showerhead | Rated or actual flow of program-installed showerhead |
| Retrofit or TOS | 2.35[699] |

L_showerdevice = Hot water waste time avoided due to thermostatic restrictor valve

= 0.89 minutes[700]

Household = Average number of people per household

| Household Unit Type[701] | Household |
|---|---|
| Single-Family - Deemed | 2.56[702] |
| Multi-Family - Deemed | 2.1[703] |
| Household type unknown | 2.42[704] |
| Custom | Actual Occupancy or Number of Bedrooms[705] |

Use Multifamily if: Building meets utility's definition for multifamily

SPCD = Showers Per Capita Per Day

[697] Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IL. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used

[698] Based on measured data from Ameren IL EM&V of Direct-Install program. Program targets showers that are rated 2.5 GPM or above. Assumes low flow showerhead not included in direct installation.

[699] Representative value from sources 1, 2, 4, 5, 6 and 7 (See Source Table at end of measure section) adjusted slightly upward to account for program participation which is expected to target customers with existing higher flow devices rather than those with existing low flow devices.

[700] Average of the following sources: ShowerStart LLC survey; "Identifying, Quantifying and Reducing Behavioral Waste in the Shower: Exploring the Savings Potential of ShowerStart", City of San Diego Water Department survey; "Water Conservation Program: ShowerStart Pilot Project White Paper", and PG&E Work Paper PGECODHW113.

[701] If household type is unknown, as may be the case for time of sale measures, then single family deemed value shall be used.

[702] ComEd Energy Efficiency/ Demand Response Plan: Plan Year 2 (6/1/2009-5/31/2010) Evaluation Report: All Electric Single Family Home Energy Performance Tune-Up Program citing 2006-2008 American Community Survey data from the US Census Bureau for Illinois cited on p. 17 of the PY2 Evaluation report. 2.75 * 93% evaluation adjustment

[703] ComEd PY3 Multifamily Evaluation Report REVISED DRAFT v5 2011-12-08.docx

[704] Unknown is based on statewide weighted average of 69% single family and 31% multifamily, based on IL data from 2009 RECS Table HC2.9 Structural and Geographic Characteristics of Homes in Midwest Region, Divisions and States, 2009.

[705] Bedrooms are suitable proxies for household occupancy, and may be preferable to actual occupancy due to turnover rates in residency and non-adult population impacts.

= 0.6[706]

365.25 = Days per year, on average.

SPH = Showerheads Per Household so that per-showerhead savings fractions can be determined

| Household Type | SPH |
|---|---|
| Single-Family | 1.79[707] |
| Multifamily | 1.3[708] |
| Household type unknown | 1.64[709] |
| Custom | Actual |

Use Multifamily if: Building meets utility's definition for multifamily

EPG_electric = Energy per gallon of hot water supplied by electric

= (8.33 * 1.0 * (ShowerTemp - SupplyTemp)) / (RE_electric * 3412)

= (8.33 * 1.0 * (101 – 54.1)) / (0.98 * 3412)

= 0.117 kWh/gal

8.33 = Specific weight of water (lbs/gallon)

1.0 = Heat Capacity of water (btu/lb-°)

ShowerTemp = Assumed temperature of water

= 101F [710]

SupplyTemp = Assumed temperature of water entering house

= 54.1F [711]

RE_electric = Recovery efficiency of electric water heater

= 98% [712]

3412 = Converts Btu to kWh (btu/kWh)

ISR = In service rate of showerhead

= Dependent on program delivery method as listed in table below

| Selection | ISR |
|---|---|
| Direct Install - Single Family | 0.98[713] |

[706] Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.
[707] Based on findings from a 2009 ComEd residential survey of 140 sites, provided by Cadmus.
[708] Ibid.
[709] Unknown is based on statewide weighted average of 69% single family and 31% multifamily, based on IL data from 2009 RECS Table HC2.9 Structural and Geographic Characteristics of Homes in Midwest Region, Divisions and States, 2009.
[710] Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.
[711] US DOE Building America Program. Building America Analysis Spreadsheet.
[712] Electric water heaters have recovery efficiency of 98%.
[713] Deemed values are from ComEd Energy Efficiency/ Demand Response Plan: Plan Year 2 (6/1/2009-5/31/2010) Evaluation Report: All Electric Single Family Home Energy Performance Tune-Up Program Table 3-8. Alternative ISRs may be developed for program delivery methods based on evaluation results.

| Selection | ISR |
|---|---|
| Direct Install – Multi Family | 0.95[714] |
| Efficiency Kits | To be determined through evaluation |

Use Multifamily if: Building meets utility's definition for multifamily

> Example
>
> For example, a direct installed valve in a single-family home with electric DHW:
>
> $\Delta kWh = 1.0 * (2.67 * 0.89 * 2.56 * 0.6 * 365.25 / 1.79) * 0.117 * 0.98$
>
> $= 85$ kWh

Secondary kWh Savings for Water Supply and Wastewater Treatment

The following savings should be included in the total savings for this measure, but should not be included in TRC tests to avoid double counting the economic benefit of water savings.

$$\Delta kWh_{water} = \Delta Water\ (gallons) / 1{,}000{,}000 * E_{water\ total}$$

Where

$E_{water\ total}$ = IL Total Water Energy Factor (kWh/Million Gallons)

=5,010[715]

> For example, a direct installed thermostatic restrictor device in a home with an single family home where the number of showers is not known:
>
> $\Delta Water\ (gallons) = ((2.67 * 0.89) * 2.56 * 0.6 * 365.25 / 1.79) * 0.98$
>
> = 730 gallons
>
> $\Delta kWh_{water} = 730/1{,}000{,}000 * 5010$
>
> = 3.7 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$$\Delta kW = \Delta kWh/Hours * CF$$

Where:

ΔkWh = calculated value above. Note do not include the secondary savings in this calculation.

Hours = Annual electric DHW recovery hours for wasted showerhead use prevented by device

= ((GPM_base_S * L_showerdevice) * Household * SPCD * 365.25 ) * 0.712[716] / GPH

GPH = Gallons per hour recovery of electric water heater calculated for 65.9F temp rise (120-54.1), 98% recovery efficiency, and typical 4.5kW electric resistance storage tank.

= 27.51

= 34.4 for SF Direct Install; 28.3 for MF Direct Install

= 30.3 for SF Retrofit and TOS; 24.8 for MF Retrofit and TOS

Use Multifamily if: Building meets utility's definition for multifamily

714 Navigant, ComEd-Nicor Gas EPY4/GPY1 Multifamily Home Energy Savings Program Evaluation Report FINAL 2013-06-05

715 This factor include 2571 kWh/MG for water supply based on Illinois energy intensity data from a 2012 ISAWWA study and 2439 kWh/MG for wastewater treatment based on national energy intensity use estimates. For more information please review Elevate Energy's 'IL TRM: Energy per Gallon Factor, May 2018 paper'.

716 71.2% is the proportion of hot 120F water mixed with 54.1F supply water to give 101F shower water.

CF = Coincidence Factor for electric load reduction

= 0.0022[717]

**Example**

For example, a direct installed thermostatic restrictor device in a home with electric DHW where the number of showers is not known.

ΔkW = 85.3/34.4 * 0.0022

= 0.0055 kW

**NATURAL GAS SAVINGS**

ΔTherms = %FossilDHW * ((GPM_base_S * L_showerdevice)* Household * SPCD * 365.25 / SPH) * EPG_gas * ISR

Where:

%FossilDHW = proportion of water heating supplied by Natural Gas heating

| DHW fuel | %Fossil_DHW |
|---|---|
| Electric | 0% |
| Natural Gas | 100% |
| Unknown | 84%[718] |

EPG_gas = Energy per gallon of Hot water supplied by gas

= (8.33 * 1.0 * (ShowerTemp - SupplyTemp)) / (RE_gas * 100,000)

= 0.00501 Therm/gal for SF homes

= 0.00583 Therm/gal for MF homes

RE_gas = Recovery efficiency of gas water heater

= 78% For SF homes[719]

= 67% For MF homes[720]

Use Multifamily if: Building has shared DHW.

[717] Calculated as follows: Assume 11% showers take place during peak hours (based on: Oreo et al, “The end uses of hot water in single family homes from flow trace analysis”, 2001.). There are 65 days in the summer peak period, so the percentage of total annual use in peak period is 0.11*65/365 = 1.96%. The number of hours of recovery during peak periods is therefore assumed to be 1.96% * 29.5 = 0.577 hours of recovery during peak period, where 29.5 equals the average annual electric DHW recovery hours for showerhead use prevented by the device including SF and MF homes with Direct Install and Retrofit/TOS measures. There are 260 hours in the peak period so the probability you will see savings during the peak period is 0.577/260 = 0.0022

[718] Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IL. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used

[719] DOE Final Rule discusses Recovery Efficiency with an average around 0.76 for Gas Fired Storage Water heaters and 0.78 for standard efficiency gas fired tankless water heaters up to 0.95 for the highest efficiency gas fired condensing tankless water heaters. These numbers represent the range of new units however, not the range of existing units in stock. Review of AHRI Directory suggests range of recovery efficiency ratings for new Gas DHW units of 70-87%. Average of existing units is estimated at 78%.

[720] Water heating in Multifamily buildings is often provided by a larger central boiler. This suggests that the average recovery efficiency is somewhere between a typical central boiler efficiency of 0.59 and the 0.75 for single family homes. An average efficiency of 0.67 is used for this analysis as a default for Multifamily buildings.

100,000 = Converts Btus to Therms (btu/Therm)

Other variables as defined above.

**Example**

For example, a direct installed thermostatic restrictor device in a gas fired DHW single family home where the number of showers is not known:

ΔTherms = 1.0 * ((2.67 * 0.89) * 2.56 * 0.6 * 365.25 / 1.79) * 0.00501 * 0.98

= 3.7 therms

### WATER IMPACT DESCRIPTIONS AND CALCULATION

ΔWater (gallons) = ((GPM_base_S * L_showerdevice) * Household * SPCD * 365.25 / SPH) * ISR

Variables as defined above

**Example**

For example, a direct installed thermostatic restrictor device in a single family home where the number of showers is not known:

ΔWater (gallons) = ((2.67 * 0.89) * 2.56 * 0.6 * 365.25 / 1.79) * 0.98

= 730 gallons

### DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

### SOURCES

| Source ID | Reference |
|---|---|
| 1 | 2011, DeOreo, William. California Single Family Water Use Efficiency Study. April 20, 2011. |
| 2 | 2000, Mayer, Peter, William DeOreo, and David Lewis. Seattle Home Water Conservation Study. December 2000. |
| 3 | 1999, Mayer, Peter, William DeOreo. Residential End Uses of Water. Published by AWWA Research Foundation and American Water Works Association. 1999. |
| 4 | 2003, Mayer, Peter, William DeOreo. Residential Indoor Water Conservation Study. Aquacraft, Inc. Water Engineering and Management. Prepared for East Bay Municipal Utility District and the US EPA. July 2003. |
| 5 | 2011, DeOreo, William. Analysis of Water Use in New Single Family Homes. By Aquacraft. For Salt Lake City Corporation and US EPA. July 20, 2011. |
| 6 | 2011, Aquacraft. Albuquerque Single Family Water Use Efficiency and Retrofit Study. For Albuquerque Bernalillo County Water Utility Authority. December 1, 2011. |
| 7 | 2008, Schultdt, Marc, and Debra Tachibana. Energy related Water Fixture Measurements: Securing the Baseline for Northwest Single Family Homes. 2008 ACEEE Summer Study on Energy Efficiency in Buildings. |
| 8 | 2011, Lutz, Jim. “Water and Energy Wasted During Residential Shower Events: Findings from a Pilot Field Study of Hot Water Distribution Systems”, Energy Analysis Department Lawrence Berkeley National Laboratory, September 2011. |
| 9 | 2008, Water Conservation Program: ShowerStart Pilot Project White Paper, City of San Diego, CA. |
| 10 | 2012, Pacific Gas and Electric Company, Work Paper PGECODHW113, Low Flow Showerhead and Thermostatic Shower Restriction Valve, Revision # 4, August 2012. |
| 11 | 2008, “Simply & Cost Effectively Reducing Shower Based Warm-Up Waste: Increasing Convenience & Conservation by Attaching ShowerStart to Existing Showerheads”, ShowerStart LLC. |
| 12 | 2014, New York State Record of Revision to the TRM, Case 07-M-0548, June 19, 2014. |

**MEASURE CODE: RS-HWE-TRVA-V04-190101**

**REVIEW DEADLINE: 1/1/2023**

## 5.4.9 Shower Timer

### Description

Shower Timers are designed to make it easy for people to consistently take short showers, resulting in water and energy savings.

The shower timer provides a reminder to participants on length of their shower visually or auditorily.

This measure was developed to be applicable to the following program type: KITS, DI.

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

The shower timer should provide a reminder to participants to keep showers to a length of 5 minutes or less.

### Definition of Baseline Equipment

The baseline is no shower timer.

### Deemed Lifetime of Efficient Equipment

The deemed lifetime is 2 years[721].

### Deemed Measure Cost

For shower timers provided in Efficiency Kits, the actual program delivery costs should be utilized.

### Loadshape

Loadshape R03 - Residential Electric DHW

### Coincidence Factor

The coincidence factor for this measure is assumed to be 2.78%.[722]

---

**Algorithm**

---

### Calculation of Energy Savings

### Electric Energy Savings

ΔkWh = %Electric DHW * GPM * (L_base – L_timer) * Household * Days/yr * SPCD * UsageFactor * EPG_Electric

Where:

%Electric DHW = Proportion of water heating supplied by electric resistance heating

---

721 Estimate of persistence of behavior change instigated by the shower timer.

722 Calculated as follows: Assume 11% showers take place during peak hours (based on: Oreo et al, "The end uses of hot water in single family homes from flow trace analysis", 2001.). There are 65 days in the summer peak period, so the percentage of total annual aerator use in peak period is 0.11*65/365 = 1.96%. The number of hours of recovery during peak periods is therefore assumed to be 1.96% * 369 = 7.23 hours of recovery during peak period, where 369 equals the average annual electric DHW recovery hours for showerhead use including SF and MF homes with Direct Install and Retrofit/TOS measures. There are 260 hours in the peak period so the probability you will see savings during the peak period is 7.23/260 = 0.0278

| DHW fuel | %ElectricDHW |
|---|---|
| Electric | 100% |
| Natural Gas | 0% |
| Unknown | 16%[723] |

GPM = Flow rate of showerhead as used

= Custom, to be determined through evaluation. If data is not available use 1.93[724]

L_base = Number of minutes in shower without a shower timer

=7.8 minutes[725]

L_timer = Number of minutes in shower after shower timer

= Custom, to be determined through evaluation. If data is not available use 5.79[726]

Household = Number in household using timer

| Household Unit Type[727] | Household |
|---|---|
| Single-Family - Deemed | 2.56[728] |
| Multi-Family - Deemed | 2.1[729] |
| Household type unknown | 2.42[730] |
| Custom | Actual Occupancy or Number of Bedrooms[731] |

Days/yr = 365.25

SPCD = Showers Per Capita Per Day

= 0.6[732]

UsageFactor = How often each participant is using shower timer

=Custom, to be determined through evaluation. If data is not available use 0.34[733]

723 Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IL. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used

724 Navigant Elementary Education GPY4 Evaluation Report, dated May 12, 2016. Average of all utilities.

725 Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group. This study of 135 single and Multifamily homes in Michigan metered energy parameters for efficient showerhead and faucet aerators.

726 Navigant Elementary Education GPY4 Evaluation Report, dated May 12, 2016. Average of all utilities.

727 If household type is unknown, as may be the case for time of sale measures, then single family deemed value shall be used.

728 ComEd Energy Efficiency/ Demand Response Plan: Plan Year 2 (6/1/2009-5/31/2010) Evaluation Report: All Electric Single Family Home Energy Performance Tune-Up Program citing 2006-2008 American Community Survey data from the US Census Bureau for Illinois cited on p. 17 of the PY2 Evaluation report. 2.75 * 93% evaluation adjustment

729 ComEd PY3 Multifamily Evaluation Report REVISED DRAFT v5 2011-12-08.docx

730 Unknown is based on statewide weighted average of 69% single family and 31% multifamily, based on IL data from 2009 RECS Table HC2.9 Structural and Geographic Characteristics of Homes in Midwest Region, Divisions and States, 2009.

731 Bedrooms are suitable proxies for household occupancy, and may be preferable to actual occupancy due to turnover rates in residency and non-adult population impacts.

732 Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.

733 Navigant Elementary Education GPY4 Evaluation Report, dated May 12, 2016. Average of all utilities.

EPG_Electric = Energy per gallon of hot water supplied by electric

= (8.33 * 1.0 * (ShowerTemp - SupplyTemp)) / (RE_electric * 3412)

= (8.33 * 1.0 * (101 – 54.1)) / (0.98 * 3412)

=0.117 kWh/gal

Based on default assumptions provided above, the savings for a single family home would be:

ΔkWh = %Electric DHW * GPM * (L_base – L_timer) * Household * Days/yr * SPCD * UsageFactor * EPG_Electric

= 0.16 * 1.93 * (7.8 – 5.79) * 2.56 * 365.25 * 0.6 * 0.34 * 0.117

=13.9kWh

Secondary kWh Savings for Water Supply and Wastewater Treatment

The following savings should be included in the total savings for this measure, but should not be included in TRC tests to avoid double counting the economic benefit of water savings.

$\Delta kWh_{water}$ = ΔWater (gallons) / 1,000,000 * $E_{water\ total}$

Where

$E_{water\ total}$ = IL Total Water Energy Factor (kWh/Million Gallons)

=5,010[734]

Based on default assumptions provided above, the savings for a single family home would be:

ΔWater (gallons) = GPM * (L_base – L_timer) * Household ***** Days/yr * SPCD * UsageFactor

= 1.93 * (7.8 – 5.79) * 2.56 * 365.25 * 0.6 * 0.34

= 740.0 gallons

$\Delta kWh_{water}$ = 740/1,000,000 * 5010

= 3.7 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = ΔkWh/Hours * CF

Where:

ΔkWh = calculated value above. Note do not include the secondary savings in this calculation.

Hours = Annual electric DHW recovery hours for showerhead use

= ((GPM_base * L_base) * Household Users * SPCD * 365.25 ) * 0.712 / GPH

GPH = Gallons per hour recovery of electric water heater calculated for 65.9F temp rise (120-54.1), 98% recovery efficiency, and typical 4.5kW electric resistance storage tank.

= 27.51

CF = Coincidence Factor for electric load reduction

= 0.0278[735]

[734] This factor include 2571 kWh/MG for water supply based on Illinois energy intensity data from a 2012 ISAWWA study and 2439 kWh/MG for wastewater treatment based on national energy intensity use estimates. For more information please review Elevate Energy's 'IL TRM: Energy per Gallon Factor, May 2018 paper'.

[735] Calculated as follows: Assume 11% showers take place during peak hours (based on: Oreo et al, "The end uses of hot water

Based on default assumptions provided above, the savings for a single family home would be:

ΔkW = ΔkWh/Hours * CF

= 0.0013 kW

**NATURAL GAS SAVINGS**

ΔTherms = %FossilDHW * GPM * (L_base – L_timer) * Household * Days/yr * SPCD * UsageFactor * EPG_Gas

%FossilDHW = Proportion of water heating supplied by electric resistance heating

| DHW fuel | %FossilDHW |
|---|---|
| Electric | 0% |
| Natural Gas | 100% |
| Unknown | 84%[736] |

EPG_gas = Energy per gallon of Hot water supplied by gas

= (8.33 * 1.0 * (ShowerTemp - SupplyTemp)) / (RE_gas * 100,000)

= 0.00501 Therm/gal for SF homes

= 0.00583 Therm/gal for MF homes

RE_gas = Recovery efficiency of gas water heater

= 78% For SF homes [737]

= 67% For MF homes[738]

Use Multifamily if: Building has shared DHW.

100,000 = Converts Btus to Therms (btu/Therm)

Other variables as defined above.

Based on default assumptions provided above, the savings for a single family home would be:

Δ Therms = %FossilDHW * GPM * (L_base – L_timer) * Household * Days/yr * SPCD * UsageFactor * EPG_Gas

= 0.84 * 1.93 * (7.8 – 5.79) * 2.56 * 365.25 * 0.6 * 0.34 * 0.00501

= 3.1 Therms

in single family homes from flow trace analysis", 2001.). There are 65 days in the summer peak period, so the percentage of total annual aerator use in peak period is 0.11*65/365 = 1.96%. The number of hours of recovery during peak periods is therefore assumed to be 1.96% * 369 = 7.23 hours of recovery during peak period where 369 equals the average annual electric DHW recovery hours for showerhead use including SF and MF homes with Direct Install and Retrofit/TOS measures. There are 260 hours in the peak period so the probability you will see savings during the peak period is 7.23/260 = 0.0278

736 Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IL. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used

737 DOE Final Rule discusses Recovery Efficiency with an average around 0.76 for Gas Fired Storage Water heaters and 0.78 for standard efficiency gas fired tankless water heaters up to 0.95 for the highest efficiency gas fired condensing tankless water heaters. These numbers represent the range of new units however, not the range of existing units in stock. Review of AHRI Directory suggests range of recovery efficiency ratings for new Gas DHW units of 70-87%. Average of existing units is estimated at 78%.

738 Water heating in Multifamily buildings is often provided by a larger central boiler. This suggests that the average recovery efficiency is somewhere between a typical central boiler efficiency of 0.59 and the 0.75 for single family homes. An average efficiency of 0.67 is used for this analysis as a default for Multifamily buildings.

**WATER DESCRIPTIONS AND CALCULATION**

ΔWater (gallons) = GPM * (L_base – L_timer) * Household * Days/yr * SPCD * UsageFactor

Variables as defined above

Based on default assumptions provided above, the savings for a single family home would be:

ΔWater (gallons) = GPM * (L_base – L_timer) * Household * Days/yr * SPCD * UsageFactor

= 1.93 * (7.8 – 5.79) * 2.56 * 365.25 * 0.6 * 0.34

= 740.0 gallons

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-DHW-SHTM-V02-190101**

**REVIEW DEADLINE: 1/1/2021**

# 5.5 Lighting End Use

## 5.5.1 Compact Fluorescent Lamp (CFL)

**NOTE: THIS MEASURE IS EFFECTIVE UNTIL 12/31/2018. IT IS LEFT IN THE MANUAL FOR REFERENCE PURPOSES AND FOR CALCULATION OF CARRY OVER SAVINGS.**

### DESCRIPTION

A low wattage qualified compact fluorescent screw-in bulb (CFL) is installed in place of a baseline screw-in bulb. Note a new ENERGY STAR specification v2.0 becomes effective on 1/2/2017 (https://www.energystar.gov/products/spec/lamps_specification_version_2_0_pd). The efficacy requirements cannot currently be met by Compact Fluorescent Lamps, and therefore this specification has been removed. ENERGY STAR will maintain a list on their website with the final qualifying list of products prior to this change and it is strongly recommended that programs continue to use this list as qualifying criteria for products in the programs.

This characterization assumes that the CFL is installed in a residential location. If the implementation strategy does not allow for the installation location to be known (e.g. an upstream retail program), a deemed split of 95% Residential and 5% Commercial assumptions should be used[739].

Federal legislation stemming from the Energy Independence and Security Act of 2007 (EISA) required all general-purpose light bulbs between 40W and 100W to be approximately 30% more energy efficient than current incandescent bulbs. Production of 100W, standard efficacy incandescent lamps ended in 2012, followed by restrictions on 75W in 2013 and 60W and 40W in 2014. The baseline for this measure has therefore become bulbs (improved incandescent or halogen) that meet the new standard.

A provision in the EISA regulations requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the baseline equivalent to a current day CFL. Therefore the measure life (number of years that savings should be claimed) should be reduced once the assumed lifetime of the bulb exceeds 2020. Due to expected delay in clearing retail inventory and to account for the operating life of a halogen incandescent potentially spanning over 2020, this shift is assumed not to occur until 2021.

This measure was developed to be applicable to the following program types: TOS, NC, DI, KITS. If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the high-efficiency equipment must be a standard qualified compact fluorescent lamp.

### DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is assumed to be an EISA qualified incandescent or halogen as provided in the table provided in the Electric Energy Savings section.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life (number of years that savings should be claimed) for bulbs installed in 2018 is assumed to be 3 years and then for every subsequent year should be reduced by one year[740].

---

[739] RES v C&I split is based on a weighted (by sales volume) average of ComEd PY6, PY7 and PY8 and Ameren PY5, PY6 and PY8 in store intercept survey results. See 'RESvCI Split_112016.xls'.

[740] Since the replacement baseline bulb from 2020 on will be equivalent to a CFL, no additional savings should be claimed from that point. Due to expected delay in clearing stock from retail outlets and to account for the operating life of a halogen incandescent potentially spanning over 2020, this shift is assumed not to occur until 2021.

### DEEMED MEASURE COST

For the Retail (Time of Sale) measure, the incremental capital cost is $1.20[741].

For the Direct Install measure, the full cost of $2.45 per bulb should be used, plus $5 labor cost[742] for a total of $7.45 per bulb. However actual program delivery costs should be utilized if available.

For bulbs provided in Efficiency Kits, the actual program delivery costs should be utilized.

### LOADSHAPE

Loadshape R06 - Residential Indoor Lighting

Loadshape R07 - Residential Outdoor Lighting

### COINCIDENCE FACTOR

The summer peak coincidence factor is assumed to be 7.1% for Time of Sale Residential and in-unit Multi Family bulbs, 27.3% for exterior bulbs and 8.1% for unknown[743] and 7.4% for Residential Direct Install[744].

**Algorithm**

### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

ΔkWh = ((WattsBase - WattsEE) / 1000) * ISR * (1-Leakage) * Hours * WHFe

Where:

WattsBase = Based on lumens of CFL bulb and program year installed:

| Minimum Lumens | Maximum Lumens | Incandescent Equivalent Post-EISA 2007 (WattsBase) |
|---|---|---|
| 5280 | 6209 | 300 |
| 3000 | 5279 | 200 |
| 2601 | 2999 | 150 |
| 1490 | 2600 | 72 |
| 1050 | 1489 | 53 |
| 750 | 1049 | 43 |
| 310 | 749 | 29 |
| 250 | 309 | 25 |

WattsEE = Actual wattage of CFL purchased / installed

ISR = In Service Rate, the percentage of units rebated that are actually in service.

741 Based upon field data collected by CLEAResult and provided by ComEd. See ComEd Pricing Projections 06302016.xlsx for analysis.

742 Based on 15 minutes at $20 an hour. Includes some portion of travel time to site.

743 Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

744 Based on lighting logger study conducted as part of the PY5/PY6 ComEd Residential Lighting Program evaluation and excluding all logged bulbs installed in closets.

| Program | | Weighted Average 1st Year In Service Rate (ISR) | 2nd year Installations | 3rd year Installations | Final Lifetime In Service Rate |
|---|---|---|---|---|---|
| Retail (Time of Sale) | | 76.5%[745] | 11.6% | 9.9% | 98.0%[746] |
| Direct Install | | 96.9%[747] | | | |
| Efficiency Kits[748] | CFL Distribution[749] | 59% | 13% | 11% | 83% |
| | School Kits[750] | 61% | 13% | 11% | 86% |
| | Direct Mail Kits[751] | 66% | 14% | 12% | 93% |

Leakage = Adjustment to account for the percentage of program bulbs that move out (and in if deemed appropriate[752]) of the Utility Jurisdiction.

KITS programs = Determined through evaluation

Upstream (TOS) Lighting programs = Determined through evaluation or use deemed assumptions below[753]:

ComEd: 2.1%

Ameren: 13.1%

All other programs = 0

Hours = Average hours of use per year

[745] 1st year in service rate is based upon review of PY6-8 evaluations from ComEd and PY5,6 and 8 for Ameren (see 'IL RES Lighting ISR_112016.xls' for more information). The average first year ISR for each utility was calculated weighted by the number of bulbs in the each year's survey. This was then weighted by annual sales to give a statewide assumption.

[746] The 98% Lifetime ISR assumption is based upon review of two evaluations:
'Nexus Market Research, RLW Analytics and GDS Associates study; "New England Residential Lighting Markdown Impact Evaluation, January 20, 2009' and 'KEMA Inc, Feb 2010, Final Evaluation Report:, Upstream Lighting Program, Volume 1.' This implies that only 2% of bulbs purchased are never installed. The second and third year installations are based upon Ameren analysis of the Californian KEMA study showing that 54% of future installs occur in year 2 and 46% in year 3. The 2nd and 3rd year installations should be counted as part of those future program year savings.

[747] Based upon review of the PY2 and PY3 ComEd Direct Install program surveys. This value includes bulb failures in the 1st year to be consistent with the Commission approval of annualization of savings for first year savings claims. ComEd PY2 All Electric Single Family Home Energy Performance Tune-Up Program Evaluation, Navigant Consulting, December 21, 2010.

[748] In Service Rates provided are for the CFL bulb within a kit only. Given the significant differences in program design and the level of education provided through Efficiency Kits programs, the evaluators should apply the ISR estimated through evaluations (either past evaluations or the current program year evaluation) of the specific Efficiency Kits program. In cases where program-specific evaluation results for an ISR are unavailable, the default ISR values for Efficiency Kits provided may be used.

[749] Free bulbs provided without request, with little or no education. Based on 'Impact and Process Evaluation of 2013 (PY6) Ameren Illinois Company Residential CFL Distribution Program', Report Table 11 and Appendix B.

[750] Kits provided free to students through school, with education program. Based on 'Impact and Process Evaluation of 2013 (PY6) Ameren Illinois Company Residential Efficiency Kits Program', table 10. Final ISR assumptions are based upon comparing with CFL Distribution First year ISR and multiplying by the CFL Distribution Final ISR value, and second and third year estimates based on same proportion of future installs.

[751] Opt-in program to receive kits via mail, with little or no education. Based on 'Impact and Process Evaluation of 2013 (PY6) Ameren Illinois Company Residential Efficiency Kits Program', table 10, as above.

[752] Leakage in is only appropriate to credit to IL utility program savings if it is reasonably expected that the IL utility program marketing efforts played an important role in influencing customer to purchase the light bulbs. Furthermore, consideration that such customers might be free riders should be addressed. If leakage in is assessed, efforts should be made to ensure no double counting of savings occurs if the evaluation is estimating both leakage in and spillover savings of light bulbs.

[753] Leakage rate is based upon review of PY6-8 evaluations from ComEd and PY5,6 and 8 for Ameren (see 'IL Leakage Rates_112016.xls' for more information).

| Program Delivery | Installation Location | Hours[754] |
|---|---|---|
| Retail (Time of Sale) and Efficiency Kits | Residential Interior and in-unit Multi Family | 759 |
| | Exterior | 2,475 [755] |
| | Unknown | 847 [756] |
| Direct Install | Residential Interior and in-unit Multi Family | 793 |
| | Exterior | 2,475 |

WHFe = Waste heat factor for energy to account for cooling energy savings from efficient lighting

| Bulb Location | WHFe |
|---|---|
| Interior single family or unknown location | 1.06 [757] |
| Multi family in unit | 1.04 [758] |
| Exterior or uncooled location | 1.0 |

**DEFERRED INSTALLS**

As presented above, the characterization assumes that a percentage of bulbs purchased are not installed until Year 2 and Year 3 (see ISR assumption above). The Illinois Technical Advisory Committee has determined the following methodology for calculating the savings of these future installs.

Year 1 (Purchase Year) installs: Characterized using assumptions provided above or evaluated assumptions if available.

Year 2 and 3 installs: Characterized using delta watts assumption and hours of use from the Install Year i.e. the actual deemed (or evaluated if available) assumptions active in Year 2 and 3 should be applied.

The NTG factor for the Purchase Year should be applied.

754 Except where noted, based on lighting logger study conducted as part of the PY5/PY6 ComEd Residential Lighting Program evaluation. Direct Install value excludes all logged bulbs installed in closets.

755 Based on secondary research conducted as part of the PY5/PY6 ComEd Residential Lighting Program evaluation.

756 Assumes 5% exterior lighting, based on PYPY5/PY6 ComEd Residential Lighting Program evaluation.

757 The value is estimated at 1.06 (calculated as 1 + (0.66*(0.27 / 2.8)). Based on cooling loads decreasing by 27% of the lighting savings (average result from REMRate modeling of several different configurations and IL locations of homes), assuming typical cooling system operating efficiency of 2.8 COP (starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm (-0.02 * SEER2) + (1.12 * SEER) (from Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), converted to COP = EER/3.412 = 2.8COP) and 66% of homes in Illinois having central cooling ("Table HC7.9 Air Conditioning in Homes in Midwest Region, Divisions, and States, 2009 from Energy Information Administration", 2009 Residential Energy Consumption Survey)

758 As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from "Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009" which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average)

For example, for a 14W CFL (60W standard incandescent and 43W EISA qualified incandescent/halogen):

$\Delta kWH_{1st\ year\ installs}$ = ((43 - 14) / 1000) * 0.765 * 847 * 1.06

= 19.9 kWh

$\Delta kWH_{2nd\ year\ installs}$ = ((43 - 14) / 1000) * 0.116 * 847 * 1.06

= 3.0 kWh

Note: Here we assume no change in hours assumption. NTG value from Purchase year applied.

$\Delta kWH_{3rd\ year\ installs}$ = ((43 - 14) / 1000) * 0.099 * 847 * 1.06

= 2.6 kWh

**HEATING PENALTY**

If electric heated home (if heating fuel is unknown assume gas, see Natural Gas section):

ΔkWh[759] = - (((WattsBase - WattsEE) / 1000) * ISR * (1-Leakage) * Hours * HF) / ηHeat

Where:

HF = Heating Factor or percentage of light savings that must be heated

= 49%[760] for interior or unknown location

= 0% for exterior or unheated location

ηHeat = Efficiency in COP of Heating equipment

= actual. If not available use[761]:

| System Type | Age of Equipment | HSPF Estimate | $COP_{HEAT}$ (COP Estimate) = (HSPF/3.413)*0.85 |
|---|---|---|---|
| Heat Pump | Before 2006 | 6.8 | 1.7 |
| | After 2006 - 2014 | 7.7 | 1.92 |
| | 2015 on | 8.2 | 2.04 |
| Resistance | N/A | N/A | 1.00 |
| Unknown[762] | N/A | N/A | 1.28 |

For example, a 14W standard CFL is purchased and installed in home with 2.0 COP (including duct loss) Heat Pump:

$\Delta kWh_{1st\ year}$ = - (((43 - 14) / 1000) * 0.765 * 759 * 0.49) / 2.0

= - 4.2 kWh

Second and third year install savings should be calculated using the appropriate ISR and the delta watts and hours from the install year.

[759] Negative value because this is an increase in heating consumption due to the efficient lighting.

[760] This means that heating loads increase by 49% of the lighting savings. This is based on the average result from REMRate modeling of several different configurations and IL locations of homes.

[761] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate. Note efficiency should include duct losses. Defaults provided assume 15% duct loss for heat pumps.

[762] Calculation assumes 35% Heat Pump and 65% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see "HC6.9 Space Heating in Midwest Region.xls", using average for East North Central Region. Average efficiency of heat pump is based on assumption that 50% are units from before 2006 and 50% from 2006-2014. Program or evaluation data should be used to improve this assumption if available.

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ((WattsBase - WattsEE) / 1 000) * ISR * (1-Leakage) * WHFd * CF

Where:

WHFd = Waste heat factor for demand to account for cooling savings from efficient lighting.

| Bulb Location | WHFd |
|---|---|
| Interior single family or unknown location | 1.11[763] |
| Multi family in unit | 1.07[764] |
| Exterior or uncooled location | 1.0 |

CF = Summer Peak Coincidence Factor for measure.

| Program Delivery | Bulb Location | CF[765] |
|---|---|---|
| Retail(Time of Sale) | Interior single family or Multi Family in unit | 7.1% |
| | Exterior | 27.3% |
| | Unknown location | 8.1% |
| Direct Install | Residential | 7.4% |

Other factors as defined above

For example, a 14W standard CFL is purchased and installed in a single family interior location:

ΔkW = ((43 - 14) / 1000) * 0.765 * 1.11 * 0.071

= 0.0017 kW

Second and third year install savings should be calculated using the appropriate ISR and the delta watts and hours from the install year.

### NATURAL GAS SAVINGS

Heating Penalty if Natural Gas heated home (or if heating fuel is unknown):

ΔTherms[766] = - (((WattsBase - WattsEE) / 1000) * ISR * (1-Leakage) * Hours * HF * 0.03412) / ηHeat

Where:

HF = Heating Factor or percentage of light savings that must be heated

= 49%[767] for interior or unknown location

= 0% for exterior or unheated location

[763] The value is estimated at 1.11 (calculated as 1 + (0.66 * 0.466 / 2.8)). See footnote relating to WHFe for details. Note the 46.6% factor represents the average Residential cooling coincidence factor calculated by dividing average load during the peak hours divided by the maximum cooling load.

[764] As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from “Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009” which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average)

[765] Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation. Direct Install value is based on resut excluding all logged bulbs installed in closets.

[766] Negative value because this is an increase in heating consumption due to the efficient lighting.

[767] This means that heating loads increase by 49% of the lighting savings. This is based on the average result from REMRate modeling of several different configurations and IL locations of homes.

0.03412 =Converts kWh to Therms

ηHeat = Efficiency of heating system

=70%[768]

For example, a 14 standard CFL is purchased and installed in a home:

ΔTherms = - (((43 - 14) / 1000) * 0.765 * 759 * 0.49 * 0.03412) / 0.7

= - 0.40 Therms

Second and third year install savings should be calculated using the appropriate ISR and the delta watts and hours from the install year.

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

The O&M assumptions that should be used in cost effectiveness calculations are provided below:

| Program Delivery | Installation Location | Replacement Period (years)[769] | Replacement Cost[770] |
|---|---|---|---|
| Retail (Time of Sale) and Efficiency Kits | Residential Interior and in-unit Multi Family | 1.3 | $1.25 |
| | Exterior | 0.4 | |
| | Unknown | 1.2 | |
| Direct Install | Residential Interior and in-unit Multi Family | 1.3 | |
| | Exterior | 0.4 | |

It is important to note that for cost-effectiveness screening purposes, the O&M cost adjustments should only be applied in cases where the light bulbs are actually in service and so should be multiplied by the appropriate ISR.

**MEASURE CODE: RS-LTG-ESCF-V08-190101**

**REVIEW DEADLINE: 1/1/2020**

[768] This has been estimated assuming that natural gas central furnace heating is typical for Illinois residences (66% of Illinois homes have a Natural Gas Furnace (based on Energy Information Administration, 2009 Residential Energy Consumption Survey) In 2000, 24% of furnaces purchased in Illinois were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 10 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows:
(0.24*0.92) + (0.76*0.8) * (1-0.15) = 0.70

[769] Calculated by dividing assumed rated life of baseline bulb by hours of use. Assumed lifetime of EISA qualified Halogen/ Incandescents is 1000 hours. The manufacturers are simply using a regular incandescent lamp with halogen fill gas rather than Halogen Infrared to meet the standard (as provided by G. Arnold, NEEP and confirmed by N. Horowitz at NRDC).

[770] Based upon field data collected by CLEAResult and provided by ComEd. See ComEd Pricing Projections 06302016.xlsx for analysis.

## 5.5.2 ENERGY STAR Specialty Compact Fluorescent Lamp (CFL)

**NOTE: THIS MEASURE IS EFFECTIVE UNTIL 12/31/2018. IT IS LEFT IN THE MANUAL FOR REFERENCE PURPOSES AND FOR CALCULATION OF CARRY OVER SAVINGS.**

**DESCRIPTION**

A qualified specialty compact fluorescent bulb is installed in place of an incandescent specialty bulb.

Note a new ENERGY STAR specification v2.0 becomes effective on 1/2/2017 (https://www.energystar.gov/products/spec/lamps_specification_version_2_0_pd). The efficacy requirements cannot currently be met by Compact Fluorescent Lamps, and therefore this specification has been removed. ENERGY STAR will maintain a list on their website with the final qualifying list of products prior to this change and it is strongly recommended that programs continue to use this list as qualifying criteria for products in the programs.

This characterization assumes that the specialty CFL is installed in a residential location. If the implementation strategy does not allow for the installation location to be known (e.g. an upstream retail program) a deemed split of 95% Residential and 5% Commercial assumptions should be used[771].

This measure was developed to be applicable to the following program types: TOS, NC, DI, KITS.

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

In order for this characterization to apply, the high-efficiency equipment must be a qualified specialty compact fluorescent lamp.

**DEFINITION OF BASELINE EQUIPMENT**

The baseline is a specialty incandescent light bulb including those exempt of the EISA 2007 standard: three-way, plant light, daylight bulb, bug light, post light, globes G40 (<40W), candelabra base (<60W), vibration service bulb, decorative candle with medium or intermediate base (<40W), shatter resistant and reflector bulbs and standard bulbs greater than 2601 lumens, and those non-exempt from EISA 2007: dimmable, globes (less than 5” diameter and >40W), candle (shapes B, BA, CA >40W, candelabra base lamps (>60W) and intermediate base lamps (>40W).

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected measure life is assumed to be 6.8 year[772] for bulbs exempt from EISA, or 3 years for bulbs non-exempt installed in 2018 and then for every subsequent year should be reduced by one year[773].

[771] RES v C&I split is based on a weighted (by sales volume) average of ComEd PY6, PY7 and PY8 and Ameren PY5, PY6 and PY8 in store intercept survey results. See ‘RESvCI Split_112015.xls’.

[772] The assumed measure life for the specialty bulb measure characterization was reported in "Residential Lighting Measure Life Study", Nexus Market Research, June 4, 2008 (measure life for markdown bulbs). Measure life estimate does not distinguish between equipment life and measure persistence. Measure life includes products that were installed and operated until failure (i.e., equipment life) as well as those that were retired early and permanently removed from service for any reason, be it early failure, breakage, or the respondent not liking the product (i.e., measure persistence).

[773] Since the replacement baseline bulb from 2020 on will be equivalent to a CFL, no additional savings should be claimed from that point. Due to expected delay in clearing stock from retail outlets and to account for the operating life of a halogen incandescent potentially spanning over 2020, this shift is assumed not to occur until 2021.

### DEEMED MEASURE COST

For the Retail (Time of Sale) measure, the incremental capital cost for this measure is $5[774].

For the Direct Install measure, the full cost of $8.50 should be used plus $5 labor[775] for a total of $13.50. However actual program delivery costs should be utilized if available.

For bulbs provided in Efficiency Kits, the actual program delivery costs should be utilized.

### LOADSHAPE

Loadshape R06 - Residential Indoor Lighting

Loadshape R07 - Residential Outdoor Lighting

### COINCIDENCE FACTOR

Unlike standard CFLs that could be installed in any room, certain types of specialty CFLs are more likely to be found in specific rooms, which affects the coincident peak factor. Coincidence factors by bulb types are presented below[776]

| Bulb Type | Peak CF |
|---|---|
| Three-way | 0.078[777] |
| Dimmable | 0.078[778] |
| Interior reflector (incl. dimmable) | 0.091 |
| Exterior reflector | 0.273 |
| Candelabra base and candle medium and intermediate base | 0.121 |
| Bug light | 0.273 |
| Post light (>100W) | 0.273 |
| Daylight | 0.081 |
| Plant light | 0.081 |
| Globe | 0.075 |
| Vibration or shatterproof | 0.081 |
| Standard spirals >= 2601 lumens, Residential, Multi-family in unit | 0.071 |
| Standard spirals >= 2601 lumens, unknown | 0.081 |
| Standard spirals >= 2601 lumens, exterior | 0.273 |
| Specialty - Generic | 0.081 |

## Algorithm

### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

ΔkWh = ((WattsBase - WattsEE) / 1000) * ISR * (1-Leakage) * Hours * WHFe

Where:

WattsBase = Actual wattage equivalent of incandescent specialty bulb, use the tables below to obtain

[774] NEEP Residential Lighting Survey, 2011

[775] Based on 15 minutes at $20 per hour.

[776] Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

[777] Based on average of bedroom, dining room, office and living room results from the lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

[778] Ibid

the incandescent bulb equivalent wattage[779]; use 60W if unknown[780]

EISA exempt bulb types:

| Bulb Type | Lower Lumen Range | Upper Lumen Range | WattsBase |
|---|---|---|---|
| **Standard Spirals >=2601** | 2601 | 2999 | 150 |
| | 3000 | 5279 | 200 |
| | 5280 | 6209 | 300 |
| **3-Way** | 250 | 449 | 25 |
| | 450 | 799 | 40 |
| | 800 | 1099 | 60 |
| | 1100 | 1599 | 75 |
| | 1600 | 1999 | 100 |
| | 2000 | 2549 | 125 |
| | 2550 | 2999 | 150 |
| **Globe (medium and intermediate bases less than 750 lumens)** | 90 | 179 | 10 |
| | 180 | 249 | 15 |
| | 250 | 349 | 25 |
| | 350 | 749 | 40 |
| **Decorative (Shapes B, BA, C, CA, DC, F, G, medium and intermediate bases less than 750 lumens)** | 70 | 89 | 10 |
| | 90 | 149 | 15 |
| | 150 | 299 | 25 |
| | 300 | 749 | 40 |
| **Globe (candelabra bases less than 1050 lumens)** | 90 | 179 | 10 |
| | 180 | 249 | 15 |
| | 250 | 349 | 25 |
| | 350 | 499 | 40 |
| | 500 | 1049 | 60 |
| **Decorative (Shapes B, BA, C, CA, DC, F, G, candelabra bases less than 1050 lumens)** | 70 | 89 | 10 |
| | 90 | 149 | 15 |
| | 150 | 299 | 25 |
| | 300 | 499 | 40 |
| | 500 | 1049 | 60 |

**Directional Lamps -** ENERGY STAR Minimum Luminous Efficacy = 40Lm/W for lamps with rated wattages less than 20Wand 50 Lm/W for lamps with rated wattages >= 20 watts[781].

For Directional R, BR, and ER lamp types[782]:

| Bulb Type | Lower Lumen Range | Upper Lumen Range | $Watts_{Base}$ |
|---|---|---|---|
| **R, ER, BR with medium screw bases w/ diameter >2.25" (*see exceptions below)** | 420 | 472 | 40 |
| | 473 | 524 | 45 |
| | 525 | 714 | 50 |

[779] Based upon the ENERGY STAR specification for lamps and the Energy Policy and Conservation Act of 2012.

[780] A 2006-2008 California Upstream Lighting Evaluation found an average incandescent wattage of 61.7 Watts (KEMA, Inc, The Cadmus Group, Itron, Inc, PA Consulting Group, Jai J. Mitchell Analytics, Draft Evaluation Report: Upstream Lighting Program. Prepared for the California Public Utilities Commission, Energy Division. December 10, 2009)

[781] From pg 10 of the Energy Star Specification for lamps v1.1

[782] From pg 11 of the Energy Star Specification for lamps v1.1

| Bulb Type | Lower Lumen Range | Upper Lumen Range | $Watts_{Base}$ |
|---|---|---|---|
| | 715 | 937 | 65 |
| | 938 | 1259 | 75 |
| | 1260 | 1399 | 90 |
| | 1400 | 1739 | 100 |
| | 1740 | 2174 | 120 |
| | 2175 | 2624 | 150 |
| | 2625 | 2999 | 175 |
| | 3000 | 4500 | 200 |
| ***R, BR, and ER with medium screw bases w/ diameter <=2.25"** | 400 | 449 | 40 |
| | 450 | 499 | 45 |
| | 500 | 649 | 50 |
| | 650 | 1199 | 65 |
| ***ER30, BR30, BR40, or ER40** | 400 | 449 | 40 |
| | 450 | 499 | 45 |
| | 500 | 649 | 50 |
| ***BR30, BR40, or ER40** | 650 | 1419 | 65 |
| ***R20** | 400 | 449 | 40 |
| | 450 | 719 | 45 |
| ***All reflector lamps below lumen ranges specified above** | 200 | 299 | 20 |
| | 300 | 399 | 30 |

Directional lamps are exempt from EISA regulations.

For PAR, MR, and MRX Lamps Types:

For these highly focused directional lamp types, it is necessary to have Center Beam Candle Power (CBCP) and beam angle measurements to accurately estimate the equivalent baseline wattage. The formula below is based on the Energy Star Center Beam Candle Power tool.[783] If CBCP and beam angle information are not available, or if the equation below returns a negative value (or undefined), use the manufacturer's recommended baseline wattage equivalent.[784]

Wattsbase =

$$375.1 - 4.355(D) - \sqrt{227{,}800 - 937.9(D) - 0.9903(D^2) - 1479(BA) - 12.02(D * BA) + 14.69(BA^2) - 16{,}720 * \ln(CBCP)}$$

Where:

D = Bulb diameter (e.g. for PAR20 D = 20)

BA = Beam angle

CBCP = Center beam candle power

The result of the equation above should be rounded DOWN to the nearest wattage established by Energy Star:

| Diameter | Permitted Wattages |
|---|---|
| 16 | 20, 35, 40, 45, 50, 60, 75 |
| 20 | 50 |
| 30S | 40, 45, 50, 60, 75 |
| 30L | 50, 75 |

783 See 'ESLampCenterBeamTool.xls'.

784 The Energy Star Center Beam Candle Power tool does not accurately model baseline wattages for lamps with certain bulb characteristic combinations – specifically for lamps with very high CBCP.

| Diameter | Permitted Wattages |
|---|---|
| 38 | 40, 45, 50, 55, 60, 65, 75, 85, 90, 100, 120, 150, 250 |

EISA non-exempt bulb types:

| Bulb Type | Lower Lumen Range | Upper Lumen Range | Incandescent Equivalent Post-EISA 2007 (WattsBase) |
|---|---|---|---|
| **Dimmable Twist, Globe (less than 5" in diameter and > 749 lumens), candle (shapes B, BA, CA > 749 lumens), Candelabra Base Lamps (>1049 lumens), Intermediate Base Lamps (>749 lumens)** | 310 | 749 | 29 |
| | 750 | 1049 | 43 |
| | 1050 | 1489 | 53 |
| | 1490 | 2600 | 72 |

WattsEE = Actual wattage of energy efficient specialty bulb purchased, use 15W if unknown[785]

ISR = In Service Rate, the percentage of units rebated that are actually in service.

| Program | | Weighted Average 1st year In Service Rate (ISR) | 2nd year Installations | 3rd year Installations | Final Lifetime In Service Rate |
|---|---|---|---|---|---|
| Retail (Time of Sale) | | 88.0%[786] | 5.4% | 4.6% | 98.0%[787] |
| Direct Install | | 96.9%[788] | | | |
| Efficiency Kits[789] | CFL Distribution[790] | 59% | 13% | 11% | 83% |
| | School Kits[791] | 61% | 13% | 11% | 86% |
| | Direct Mail | 66% | 14% | 12% | 93% |

[785] An evaluation (Energy Efficiency / Demand Response Plan: Plan Year 2 (6/1/2009-5/31/2010) Evaluation Report: Residential Energy Star ® Lighting ) reported 13-17W as the most common specialty CFL wattage (69% of program bulbs). 2009 California data also reported an average CFL wattage of 15.5 Watts (KEMA, Inc, The Cadmus Group, Itron, Inc, PA Consulting Group, Jai J. Mitchell Analytics, Draft Evaluation Report: Upstream Lighting Program, Prepared for the California Public Utilities Commission, Energy Division. December 10, 2009).

[786] 1st year in service rate is based upon review of PY4-6 evaluations from ComEd and PY5-6 from Ameren (see 'IL RES Lighting ISR_122014.xls' for more information. The average first year ISR was calculated weighted by the number of bulbs in the each year's survey.

[787] The 98% Lifetime ISR assumption is consistent with the assumption for standard CFLs (in the absence of evidence that it should be different for this bulb type) based upon review of two evaluations:
'Nexus Market Research, RLW Analytics and GDS Associates study; "New England Residential Lighting Markdown Impact Evaluation, January 20, 2009' and 'KEMA Inc, Feb 2010, Final Evaluation Report:, Upstream Lighting Program, Volume 1.' This implies that only 2% of bulbs purchased are never installed. The second and third year installations are based upon Ameren analysis of the Californian KEMA study showing that 54% of future installs occur in year 2 and 46% in year 3. The 2nd and 3rd year installations should be counted as part of those future program year savings.

[788] Consistent with assumption for standard CFLs (in the absence of evidence that it should be different for this bulb type). Based upon review of the PY2 and PY3 ComEd Direct Install program surveys. This value includes bulb failures in the 1st year to be consistent with the Commission approval of annualization of savings for first year savings claims. ComEd PY2 All Electric Single Family Home Energy Performance Tune-Up Program Evaluation, Navigant Consulting, December 21, 2010.

[789] In Service Rates provided are for the bulb within a kit only. Given the significant differences in program design and the level of education provided through Efficiency Kits programs, the evaluators should apply the ISR estimated through evaluations (either past evaluations or the current program year evaluation) of the specific Efficiency Kits program. In cases where program-specific evaluation results for an ISR are unavailable, the default ISR values for Efficiency Kits provide may be used.

[790] Free bulbs provided without request, with little or no education. Consistent with Standard CFL assumptions.

[791] Kits provided free to students through school, with education program. Consistent with Standard CFL assumptions.

| Program | | Weighted Average 1st year In Service Rate (ISR) | 2nd year Installations | 3rd year Installations | Final Lifetime In Service Rate |
|---|---|---|---|---|---|
| | Kits[792] | | | | |

Leakage = Adjustment to account for the percentage of program bulbs that move out (and in if deemed appropriate[793]) of the Utility Jurisdiction.

KITS programs = Determined through evaluation

Upstream (TOS) Lighting programs = Determined through evaluation

or use deemed assumptions below[794]:

ComEd: 2.1%

Ameren: 13.1%

All other programs = 0

Hours = Average hours of use per year, varies by bulb type as presented below:[795]

| Bulb Type | Annual hours of use (HOU) |
|---|---|
| Three-way | 850 |
| Dimmable | 850 |
| Interior reflector (incl. dimmable) | 861 |
| Exterior reflector | 2475 |
| Candelabra base and candle medium and intermediate base | 1190 |
| Bug light | 2475 |
| Post light (>100W) | 2475 |
| Daylight | 847 |
| Plant light | 847 |
| Globe | 639 |
| Vibration or shatterproof | 847 |
| Standard Spiral >2601 lumens, Residential, Multi Family in-unit | 759 |
| Standard Spiral >2601 lumens, unknown | 847 |
| Standard Spiral >2601 lumens, Exterior | 2475 |
| Specialty - Generic | 847 |

WHFe = Waste heat factor for energy to account for cooling savings from efficient lighting

[792] Opt-in program to receive kits via mail, with little or no education. Consistent with Standard CFL assumptions.

[793] Leakage in is only appropriate to credit to IL utility program savings if it is reasonably expected that the IL utility program marketing efforts played an important role in influencing customer to purchase the light bulbs. Furthermore, consideration that such customers might be free riders should be addressed. If leakage in is assessed, efforts should be made to ensure no double counting of savings occurs if the evaluation is estimating both leakage in and spillover savings of light bulbs.

[794] Leakage rate is based upon review of PY6-8 evaluations from ComEd and PY5,6 and 8 for Ameren (see 'IL Leakage Rates_112016.xls' for more information).

[795] Hours of use by specialty bulb type calculated using the average hours of use in locations or rooms where each type of specialty bulb is most commonly found. Values for Reflector, Decorative and Globe are taken directly from the lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation. All other hours have been updated based on the room specific hours of use from the PY5/PY6 logger study.

| Bulb Location | WHFe |
|---|---|
| Interior single family or unknown location | 1.06 [796] |
| Multi family in unit | 1.04 [797] |
| Exterior or uncooled location | 1.0 |

**DEFERRED INSTALLS**

As presented above, the characterization assumes that a percentage of bulbs purchased are not installed until Year 2 and Year 3 (see ISR assumption above). The Illinois Technical Advisory Committee has determined the following methodology for calculating the savings of these future installs.

Year 1 (Purchase Year) installs: Characterized using assumptions provided above or evaluated assumptions if available.

Year 2 and 3 installs: Characterized using delta watts assumption and hours of use from the Install Year i.e. the actual deemed (or evaluated if available) assumptions active in Year 2 and 3 should be applied.

The NTG factor for the Purchase Year should be applied.

For example, for a 13W dimmable CFL impacted by EISA 2007 (60W standard incandescent and 43W EISA qualified incandescent/halogen).

$\Delta kWH_{1st\ year\ installs}$ = ((60 - 13) / 1000) * 0.823 * 850 * 1.06

= 34.9 kWh

$\Delta kWH_{2nd\ year\ installs}$ = ((43 - 13) / 1000) * 0.085 * 850 * 1.06

= 2.3 kWh

Note: Here we assume no change in hours assumption. NTG value from Purchase year applied.

$\Delta kWH_{3rd\ year\ installs}$ = ((43 - 13) / 1000) * 0.072 * 850 * 1.06

= 1.9 kWh

Note: delta watts is equivalent to install year. Here we assume no change in hours assumption.

**HEATING PENALTY**

If electric heated home (if heating fuel is unknown assume gas, see Natural Gas section):

ΔkWh[798] = - (((WattsBase - WattsEE) / 1000) * ISR * (1-Leakage) * Hours * HF) / ηHeat

Where:

HF = Heating Factor or percentage of light savings that must be heated

= 49%[799] for interior or unknown location

[796] The value is estimated at 1.06 (calculated as 1 + (0.66*(0.27 / 2.8)). Based on cooling loads decreasing by 27% of the lighting savings (average result from REMRate modeling of several different configurations and IL locations of homes), assuming typical cooling system operating efficiency of 2.8 COP (starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm (-0.02 * SEER2) + (1.12 * SEER) (from Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), converted to COP = EER/3.412 = 2.8COP) and 66% of homes in Illinois having central cooling ("Table HC7.9 Air Conditioning in Homes in Midwest Region, Divisions, and States, 2009 from Energy Information Administration", 2009 Residential Energy Consumption Survey)

[797] As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from "Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009" which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average).

[798] Negative value because this is an increase in heating consumption due to the efficient lighting.

[799] This means that heating loads increase by 49% of the lighting savings. This is based on the average result from REMRate

= 0% for exterior location

ηHeat = Efficiency in COP of Heating equipment

= actual. If not available use[800]:

| System Type | Age of Equipment | HSPF Estimate | $COP_{HEAT}$ (COP Estimate) = (HSPF/3.413)*0.85 |
|---|---|---|---|
| Heat Pump | Before 2006 | 6.8 | 1.7 |
| | After 2006 - 2014 | 7.7 | 1.92 |
| | 2015 on | 8.2 | 2.04 |
| Resistance | N/A | N/A | 1.00 |
| Unknown[801] | N/A | N/A | 1.28 |

For example, a 15W globe CFL replacing a 60W incandescent specialty bulb installed in home with 2.0 COP Heat Pump (including duct loss):

$\Delta kWh_{1st\ year}$ = - (((60 - 15) / 1000) * 0.823 * 639 * 0.49) / 2.0

= - 5.8 kWh

Second and third year savings should be calculated using the appropriate ISR.

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW =((WattsBase - WattsEE) / 1000) * ISR * (1-Leakage) * WHFd * CF

Where:

WHFd = Waste heat factor for demand to account for cooling savings from efficient lighting.

| Bulb Location | WHFd |
|---|---|
| Interior single family or unknown location | 1.11[802] |
| Multi family in unit | 1.07[803] |
| Exterior or uncooled location | 1.0 |

CF = Summer Peak Coincidence Factor for measure. Coincidence factors by bulb types are presented below[804]

modeling of several different configurations and IL locations of homes.

[800] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate. Note efficiency should include duct losses. Defaults provided assume 15% duct loss for heat pumps.

[801] Calculation assumes 35% Heat Pump and 65% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see "HC6.9 Space Heating in Midwest Region.xls", using average for East North Central Region. Average efficiency of heat pump is based on assumption that 50% are units from before 2006 and 50% from 2006-2014. Program or evaluation data should be used to improve this assumption if available.

[802] The value is estimated at 1.11 (calculated as 1 + (0.66 * 0.466 / 2.8)). See footnote relating to WHFe for details. Note the 46.6% factor represents the average Residential cooling coincidence factor calculated by dividing average load during the peak hours divided by the maximum cooling load.

[803] As above but using estimate of 45% of multifamily buildings in Illinois having central cooling (based on data from "Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009" which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average).

[804] Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

| Bulb Type | Peak CF |
|---|---|
| Three-way | 0.078[805] |
| Dimmable | 0.078[806] |
| Interior reflector (incl. dimmable) | 0.091 |
| Exterior reflector | 0.273 |
| Candelabra base and candle medium and intermediate base | 0.121 |
| Bug light | 0.273 |
| Post light (>100W) | 0.273 |
| Daylight | 0.081 |
| Plant light | 0.081 |
| Globe | 0.075 |
| Vibration or shatterproof | 0.081 |
| Standard Spiral >=2601 lumens, Residential, Multi-family in unit | 0.071 |
| Standard spirals >= 2601 lumens, unknown | 0.081 |
| Standard spirals >= 2601 lumens, exterior | 0.273 |
| Specialty - Generic | 0.081 |

Other factors as defined above

For example, a 15W specialty CFL replacing a 60W incandescent specialty bulb:

$\Delta kW_{1st\ year}$ = ((60 - 15) / 1000) * 0.823 * 1.11 * 0.081

= 0.003 kW

Second and third year savings should be calculated using the appropriate ISR.

**NATURAL GAS SAVINGS**

Heating Penalty if Natural Gas heated home (or if heating fuel is unknown):

ΔTherms[807] = - (((WattsBase - WattsEE) / 1000) * ISR * (1-Leakage) * Hours * HF * 0.03412) / ηHeat

Where:

HF = Heating Factor or percentage of light savings that must be heated

= 49%[808] for interior or unknown location

= 0% for exterior location

0.03412 =Converts kWh to Therms

ηHeat = Efficiency of heating system

=70%[809]

805 Based on average of bedroom, dining room, office and living room results from the lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

806 Ibid

807 Negative value because this is an increase in heating consumption due to the efficient lighting.

808 This means that heating loads increase by 49% of the lighting savings. This is based on the average result from REMRate modeling of several different configurations and IL locations of homes.

809 This has been estimated assuming that natural gas central furnace heating is typical for Illinois residences (66% of Illinois homes have a Natural Gas Furnace (based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IL. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.)

In 2000, 24% of furnaces purchased in Illinois were condensing (based on data from GAMA, provided to Department of Energy

For example, a 15W Globe specialty CFL replacing a 60W incandescent specialty bulb:

$$\Delta Therms = - (((60 - 15) / 1000) * 0.823 * 639 * 0.49 * 0.03412) / 0.7$$

$$= - 0.57 \text{ Therms}$$

Second and third year savings should be calculated using the appropriate ISR.

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

The following O&M assumptions should be used: Life of the baseline bulb is assumed to be 1.32 year[810]; baseline replacement cost is assumed to be $3.5[811].

It is important to note that for cost-effectiveness screening purposes, the O&M cost adjustments should only be applied in cases where the light bulbs area actually in service and so should be multiplied by the appropriate ISR.

**MEASURE CODE: RS-LTG-ESCC-V07-190101**

**REVIEW DEADLINE: 1/1/2020**

during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 10 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows:

(0.24*0.92) + (0.76*0.8) * (1-0.15) = 0.70

[810] Assuming 1000 hour rated life for incandescent bulb: 1000/759 = 1.32

[811] NEEP Residential Lighting Survey, 2011

## 5.5.3 ENERGY STAR Torchiere

**NOTE: THIS MEASURE IS EFFECTIVE UNTIL 12/31/2018. IT IS LEFT IN THE MANUAL FOR REFERENCE PURPOSES AND FOR CALCULATION OF CARRY OVER SAVINGS.**

#### DESCRIPTION

A high efficiency ENERGY STAR fluorescent torchiere is purchased in place of a baseline mix of halogen and incandescent torchieres and installed in a residential setting.

This measure was developed to be applicable to the following program types: TOS, NC.

If applied to other program types, the measure savings should be verified.

#### DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the fluorescent torchiere must meet ENERGY STAR efficiency standards.

#### DEFINITION OF BASELINE EQUIPMENT

The baseline is based on a mix of halogen and incandescent torchieres.

#### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The lifetime of the measure is assumed to be 8 years[812].

#### DEEMED MEASURE COST

The incremental cost for this measure is assumed to be $5[813].

#### LOADSHAPE

Loadshape R06 - Residential Indoor Lighting
Loadshape R07 - Residential Outdoor Lighting

#### COINCIDENCE FACTOR

The summer peak coincidence factor for this measure is 7.1% for Residential and in-unit Multi Family bulbs and 8.1% for bulbs installed in unknown locations[814].

### Algorithm

#### CALCULATION OF SAVINGS

#### ELECTRIC ENERGY SAVINGS

$$\Delta kWh = ((\Delta Watts) / 1000) * ISR * (1 - Leakage) * HOURS * WHFe$$

Where:

$\Delta Watts$ = Average delta watts per purchased ENERGY STAR torchiere

[812] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
[813] DEER 2008 Database Technology and Measure Cost Data (www.deeresources.com) and consistent with Efficiency Vermont TRM.
[814] Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

= 115.8 [815]

ISR = In Service Rate or percentage of units rebated that get installed.

= 0.86 [816]

Leakage = Adjustment to account for the percentage of program bulbs that move out (and in if deemed appropriate[817]) of the Utility Jurisdiction.

KITS programs = Determined through evaluation

Upstream (TOS) Lighting programs = Determined through evaluation

or use deemed assumptions below[818]:

ComEd: 2.1%

Ameren: 13.1%

All other programs = 0

HOURS = Average hours of use per year

| Installation Location | Hours |
|---|---|
| Residential and in-unit Multi Family | 1095 (3.0 hrs per day)[819] |

WHFe = Waste Heat Factor for Energy to account for cooling savings from efficient lighting

| Bulb Location | WHFe |
|---|---|
| Interior single family or unknown location | 1.06 [820] |
| Multi family in unit | 1.04 [821] |
| Exterior or uncooled location | 1.0 |

For single family buildings:

ΔkWh = (115.8 /1000) * 0.86 * 1095 * 1.06

[815] Nexus Market Research, "Impact Evaluation of the Massachusetts, Rhode Island and Vermont 2003 Residential Lighting Programs", Final Report, October 1, 2004, p. 43 (Table 4-9)

[816] Nexus Market Research, RLW Analytics "Impact Evaluation of the Massachusetts, Rhode Island, and Vermont 2003 Residential Lighting Programs" table 6-3 on p63 indicates that 86% torchieres were installed in year one.

[817] Leakage in is only appropriate to credit to IL utility program savings if it is reasonably expected that the IL utility program marketing efforts played an important role in influencing customer to purchase the light bulbs. Furthermore, consideration that such customers might be free riders should be addressed. If leakage in is assessed, efforts should be made to ensure no double counting of savings occurs if the evaluation is estimating both leakage in and spillover savings of light bulbs.

[818] Leakage rate is based upon review of PY6-8 evaluations from ComEd and PY5,6 and 8 for Ameren (see 'IL Leakage Rates_112016.xls' for more information).

[819] Nexus Market Research, "Impact Evaluation of the Massachusetts, Rhode Island and Vermont 2003 Residential Lighting Programs", Final Report, October 1, 2004, p. 104 (Table 9-7)

[820] The value is estimated at 1.06 (calculated as 1 + (0.66*(0.27 / 2.8)). Based on cooling loads decreasing by 27% of the lighting savings (average result from REMRate modeling of several different configurations and IL locations of homes), assuming typical cooling system operating efficiency of 2.8 COP (starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm (-0.02 * SEER2) + (1.12 * SEER) (from Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), converted to COP = EER/3.412 = 2.8COP) and 66% of homes in Illinois having central cooling ("Table HC7.9 Air Conditioning in Homes in Midwest Region, Divisions, and States, 2009 from Energy Information Administration", 2009 Residential Energy Consumption Survey)

[821] As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from "Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009" which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average)

= 116 kWh

For multi family in unit:

ΔkWh = (115.8 /1000) * 0.86 * 1095 * 1.04

= 113 kWh

**HEATING PENALTY**

If electric heated home (if heating fuel is unknown assume gas, see Natural Gas section):

ΔkWh[822] = - ((ΔWatts) /1000) * ISR * (1-Leakage) * HOURS * HF) / ηHeat

Where:

HF = Heating Factor or percentage of light savings that must be heated

= 49%[823] for interior or unknown location

ηHeat = Efficiency in COP of Heating equipment

= Actual. If not available use defaults provided below[824]:

| System Type | Age of Equipment | HSPF Estimate | $COP_{HEAT}$ (COP Estimate) = (HSPF/3.413)*0.85 |
|---|---|---|---|
| Heat Pump | Before 2006 | 6.8 | 1.7 |
| | After 2006 - 2014 | 7.7 | 1.92 |
| | 2015 on | 8.2 | 2.04 |
| Resistance | N/A | N/A | 1.00 |
| Unknown[825] | N/A | N/A | 1.28 |

For example, an ES torchiere installed in a house with a 2016 heat pump:

ΔkWh = - ((115.8) / 1000) * 0.86 * 1095 * 0.49) / 2.04

= - 26.2 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = ((ΔWatts) /1000) * ISR * (1-Leakage) * WHFd * CF

Where:

WHFd = Waste Heat Factor for Demand to account for cooling savings from efficient lighting

[822] Negative value because this is an increase in heating consumption due to the efficient lighting.

[823] This means that heating loads increase by 49% of the lighting savings. This is based on the average result from REMRate modeling of several different configurations and IL locations of homes.

[824] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate. Note efficiency should include duct losses. Defaults provided assume 15% duct loss for heat pumps.

[825] Calculation assumes 35% Heat Pump and 65% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see “HC6.9 Space Heating in Midwest Region.xls”, using average for East North Central Region. Average efficiency of heat pump is based on assumption that 50% are units from before 2006 and 50% from 2006-2014. Program or evaluation data should be used to improve this assumption if available.

| Bulb Location | WHFd |
|---|---|
| Interior single family or unknown location | 1.11[826] |
| Multi family in unit | 1.07[827] |
| Exterior or uncooled location | 1.0 |

CF = Summer Peak Coincidence Factor for measure

| Bulb Location | CF[828] |
|---|---|
| Interior single family or Multi family in unit | 7.1% |
| Unknown location | 8.1% |

For single family and multi-family in unit buildings:

ΔkW = (115.8 / 1000) * 0.86 * 1.11 * 0.071

= 0.008kW

For unknown location:

ΔkW = (115.8 / 1000) * 0.86 * 1.07 * 0.081

= 0.009 kW

**NATURAL GAS SAVINGS**

Heating penalty if Natural Gas heated home, or if heating fuel is unknown.

$\Delta Therms_{WH}$ = - (((ΔWatts) /1000) * ISR * (1-Leakage) * HOURS * 0.03412 * HF) / ηHeat

Where:

$\Delta Therms_{WH}$ = gross customer annual heating fuel increased usage for the measure from the reduction in lighting heat in therms.

0.03412 = conversion from kWh to therms

HF = Heating Factor or percentage of light savings that must be heated

= 49% [829]

ηHeat = average heating system efficiency

= 70% [830]

---

[826] The value is estimated at 1.11 (calculated as 1 + (0.66 * 0.466 / 2.8)). See footnote relating to WHFe for details. Note the 46.6% factor represents the average Residential cooling coincidence factor calculated by dividing average load during the peak hours divided by the maximum cooling load.

[827] As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from "Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009" which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average)

[828] Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

[829] This means that heating loads increase by 49% of the lighting savings. This is based on the average result from REMRate modeling of several different configurations and IL locations of homes.

[830] This has been estimated assuming that natural gas central furnace heating is typical for Illinois residences (66% of Illinois homes have a Natural Gas Furnace (based on Energy Information Administration, 2009 Residential Energy Consumption Survey) In 2000, 24% of furnaces purchased in Illinois were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 10 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows:

$\Delta Therms_{WH}$ = - ((115.8 / 1000) * 0.86 * 1095 * 0.03412 * 0.49) / 0.70

= - 2.60 therms

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

Life of the baseline bulb is assumed to be 1.83 years[831] for residential and multifamily in unit. Baseline bulb cost replacement is assumed to be $6.[832]

It is important to note that for cost-effectiveness screening purposes, the O&M cost adjustments should only be applied in cases where the light bulbs area actually in service and so should be multiplied by the appropriate ISR.

**MEASURE CODE: RS-LTG-ESTO-V06-190101**

**REVIEW DEADLINE: 1/1/2020**

(0.24*0.92) + (0.76*0.8) * (1-0.15) = 0.70

[831] Based on VEIC assumption of baseline bulb (mix of incandescent and halogen) average rated life of 2000 hours, 2000/1095 = 1.83 years.

[832] Derived from Efficiency Vermont TRM.

## 5.5.4 Exterior Hardwired Compact Fluorescent Lamp (CFL) Fixture

**NOTE: THIS MEASURE IS EFFECTIVE UNTIL 12/31/2018. IT IS LEFT IN THE MANUAL FOR REFERENCE PURPOSES AND FOR CALCULATION OF CARRY OVER SAVINGS.**

### DESCRIPTION

An ENERGY STAR lighting fixture wired for exclusive use with pin-based compact fluorescent lamps is installed in an exterior residential setting. This measure could relate to either a fixture replacement or new installation (i.e. time of sale).

Federal legislation stemming from the Energy Independence and Security Act of 2007 required all general-purpose light bulbs between 40 and 100W to be approximately 30% more energy efficient than current incandescent bulbs. Production of 100W, standard efficacy incandescent lamps ends in 2012, followed by restrictions on 75W in 2013 and 60W and 40W in 2014. The baseline for this measure has therefore become bulbs (improved incandescent or halogen) that meet the new standard.

A provision in the EISA regulations requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the baseline equivalent to a current day CFL. Therefore the measure life (number of years that savings should be claimed) should be reduced once the assumed lifetime of the bulb exceeds 2020. Due to expected delay in clearing retail inventory and to account for the operating life of a halogen incandescent potentially spanning over 2020, this shift is assumed not to occur until 2021.

This measure was developed to be applicable to the following program types: TOS, NC. If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

The efficient condition is an ENERGY STAR lighting exterior fixture for pin-based compact fluorescent lamps.

### DEFINITION OF BASELINE EQUIPMENT

The baseline condition is a standard EISA qualified incandescent or halogen exterior fixture as provided in the table provided in the Electric Energy Savings section.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected life of an exterior fixture is 20 years[833]. However due to the backstop provision in the Energy Independence and Security Act of 2007 that requires by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, the baseline replacement would become a CFL in that year. The expected measure life for CFL fixtures installed in 2018 is therefore assumed to be 3 years. For bulbs installed in 2019, this would be reduced to 2 years[834].

### DEEMED MEASURE COST

The incremental cost for an exterior fixture is assumed to be $32[835].

### LOADSHAPE

Loadshape R07 - Residential Outdoor Lighting

[833] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007 gives 20 years for an interior fluorescent fixture.
[834] Due to expected delay in clearing stock from retail outlets and to account for the operating life of a halogen incandescent potentially spanning over 2020, this shift is assumed not to occur until 2021.
[835] ENERGY STAR Qualified Lighting Savings Calculator default incremental cost input for exterior fixture.

**COINCIDENCE FACTOR**

The summer peak coincidence factor is assumed to be 27.3%[836].

## Algorithm

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

ΔkWh =((WattsBase - WattsEE) / 1000) * ISR * (1-Leakage) * Hours

Where:

WattsBase = Based on lumens of CFL bulb and program year purchased:

| Minimum Lumens | Maximum Lumens | Incandescent Equivalent Post-EISA 2007 (WattsBase) |
|---|---|---|
| 5280 | 6209 | 300 |
| 3000 | 5279 | 200 |
| 2601 | 2999 | 150 |
| 1490 | 2600 | 72 |
| 1050 | 1489 | 53 |
| 750 | 1049 | 43 |
| 310 | 749 | 29 |
| 250 | 309 | 25 |

WattsEE = Actual wattage of CFL purchased

ISR = In Service Rate or the percentage of units rebated that get installed.

| Program | Weighted Average 1st year In Service Rate (ISR) | 2nd year Installations | 3rd year Installations | Final Lifetime In Service Rate |
|---|---|---|---|---|
| Retail (Time of Sale) | 87.5%[837] | 5.7% | 4.8% | 98.0%[838] |
| Direct Install | 96.9[839] | | | |

Leakage = Adjustment to account for the percentage of program bulbs that move out (and in if

[836] Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.
[837] 1st year in service rate is based upon review of PY2-3 evaluations from ComEd (see 'IL RES Lighting ISR.xls' for more information. The average first year ISR was calculated weighted by the number of bulbs in the each year's survey.
[838] The 98% Lifetime ISR assumption is consistent with the assumption for standard CFLs (in the absence of evidence that it should be different for this bulb type) based upon review of two evaluations:
'Nexus Market Research, RLW Analytics and GDS Associates study; "New England Residential Lighting Markdown Impact Evaluation, January 20, 2009' and 'KEMA Inc, Feb 2010, Final Evaluation Report:, Upstream Lighting Program, Volume 1.' This implies that only 2% of bulbs purchased are never installed. The second and third year installations are based upon Ameren analysis of the Californian KEMA study showing that 54% of future installs occur in year 2 and 46% in year 3. The 2nd and 3rd year installations should be counted as part of those future program year savings.
[839] In the absence of evaluation results for Direct Install Fixtures specifically, this is made consistent with the Direct Install CFL measure which is based upon review of the PY2 and PY3 ComEd Direct Install program surveys.

deemed appropriate[840]) of the Utility Jurisdiction.

KITS programs = Determined through evaluation

Upstream (TOS) Lighting programs = Determined through evaluation

or use deemed assumptions below[841]:

ComEd: 1.05%

Ameren: 6.55%

All other programs = 0

Hours = Average hours of use per year

=2475 (6.78 hrs per day)[842]

**DEFERRED INSTALLS**

As presented above, the characterization assumes that a percentage of bulbs purchased are not installed until Year 2 and Year 3 (see ISR assumption above). The Illinois Technical Advisory Committee has determined the following methodology for calculating the savings of these future installs.

Year 1 (Purchase Year) installs: Characterized using assumptions provided above or evaluated assumptions if available.

Year 2 and 3 installs: Characterized using delta watts assumption and hours of use from the Install Year i.e. the actual deemed (or evaluated if available) assumptions active in Year 2 and 3 should be applied.

The NTG factor for the Purchase Year should be applied.

For example, for a 2 x 14W pin based CFL fixture (43W EISA qualified incandescent/halogen).

$\Delta kWH_{1st\ year\ installs}$ = ((86 - 28) / 1000) * 0.875 * 2475

= 125.6 kWh

$\Delta kWH_{2nd\ year\ installs}$ = ((86 - 28) / 1000) * 0.057 * 2475

= 8.2 kWh

Note: Here we assume no change in hours assumption. NTG value from Purchase year applied.

$\Delta kWH_{3rd\ year\ installs}$ = ((86 - 28) / 1000) * 0.048 * 2475

= 6.9 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = ((WattsBase - WattsEE) / 1 000) * ISR * (1-Leakage) * CF

Where:

CF = Summer Peak Coincidence Factor for measure.

[840] Leakage in is only appropriate to credit to IL utility program savings if it is reasonably expected that the IL utility program marketing efforts played an important role in influencing customer to purchase the light bulbs. Furthermore, consideration that such customers might be free riders should be addressed. If leakage in is assessed, efforts should be made to ensure no double counting of savings occurs if the evaluation is estimating both leakage in and spillover savings of light bulbs.

[841] Leakage rate is based upon TAC agreed 50% of the lamp leakage assumptions (based upon review of PY6-8 evaluations from ComEd and PY5,6 and 8 for Ameren (see 'IL Leakage Rates_112016.xls' for more information)).

[842] Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

= 27.3%[843]

Other factors as defined above

For example, a 2 x 14W pin-based CFL fixture:

$\Delta kW_{1st\ year}$ = ((86 - 28) / 1000) * 0.875 * 0.273

= 0.0142 kW

Second and third year install savings should be calculated using the appropriate ISR and the delta watts and hours from the install year.

### NATURAL GAS SAVINGS

N/A

### WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

### DEEMED O&M COST ADJUSTMENT CALCULATION

Life of the baseline bulb is assumed to be 0.4 years[844] for exterior applications. Baseline bulb cost replacement is assumed to be $1.25.[845]

It is important to note that for cost-effectiveness screening purposes, the O&M cost adjustments should only be applied in cases where the light bulbs area actually in service and so should be multiplied by the appropriate ISR.

### MEASURE CODE: RS-LRG-EFOX-V08-190101

### REVIEW DEADLINE: 1/1/2020

[843] Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

[844] Calculated by dividing assumed rated life of baseline bulb by hours of use. Assumed lifetime of EISA qualified Halogen/ Incandescents is 1000 hours. The manufacturers are simply using a regular incandescent lamp with halogen fill gas rather than Halogen Infrared to meet the standard (as provided by G. Arnold, NEEP and confirmed by N. Horowitz at NRDC).

[845] Based upon field data collected by CLEAResult and provided by ComEd. See ComEd Pricing Projections 06302016.xlsx for analysis.

## 5.5.5 Interior Hardwired Compact Fluorescent Lamp (CFL) Fixture

**NOTE: THIS MEASURE IS EFFECTIVE UNTIL 12/31/2018. IT IS LEFT IN THE MANUAL FOR REFERENCE PURPOSES AND FOR CALCULATION OF CARRY OVER SAVINGS.**

**DESCRIPTION**

An ENERGY STAR lighting fixture wired for exclusive use with pin-based compact fluorescent lamps is installed in an interior residential setting. This measure could relate to either a fixture replacement or new installation (i.e. time of sale).

Federal legislation stemming from the Energy Independence and Security Act of 2007 required all general-purpose light bulbs between 40 and 100W to be approximately 30% more energy efficient than current incandescent bulbs. Production of 100W, standard efficacy incandescent lamps ends in 2012, followed by restrictions on 75W in 2013 and 60W and 40W in 2014. The baseline for this measure has therefore become bulbs (improved incandescent or halogen) that meet the new standard.

A provision in the EISA regulations requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the baseline equivalent to a current day CFL. Therefore the measure life (number of years that savings should be claimed) should be reduced once the assumed lifetime of the bulb exceeds 2020. Due to expected delay in clearing retail inventory and to account for the operating life of a halogen incandescent potentially spanning over 2020, this shift is assumed not to occur until 2021.

This measure was developed to be applicable to the following program types: TOS, NC. If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

The efficient condition is an ENERGY STAR lighting interior fixture for pin-based compact fluorescent lamps.

**DEFINITION OF BASELINE EQUIPMENT**

The baseline condition is a standard EISA qualified incandescent or halogen interior fixture as provided in the table provided in the Electric Energy Savings section.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected life of an interior fixture is 20 years[846]. However due to the backstop provision in the Energy Independence and Security Act of 2007 that requires by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, the baseline replacement would become equivalent to a CFL in that year. The expected measure life for CFL fixtures installed in 2018 is therefore assumed to be 3 years. For bulbs installed in 2019, this would be reduced to 2 years and should be reduced each year[847].

**DEEMED MEASURE COST**

The incremental cost for an interior fixture is assumed to be $32[848].

**LOADSHAPE**

Loadshape R06 - Residential Indoor Lighting

---

[846] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007 gives 20 years for an interior fluorescent fixture.

[847] Due to expected delay in clearing stock from retail outlets and to account for the operating life of a halogen incandescent potentially spanning over 2020, this shift is assumed not to occur until 2021.

[848] ENERGY STAR Qualified Lighting Savings Calculator default incremental cost input for interior fixture.

**COINCIDENCE FACTOR**

The summer peak coincidence factor is assumed to be 7.1%[849] for Residential and in-unit Multi Family bulbs.

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

ΔkWh = ((WattsBase - WattsEE) / 1000) * ISR * (1-Leakage) * Hours * WHFe

Where:

WattsBase = Based on lumens of CFL bulb and program year purchased:

| Minimum Lumens | Maximum Lumens | Incandescent Equivalent Post-EISA 2007 ($Watts_{Base}$) |
|---|---|---|
| 5280 | 6209 | 300 |
| 3000 | 5279 | 200 |
| 2601 | 2999 | 150 |
| 1490 | 2600 | 72 |
| 1050 | 1489 | 53 |
| 750 | 1049 | 43 |
| 310 | 749 | 29 |
| 250 | 309 | 25 |

WattsEE = Actual wattage of CFL purchased

ISR = In Service Rate or the percentage of units rebated that get installed.

| Program | Weighted Average 1st year In Service Rate (ISR) | 2nd year Installations | 3rd year Installations | Final Lifetime In Service Rate |
|---|---|---|---|---|
| Retail (Time of Sale) | 87.5%[850] | 5.7% | 4.8% | 98.0%[851] |
| Direct Install | 96.9[852] | | | |

Leakage = Adjustment to account for the percentage of program bulbs that move out (and in if

[849] Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

[850] 1st year in service rate is based upon review of PY2-3 evaluations from ComEd (see 'IL RES Lighting ISR.xls' for more information. The average first year ISR was calculated weighted by the number of bulbs in the each year's survey.

[851] The 98% Lifetime ISR assumption is consistent with the assumption for standard CFLs (in the absence of evidence that it should be different for this bulb type) based upon review of two evaluations:
'Nexus Market Research, RLW Analytics and GDS Associates study; "New England Residential Lighting Markdown Impact Evaluation, January 20, 2009' and 'KEMA Inc, Feb 2010, Final Evaluation Report:, Upstream Lighting Program, Volume 1.' This implies that only 2% of bulbs purchased are never installed. The second and third year installations are based upon Ameren analysis of the Californian KEMA study showing that 54% of future installs occur in year 2 and 46% in year 3. The 2nd and 3rd year installations should be counted as part of those future program year savings.

[852] In the absence of evaluation results for Direct Install Fixtures specifically, this is made consistent with the Direct Install CFL measure which is based upon review of the PY2 and PY3 ComEd Direct Install program surveys.

deemed appropriate[853]) of the Utility Jurisdiction.

KITS programs = Determined through evaluation

Upstream (TOS) Lighting programs = Determined through evaluation

or use deemed assumptions below[854]:

ComEd: 1.05%

Ameren: 6.55%

All other programs = 0

Hours = Average hours of use per year

| Installation Location | Hours |
|---|---|
| Residential and in-unit Multi Family | 759 [855] |

WHFe = Waste heat factor for energy to account for cooling energy savings from efficient lighting

| Bulb Location | WHFe |
|---|---|
| Interior single family or unknown location | 1.06 [856] |
| Multi family in unit | 1.04 [857] |

**DEFERRED INSTALLS**

As presented above, the characterization assumes that a percentage of bulbs purchased are not installed until Year 2 and Year 3 (see ISR assumption above). The Illinois Technical Advisory Committee has determined the following methodology for calculating the savings of these future installs.

Year 1 (Purchase Year) installs: Characterized using assumptions provided above or evaluated assumptions if available.

Year 2 and 3 installs: Characterized using delta watts assumption and hours of use from the Install Year i.e. the actual deemed (or evaluated if available) assumptions active in Year 2 and 3 should be applied.

The NTG factor for the Purchase Year should be applied.

[853] Leakage in is only appropriate to credit to IL utility program savings if it is reasonably expected that the IL utility program marketing efforts played an important role in influencing customer to purchase the light bulbs. Furthermore, consideration that such customers might be free riders should be addressed. If leakage in is assessed, efforts should be made to ensure no double counting of savings occurs if the evaluation is estimating both leakage in and spillover savings of light bulbs.

[854] Leakage rate is based upon TAC agreed 50% of the lamp leakage assumptions (based upon review of PY6-8 evaluations from ComEd and PY5,6 and 8 for Ameren (see 'IL Leakage Rates_112016.xls' for more information)).

[855] Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

[856] The value is estimated at 1.06 (calculated as 1 + (0.66*(0.27 / 2.8)). Based on cooling loads decreasing by 27% of the lighting savings (average result from REMRate modeling of several different configurations and IL locations of homes), assuming typical cooling system operating efficiency of 2.8 COP (starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm (-0.02 * SEER2) + (1.12 * SEER) (from Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), converted to COP = EER/3.412 = 2.8COP) and 66% of homes in Illinois having central cooling ("Table HC7.9 Air Conditioning in Homes in Midwest Region, Divisions, and States, 2009 from Energy Information Administration", 2009 Residential Energy Consumption Survey)

[857] As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from "Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009" which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average)

For example, for a 2 x 14W pin based CFL fixture (43W EISA qualified incandescent/halogen):

$\Delta kWH_{1st\ year\ installs}$ = ((86 - 28) / 1000) * 0.875 * 759 * 1.06
= 40.8 kWh

$\Delta kWH_{2nd\ year\ installs}$ = ((86 - 28) / 1000) * 0.057 * 759 * 1.06
= 2.7 kWh

Note: Here we assume no change in hours assumption. NTG value from Purchase year applied.

$\Delta kWH_{3rd\ year\ installs}$ = ((86 - 28) / 1000) * 0.048 * 759 * 1.06
= 2.2 kWh

**HEATING PENALTY**

If electric heated building:

ΔkWh[858] = - (((WattsBase - WattsEE) / 1000) * ISR * (1-Leakage) * Hours * HF) / ηHeat

Where:

HF = Heating Factor or percentage of light savings that must be heated
= 49%[859] for interior or unknown location
= 0% for unheated location

ηHeat = Efficiency in COP of Heating equipment
= actual. If not available use[860]:

| System Type | Age of Equipment | HSPF Estimate | $COP_{HEAT}$ (COP Estimate) = (HSPF/3.413)*0.85 |
|---|---|---|---|
| Heat Pump | Before 2006 | 6.8 | 1.7 |
| | After 2006 - 2014 | 7.7 | 1.92 |
| | 2015 on | 8.2 | 2.04 |
| Resistance | N/A | N/A | 1.00 |
| Unknown[861] | N/A | N/A | 1.28 |

[858] Negative value because this is an increase in heating consumption due to the efficient lighting.
[859] This means that heating loads increase by 49% of the lighting savings. This is based on the average result from REMRate modeling of several different configurations and IL locations of homes.
[860] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate. Note efficiency should include duct losses. Defaults provided assume 15% duct loss for heat pumps.
[861] Calculation assumes 35% Heat Pump and 65% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see “HC6.9 Space Heating in Midwest Region.xls”, using average for East North Central Region. Average efficiency of heat pump is based on assumption that 50% are units from before 2006 and 50% from 2006-2014. Program or evaluation data should be used to improve this assumption if available.

For example, a 2 x 14W pin-based CFL fixture is purchased and installed in home with 2.0 COP (including duct loss) Heat Pump:

$\Delta kWh_{1st\ year}$ = - (((86 – 28) / 1000) * 0.875 * 759 * 0.49) / 2.0

= - 9.4 kWh

Second and third year install savings should be calculated using the appropriate ISR and the delta watts and hours from the install year.

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = ((WattsBase - WattsEE) / 1 000) * ISR * (1-Leakage) * WHFd * CF

Where:

WHFd = Waste heat factor for demand to account for cooling savings from efficient lighting.

| Bulb Location | WHFd |
|---|---|
| Interior single family or unknown location | 1.11[862] |
| Multi family in unit | 1.07[863] |
| Exterior or uncooled location | 1.0 |

CF = Summer Peak Coincidence Factor for measure.

| Bulb Location | CF[864] |
|---|---|
| Interior single family or unknown location | 7.1% |
| Multi family in unit | 7.1% |

Other factors as defined above

For example, a 14W pin-based CFL fixture:

$\Delta kW_{1st\ year}$ = ((86- 28) / 1000) * 0.875 * 1.11 * 0.071

= 0.004 kW

Second and third year install savings should be calculated using the appropriate ISR and the delta watts and hours from the install year.

**NATURAL GAS SAVINGS**

ΔTherms[865] = - (((WattsBase - WattsEE) / 1000) * ISR * (1-Leakage) * Hours * HF * 0.03412) / ηHeat

Where:

HF = Heating Factor or percentage of light savings that must be heated

= 49%[866] for interior or unknown location

---

[862] The value is estimated at 1.11 (calculated as 1 + (0.66 * 0.466 / 2.8)). See footnote relating to WHFe for details. Note the 46.6% factor represents the average Residential cooling coincidence factor calculated by dividing average load during the peak hours divided by the maximum cooling load.

[863] As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from "Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009" which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average)

[864] Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

[865] Negative value because this is an increase in heating consumption due to the efficient lighting.

[866] This means that heating loads increase by 49% of the lighting savings. This is based on the average result from REMRate

= 0% for unheated location

0.03412 =Converts kWh to Therms

ηHeat = Efficiency of heating system

=70%[867]

For example, a 2 x 14W pin-based CFL fixture is purchased and installed in home with gas heat at 70% efficiency:

$\Delta Therms_{1st\ year}$ = -((86 - 28) / 1000) * 0.875 * 759 * 0.49 * 0.03412) / 0.7

= - 0.9 Therms

Second and third year install savings should be calculated using the appropriate ISR and the delta watts and hours from the install year.

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

Life of the baseline bulb is assumed to be 1.3 years[868] for interior applications. Baseline bulb cost replacement is assumed to be $1.25.[869]

It is important to note that for cost-effectiveness screening purposes, the O&M cost adjustments should only be applied in cases where the light bulbs area actually in service and so should be multiplied by the appropriate ISR.

**MEASURE CODE: RS-LTG-IFIX-V08-190101**

**REVIEW DEADLINE: 1/1/2020**

modeling of several different configurations and IL locations of homes.

[867] This has been estimated assuming that natural gas central furnace heating is typical for Illinois residences (66% of Illinois homes have a Natural Gas Furnace (based on Energy Information Administration, 2009 Residential Energy Consumption Survey) In 2000, 24% of furnaces purchased in Illinois were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 10 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows:

(0.24*0.92) + (0.76*0.8) * (1-0.15) = 0.70

[868] Calculated by dividing assumed rated life of baseline bulb by hours of use. Assumed lifetime of EISA qualified Halogen/ Incandescents is 1000 hours. The manufacturers are simply using a regular incandescent lamp with halogen fill gas rather than Halogen Infrared to meet the standard (as provided by G. Arnold, NEEP and confirmed by N. Horowitz at NRDC).

[869] Based upon field data collected by CLEAResult and provided by ComEd. See ComEd Pricing Projections 06302016.xlsx for analysis.

## 5.5.6 LED Specialty Lamps

### DESCRIPTION

This measure describes savings from a variety of specialty LED lamp types (including globe, decorative and downlights). This characterization assumes that the LED lamp is installed in a residential location. Where the implementation strategy does not allow for the installation location to be known (e.g. an upstream retail program) a deemed split of 95% Residential and 5% Commercial assumptions should be used[870].

This measure was developed to be applicable to the following program types: TOS, NC, EREP, KITS.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed equipment must be an ENERGY STAR LED lamp or fixture. Note a new ENERGY STAR specification v2.1 becomes effective on 1/2/2017.

### DEFINITION OF BASELINE EQUIPMENT

Specialty and Directional lamps were not included in the original definition of General Service Lamps in the Energy Independence and Security Act of 2007 (EISA). Therefore, the initial baseline is an incandescent / halogen lamp described in the table below.

However, a DOE Final Rule released on 1/19/2017 updated the EISA regulations to remove the exemption for these lamp types such that they become subject to the backstop provision defined within the original legislation. The backstop provision requires that by January 1, 2020, all lamps sold must meet efficiency criteria of at least 45 lumens per watt. Since baseline lamps have significantly lower rated lifetimes, this requires that a baseline shift reducing the annual savings is incorporated during the lifetime of the measure.

There is however, uncertainty around the final application of the EISA backstop provision, particularly whether the expanded definition will hold, as well as uncertainty regarding how the market for these products would change absent the backstop. Therefore the 2019 version of this measure delays application of the midlife adjustment associated with the backstop provision to 1/1/2024. However, TAC members commit to making appropriate mid-year adjustments to the measure characterization in the event that new information adds sufficient clarity and concludes any legal challenges to support making a change to this agreement. This means that if within PY2019, it becomes clear that the EISA backstop *will* apply to the measures characterized herein, the timing of the midlife adjustment will be changed to be applied in 2021, consistent with the omnidirectional measure. Likewise, if it becomes clear that these lamp types will revert to being exempt, the midlife adjustment will be removed. In addition, the TAC and IL TRM Administrator must consider NTG and lifetime assumptions and if consensus is reached apply coordinated adjustments to the TRM at that time (if consensus is not reached the most recent NTG evaluation results for these measures will be applied). Any mid-year adjustments to the TRM and NTG would be applied for all installs beginning 30 days after agreement is reached, rather than waiting for the next TRM update.

The baseline for the early replacement measure is the existing bulb being replaced.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The deemed measure life is 6.1 years[871] for exterior applications. For all other applications, lifetimes are capped at 10 years[872].

---

[870] RES v C&I split is based on a weighted (by sales volume) average of ComEd PY7, PY8 and PY9 in store intercept survey results. See 'RESvCI Split_2018.xlsx'.

[871] ENERGY STAR v2.1 requires all LED bulbs to be rated for at least 15,000 hours. 15000/2475 (exterior hours of use) = 6.1 years.

[872] Based on recommendation in the Dunsky Energy Consulting, Livingston Energy Innovations and Opinion Dynamics Corporation; NEEP Emerging Technology Research Report, p 6-18.

For early replacement measures, if replacing a halogen or incandescent bulb, the remaining life is assumed to be 333 hours. For CFLs, the remaining life is 3,333 hours[873].

**DEEMED MEASURE COST**

The price of LED lamps is falling quickly. Where possible, the actual cost should be used and compared to the baseline cost provided below. If the incremental cost is unknown, assume the following[874]:

| Bulb Type | Year | Incandescent | LED | Incremental Cost |
|---|---|---|---|---|
| Directional | 2019 and on | $3.53 | $5.18 | $1.65 |
| Decorative and Globe | 2019 and on | $1.74 | $3.40 | $1.66 |

**LOADSHAPE**

Loadshape R06 - Residential Indoor Lighting

Loadshape R07 - Residential Outdoor Lighting

**COINCIDENCE FACTOR**

The summer peak coincidence factor is assumed to be 0.109 for residential and in-unit multifamily bulbs[875], 0.273 for exterior bulbs[876] and 0.117 for unknown[877].Use Multifamily if: Building meets utility's definition for multifamily.

## Algorithm

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

$\Delta kWh$ = ((WattsBase - WattsEE) / 1000) * ISR * (1-Leakage) * Hours * WHFe

Where:

$Watts_{base}$ = Input wattage of the existing or baseline system. Reference the table below for default values.[878]

$Watts_{EE}$ = Actual wattage of LED purchased / installed. If unknown, use default provided below.

[873] Representing a third of the expected lamp lifetime.
[874] Baseline and LED lamp costs for both directional and decorative and globe are based on field data collected by CLEAResult and provided by ComEd. See ComEd Pricing Projections 06302016.xlsx for analysis. .
[875] Based on the IL Statewide LED Lighting Logger study conducted as part of the PY8/PY9 evaluations of the Ameren Illinois and ComEd Residential Lighting programs.
[876] Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation. the IL Statewide LED Lighting Logger study conducted as part of the PY8/PY9 evaluations of the Ameren Illinois and ComEd Residential Lighting programs was unable to provide coincidence factors for specialty LEDs in exterior applications.
[877] Based on a weighted average of coincidence factors in interior and exterior applications, assuming 5% exterior lighting. The distribution of LEDs is based on the on-site lighting inventory conducted as part of the IL Statewide LED Lighting Logger study.
[878] See file "LED baseline and EE wattage table_2018.xlsx" for details on lamp wattage calculations.

**Decorative Lamps – ENERGY STAR Minimum Luminous Efficacy = 65Lm/W for all lamps**

| Bulb Type | Minimum Lumens | Maximum Lumens | Lumens used to calculate LED Wattage (midpoint) | LED Wattage ($Watts_{EE}$) | Baseline 2014-2023 ($Watts_{Base}$) | Delta Watts 2014-2023 (WattsEE) | Baseline From 1/1/2024 ($Watts_{Base}$) [879] | Delta Watts From 1/1/2024 (WattsEE) |
|---|---|---|---|---|---|---|---|---|
| **3-Way** | 250 | 449 | 350 | 4.4 | 25 | 20.6 | 7.8 | 3.3 |
| | 450 | 799 | 625 | 7.9 | 40 | 32.1 | 13.9 | 6.0 |
| | 800 | 1,099 | 950 | 12.1 | 60 | 47.9 | 21.1 | 9.0 |
| | 1,100 | 1,599 | 1350 | 17.1 | 75 | 57.9 | 30.0 | 12.9 |
| | 1,600 | 1,999 | 1800 | 22.8 | 100 | 77.2 | 40.0 | 17.1 |
| | 2,000 | 2,549 | 2275 | 28.9 | 125 | 96.1 | 50.5 | 21.7 |
| | 2,550 | 2,999 | 2775 | 35.2 | 150 | 114.8 | 61.7 | 26.4 |
| **Globe (medium and intermediate bases less than 750 lumens)** | 90 | 179 | 135 | 2.1 | 10 | 7.9 | 3.0 | 0.9 |
| | 180 | 249 | 215 | 3.3 | 15 | 11.7 | 4.8 | 1.5 |
| | 250 | 349 | 300 | 4.6 | 25 | 20.4 | 6.7 | 2.0 |
| | 350 | 749 | 550 | 8.5 | 40 | 31.5 | 12.2 | 3.8 |
| **Decorative (Shapes B, BA, C, CA, DC, F, G, medium and intermediate bases less than 750 lumens)** | 70 | 89 | 80 | 1.2 | 10 | 8.8 | 1.8 | 0.5 |
| | 90 | 149 | 120 | 1.8 | 15 | 13.2 | 2.7 | 0.8 |
| | 150 | 299 | 225 | 3.5 | 25 | 21.5 | 5.0 | 1.5 |
| | 300 | 749 | 525 | 8.1 | 40 | 31.9 | 11.7 | 3.6 |
| **Globe (candelabra bases less than 1050 lumens)** | 90 | 179 | 135 | 2.1 | 10 | 7.9 | 3.0 | 0.9 |
| | 180 | 249 | 215 | 3.3 | 15 | 11.7 | 4.8 | 1.5 |
| | 250 | 349 | 300 | 4.6 | 25 | 20.4 | 6.7 | 2.0 |
| | 350 | 499 | 425 | 6.5 | 40 | 33.5 | 9.4 | 2.9 |
| | 500 | 1,049 | 775 | 11.9 | 60 | 48.1 | 17.2 | 5.3 |
| **Decorative (Shapes B, BA, C, CA, DC, F, G, candelabra bases less than 1050 lumens)** | 70 | 89 | 80 | 1.2 | 10 | 8.8 | 1.8 | 0.5 |
| | 90 | 149 | 120 | 1.8 | 15 | 13.2 | 2.7 | 0.8 |
| | 150 | 299 | 225 | 3.5 | 25 | 21.5 | 5.0 | 1.5 |
| | 300 | 499 | 400 | 6.1 | 40 | 33.9 | 8.9 | 2.7 |
| | 500 | 1,049 | 775 | 11.9 | 60 | 48.1 | 17.2 | 5.3 |

**Directional Lamps -** ENERGY STAR Minimum Luminous Efficacy = 70Lm/W for <90 CRI lamps and 61 Lm/W for >=90CRI lamps.

For Directional R, BR, and ER lamp types[880]:

[879] Calculated as 45lm/W for all EISA non-exempt bulbs
[880] From pg 13 of the ENERGY STAR Specification for lamps v2.1

| Bulb Type | Minimum Lumens | Maximum Lumens | Lumens used to calculate LED Wattage (midpoint) | LED Wattage ($Watts_{EE}$) | Baseline 2014-2023 ($Watts_{Base}$) | Delta Watts 2014-2023 (WattsEE) | Baseline From 1/1/2024 ($Watts_{Base}$) [881] | Delta Watts From 1/1/2024 (WattsEE) |
|---|---|---|---|---|---|---|---|---|
| R, ER, BR with medium screw bases w/ diameter >2.25" (*see exceptions below) | 420 | 472 | 446 | 6.6 | 40 | 33.4 | 9.9 | 3.4 |
| | 473 | 524 | 499 | 7.3 | 45 | 37.7 | 11.1 | 3.8 |
| | 525 | 714 | 620 | 9.1 | 50 | 40.9 | 13.8 | 4.7 |
| | 715 | 937 | 826 | 12.1 | 65 | 52.9 | 18.4 | 6.2 |
| | 938 | 1259 | 1099 | 16.2 | 75 | 58.8 | 24.4 | 8.3 |
| | 1260 | 1399 | 1330 | 19.6 | 90 | 70.4 | 29.6 | 10.0 |
| | 1400 | 1739 | 1570 | 23.1 | 100 | 76.9 | 34.9 | 11.8 |
| | 1740 | 2174 | 1957 | 28.8 | 120 | 91.2 | 43.5 | 14.7 |
| | 2175 | 2624 | 2400 | 35.3 | 150 | 114.7 | 53.3 | 18.0 |
| | 2625 | 2999 | 2812 | 41.3 | 175 | 133.7 | 62.5 | 21.1 |
| | 3000 | 4500 | 3750 | 55.1 | 200 | 144.9 | 83.3 | 28.2 |
| *R, BR, and ER with medium screw bases w/ diameter <=2.25" | 400 | 449 | 425 | 6.2 | 40 | 33.8 | 9.4 | 3.2 |
| | 450 | 499 | 475 | 7.0 | 45 | 38.0 | 10.6 | 3.6 |
| | 500 | 649 | 575 | 8.5 | 50 | 41.5 | 12.8 | 4.3 |
| | 650 | 1199 | 925 | 13.6 | 65 | 51.4 | 20.6 | 7.0 |
| *ER30, BR30, BR40, or ER40 | 400 | 449 | 425 | 6.2 | 40 | 33.8 | 9.4 | 3.2 |
| | 450 | 499 | 475 | 7.0 | 45 | 38.0 | 10.6 | 3.6 |
| | 500 | 649 | 575 | 8.5 | 50 | 41.5 | 12.8 | 4.3 |
| *BR30, BR40, or ER40 | 650 | 1419 | 1035 | 15.2 | 65 | 49.8 | 23.0 | 7.8 |
| *R20 | 400 | 449 | 425 | 6.2 | 40 | 33.8 | 9.4 | 3.2 |
| | 450 | 719 | 585 | 8.6 | 45 | 36.4 | 13.0 | 4.4 |
| *All reflector lamps below lumen ranges specified above | 200 | 299 | 250 | 3.7 | 20 | 16.3 | 5.6 | 1.9 |
| | 300 | 399 | 350 | 5.1 | 30 | 24.9 | 7.8 | 2.6 |

For PAR, MR, and MRX Lamps Types:

For these highly focused directional lamp types, it is necessary to have Center Beam Candle Power (CBCP) and beam angle measurements to accurately estimate the equivalent baseline wattage. The formula below is based on the ENERGY STAR Center Beam Candle Power tool.[882] If CBCP and beam angle information are not available or if the equation below returns a negative value (or undefined), use the manufacturer's recommended baseline wattage equivalent.[883]

$$\text{Wattsbase} =$$

$$375.1 - 4.355(D) - \sqrt{227{,}800 - 937.9(D) - 0.9903(D^2) - 1479(BA) - 12.02(D * BA) + 14.69(BA^2) - 16{,}720 * \ln(CBCP)}$$

Where:

D = Bulb diameter (e.g. for PAR20 D = 20)

---

[881] Calculated as 45lm/W for all EISA non-exempt bulbs

[882] See 'ESLampCenterBeamTool.xls'.

[883] The ENERGY STAR Center Beam Candle Power tool does not accurately model baseline wattages for lamps with certain bulb characteristic combinations – specifically for lamps with very high CBCP.

BA = Beam angle

CBCP = Center beam candle power

The result of the equation above should be rounded DOWN to the nearest wattage established by ENERGY STAR:

| Diameter | Permitted Wattages |
|---|---|
| 16 | 20, 35, 40, 45, 50, 60, 75 |
| 20 | 50 |
| 30S | 40, 45, 50, 60, 75 |
| 30L | 50, 75 |
| 38 | 40, 45, 50, 55, 60, 65, 75, 85, 90, 100, 120, 150, 250 |

Additional EISA non-exempt bulb types:

| Bulb Type | Minimum Lumens | Maximum Lumens | Lumens used to calculate LED Wattage (midpoint) | LED Wattage ($Watts_{EE}$) | Baseline 2014-2023 ($Watts_{Base}$) | Delta Watts 2014-2023 (WattsEE) | Baseline From 1/1/2024 ($Watts_{Base}$)[884] | Delta Watts From 1/1/2024 (WattsEE) |
|---|---|---|---|---|---|---|---|---|
| **Dimmable Twist, Globe (less than 5" in diameter and > 749 lumens), candle (shapes B, BA, CA > 749 lumens), Candelabra Base Lamps (>1049 lumens), Intermediate Base Lamps (>749 lumens)** | 310 | 749 | 530 | 6.7 | 29 | 22.3 | 11.8 | 5.0 |
| | 750 | 1049 | 900 | 11.4 | 43 | 31.6 | 20.0 | 8.6 |
| | 1050 | 1489 | 1270 | 16.1 | 53 | 36.9 | 28.2 | 12.1 |
| | 1490 | 2600 | 2045 | 26.0 | 72 | 46.0 | 45.4 | 19.5 |

ISR = In Service Rate or the percentage of lamps rebated that get installed

| Program | Weighted Average 1st year In Service Rate (ISR) | 2nd year Installations | 3rd year Installations | Final Lifetime In Service Rate |
|---|---|---|---|---|
| Retail (Time of Sale) | 84.0%[885] | 7.6% | 6.4% | 98.0%[886] |
| Direct Install | 96.9%[887] | | | |

[884] Calculated as 45lm/W for all EISA non-exempt bulbs

[885] 1st year in service rate is based upon analysis of ComEd PY7, PY8, and PY9 intercept data (see 'Res Lighting ISR_2018.xlsx' for more information).

[886] The 98% Lifetime ISR assumption is based upon the standard CFL measure in the absence of any better reference. This value is based upon review of two evaluations:
'Nexus Market Research, RLW Analytics and GDS Associates study; "New England Residential Lighting Markdown Impact Evaluation, January 20, 2009' and 'KEMA Inc, Feb 2010, Final Evaluation Report:, Upstream Lighting Program, Volume 1.' This implies that only 2% of bulbs purchased are never installed. The second and third year installations are based upon Ameren analysis of the Californian KEMA study showing that 54% of future installs occur in year 2 and 46% in year 3. The 2nd and 3rd year installations should be counted as part of those future program year savings.

[887] Consistent with assumption for standard CFLs (in the absence of evidence that it should be different for this bulb type). Based upon review of the PY2 and PY3 ComEd Direct Install program surveys. This value includes bulb failures in the 1st year to

| Program | Weighted Average 1st year In Service Rate (ISR) | 2nd year Installations | 3rd year Installations | Final Lifetime In Service Rate |
|---|---|---|---|---|
| School Kits | 60%[888] | 13% | 11% | 84% |

Leakage = Adjustment to account for the percentage of program bulbs that move out (and in if deemed appropriate[889]) of the Utility Jurisdiction.

KITS programs = Determined through evaluation

Upstream (TOS) Lighting programs = Use deemed assumptions below[890]:

ComEd: 2.0%

Ameren: 13.1%

All other programs = 0

Hours = Average hours of use per year

| Installation Location | Annual hours of use (HOU) |
|---|---|
| Residential and In-Unit Multi Family | 763[891] |
| Exterior | 2,475[892] |
| Unknown | 1,020[893] |

WHFe = Waste heat factor for energy to account for cooling savings from efficient lighting

| Bulb Location | WHFe |
|---|---|
| Interior single family | 1.06 [894] |

be consistent with the Commission approval of annualization of savings for first year savings claims. ComEd PY2 All Electric Single Family Home Energy Performance Tune-Up Program Evaluation, Navigant Consulting, December 21, 2010.

888 1st year ISR for school kits based on ComEd PY9 data for the Elementary Energy Education program.

889 Leakage in is only appropriate to credit to IL utility program savings if it is reasonably expected that the IL utility program marketing efforts played an important role in influencing customer to purchase the light bulbs. Furthermore, consideration that such customers might be free riders should be addressed. If leakage in is assessed, efforts should be made to ensure no double counting of savings occurs if the evaluation is estimating both leakage in and spillover savings of light bulbs.

890 Leakage rate is based upon review of PY7-9 evaluations from ComEd and PY5,6 and 8 for Ameren (see for more information).

891 Based on the IL Statewide LED Lighting Logger study conducted as part of the PY8/PY9 evaluations of the Ameren Illinois and ComEd Residential Lighting programs.

892 Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation. The IL Statewide LED Lighting Logger study conducted as part of the PY8/PY9 evaluations of the Ameren Illinois and ComEd Residential Lighting programs was unable to provide hours of use for specialty LEDs in exterior applications.

893 Based on a weighted average of interior and exterior hours of use from the IL Statewide LED Lighting Logger study conducted as part of the PY8/PY9 evaluations of the Ameren Illinois and ComEd Residential Lighting programs, assuming 15% exterior specialty lighting. The distribution of LEDs is based on the on-site lighting inventory conducted as part of the IL Statewide LED Lighting Logger study.

894 The value is estimated at 1.06 (calculated as 1 + (0.66*(0.27 / 2.8)). Based on cooling loads decreasing by 27% of the lighting savings (average result from REMRate modeling of several different configurations and IL locations of homes), assuming typical cooling system operating efficiency of 2.8 COP (starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm (-0.02 * SEER2) + (1.12 * SEER) (from Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), converted to COP = EER/3.412 = 2.8COP) and 66% of homes in Illinois having central cooling ("Table HC7.9 Air Conditioning in Homes in Midwest Region, Divisions, and States, 2009 from Energy Information Administration", 2009 Residential Energy Consumption Survey)

| Bulb Location | WHFe |
|---|---|
| Multifamily in unit | 1.04 [895] |
| Exterior or uncooled location | 1.0 |
| Unknown location | 1.046[896] |

Use Multifamily if: Building meets utility's definition for multifamily

For example, a 13W PAR20 LED is purchased through a ComEd upstream program and installed in place of a 750 lumen PAR20 incandescent screw-in lamp with medium screw base, diameter >2.5" in a single family interior location:

ΔkWh = ((45 - 13) / 1000) * 0.840 * (1 – 0.02) * 763 * 1.06

= 21.3 kWh

**Mid Life Baseline Adjustment**

An appropriate baseline adjustment should be included to account for the 2020 EISA backstop provision making replacement baseline lamps meet 45 lumens/watt. Due to uncertainty around the final application of the EISA backstop provision, particularly whether the expanded definition will hold, as well as uncertainty regarding how the market for these products would change absent the backstop, the 2019 version of this measure delays application of the midlife adjustment associated with the backstop provision to 1/1/2024.

Note for early replacement measures an additional baseline shift accounting for the replacement of the existing unit with a new baseline lamp should be accounted for.

| | Bulb Type | Lower Lumen Range | Upper Lumen Range | LED Wattage ($Watts_{EE}$) | Delta Watts 2014-2023 (WattsEE) | Delta Watts From 1/1/2024 (WattsEE) | Mid Life adjustment (made from 01/2024) to first year savings |
|---|---|---|---|---|---|---|---|
| Decorative EISA 2014 Exempt, 2020 Non-Exempt | 3-Way[897] | 250 | 449 | 4.4 | 20.6 | 3.3 | 16.2% |
| | | 450 | 799 | 7.9 | 32.1 | 6.0 | 18.6% |
| | | 800 | 1,099 | 12.1 | 47.9 | 9.0 | 18.9% |
| | | 1,100 | 1,599 | 17.1 | 57.9 | 12.9 | 22.2% |
| | | 1,600 | 1,999 | 22.8 | 77.2 | 17.1 | 22.2% |
| | | 2,000 | 2,549 | 28.9 | 96.1 | 21.7 | 22.5% |
| | | 2,550 | 2,999 | 35.2 | 114.8 | 26.4 | 23.0% |
| | Globe (medium and intermediate bases less than 750 lumens) | 90 | 179 | 2.1 | 7.9 | 0.9 | 11.6% |
| | | 180 | 249 | 3.3 | 11.7 | 1.5 | 12.5% |
| | | 250 | 349 | 4.6 | 20.4 | 2.0 | 10.0% |
| | | 350 | 749 | 8.5 | 31.5 | 3.8 | 11.9% |
| | Decorative (Shapes B, BA, C, CA, | 70 | 89 | 1.2 | 8.8 | 0.5 | 6.2% |
| | | 90 | 149 | 1.8 | 13.2 | 0.8 | 6.2% |

[895] As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from "Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009" which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average)

[896] Unknown is weighted average of interior v exterior (assuming 15% exterior specialty lighting based on distribution of LEDs from on-site lighting inventory conducted as part of the IL Statewide LED Lighting Logger study) and SF v MF interior based on statewide weighted average of 69% single family and 31% multifamily, based on IL data from 2009 RECS Table HC2.9 Structural and Geographic Characteristics of Homes in Midwest Region, Divisions and States, 2009.

[897] For 3-way bulbs or fixtures, the product's median lumens value will be used to determine both LED and baseline wattages.

| | Bulb Type | Lower Lumen Range | Upper Lumen Range | LED Wattage ($Watts_{EE}$) | Delta Watts 2014-2023 (WattsEE) | Delta Watts From 1/1/2024 (WattsEE) | Mid Life adjustment (made from 01/2024) to first year savings |
|---|---|---|---|---|---|---|---|
| | DC, F, G, medium and intermediate bases less than 750 lumens) | 150 | 299 | 3.5 | 21.5 | 1.5 | 7.1% |
| | | 300 | 749 | 8.1 | 31.9 | 3.6 | 11.2% |
| | Globe (candelabra bases less than 1050 lumens) | 90 | 179 | 2.1 | 7.9 | 0.9 | 11.6% |
| | | 180 | 249 | 3.3 | 11.7 | 1.5 | 12.5% |
| | | 250 | 349 | 4.6 | 20.4 | 2.0 | 10.0% |
| | | 350 | 499 | 6.5 | 33.5 | 2.9 | 8.7% |
| | | 500 | 1,049 | 11.9 | 48.1 | 5.3 | 11.0% |
| | Decorative (Shapes B, BA, C, CA, DC, F, G, candelabra bases less than 1050 lumens) | 70 | 89 | 1.2 | 8.8 | 0.5 | 6.2% |
| | | 90 | 149 | 1.8 | 13.2 | 0.8 | 6.2% |
| | | 150 | 299 | 3.5 | 21.5 | 1.5 | 7.1% |
| | | 300 | 499 | 6.1 | 33.9 | 2.7 | 8.1% |
| | | 500 | 1,049 | 11.9 | 48.1 | 5.3 | 11.0% |
| Directional EISA 2014 Exempt, 2020 Non-Exempt | R, ER, BR with medium screw bases w/ diameter >2.25" (*see exceptions below) | 420 | 472 | 6.6 | 33.4 | 3.4 | 10.0% |
| | | 473 | 524 | 7.3 | 37.7 | 3.8 | 10.0% |
| | | 525 | 714 | 9.1 | 40.9 | 4.7 | 11.4% |
| | | 715 | 937 | 12.1 | 52.9 | 6.2 | 11.8% |
| | | 938 | 1259 | 16.2 | 58.8 | 8.3 | 14.0% |
| | | 1260 | 1399 | 19.6 | 70.4 | 10.0 | 14.2% |
| | | 1400 | 1739 | 23.1 | 76.9 | 11.8 | 15.3% |
| | | 1740 | 2174 | 28.8 | 91.2 | 14.7 | 16.1% |
| | | 2175 | 2624 | 35.3 | 114.7 | 18.0 | 15.7% |
| | | 2625 | 2999 | 41.3 | 133.7 | 21.1 | 15.8% |
| | | 3000 | 4500 | 55.1 | 144.9 | 28.2 | 19.5% |
| | *R, BR, and ER with medium screw bases w/ diameter <=2.25" | 400 | 449 | 6.2 | 33.8 | 3.2 | 9.5% |
| | | 450 | 499 | 7.0 | 38.0 | 3.6 | 9.4% |
| | | 500 | 649 | 8.5 | 41.5 | 4.3 | 10.4% |
| | | 650 | 1199 | 13.6 | 51.4 | 7.0 | 13.5% |
| | *ER30, BR30, BR40, or ER40 | 400 | 449 | 6.2 | 33.8 | 3.2 | 9.5% |
| | | 450 | 499 | 7.0 | 38.0 | 3.6 | 9.4% |
| | | 500 | 649 | 8.5 | 41.5 | 4.3 | 10.4% |
| | *BR30, BR40, or ER40 | 650 | 1419 | 15.2 | 49.8 | 7.8 | 15.6% |
| | *R20 | 400 | 449 | 6.2 | 33.8 | 3.2 | 9.5% |
| | | 450 | 719 | 8.6 | 36.4 | 4.4 | 12.1% |
| | *All reflector lamps below lumen ranges specified above | 200 | 299 | 3.7 | 16.3 | 1.9 | 11.5% |
| | | 300 | 399 | 5.1 | 24.9 | 2.6 | 10.6% |
| EISA Non-Exem | Dimmable Twist, Globe (less than 5" | 310 | 749 | 6.7 | 22.3 | 5.0 | 22.6% |
| | | 750 | 1049 | 11.4 | 31.6 | 8.6 | 27.1% |

| | Bulb Type | Lower Lumen Range | Upper Lumen Range | LED Wattage ($Watts_{EE}$) | Delta Watts 2014-2023 (WattsEE) | Delta Watts From 1/1/2024 (WattsEE) | Mid Life adjustment (made from 01/2024) to first year savings |
|---|---|---|---|---|---|---|---|
| | **in diameter and > 749 lumens), candle (shapes B, BA, CA > 749 lumens), Candelabra Base Lamps (>1049 lumens), Intermediate Base Lamps (>749 lumens)** | 1050 | 1489 | 16.1 | 36.9 | 12.1 | 32.8% |
| | | 1490 | 2600 | 26.0 | 46.0 | 19.5 | 42.3% |

**DEFERRED INSTALLS**

As presented above, the characterization assumes that a percentage of bulbs purchased are not installed until Year 2 and Year 3 (see ISR assumption above). The Illinois Technical Advisory Committee has determined the following methodology for calculating the savings of these future installs.

Year 2 and 3 installs: Characterized using delta watts assumption and hours of use from the Install Year i.e. the actual deemed assumptions active in Year 2 and 3 should be applied.

The NTG factor for the Purchase Year (Year 1) should be applied.

**HEATING PENALTY**

If electric heated home (if heating fuel is unknown assume gas, see Natural Gas section):

ΔkWh[898] = - (((WattsBase - WattsEE) / 1000) * ISR * (1-Leakage) * Hours * HF) / ηHeat

Where:

HF = Heating Factor or percentage of light savings that must be heated

= 49%[899] for interior location

= 0% for exterior location

= 42%[900] for unknown location

ηHeat = Efficiency in COP of Heating equipment

= Actual. If not available use: [901]:

[898] Negative value because this is an increase in heating consumption due to the efficient lighting.

[899] This means that heating loads increase by 49% of the lighting savings. This is based on the average result from REMRate modeling of several different configurations and IL locations of homes.

[900] Based on a weighted average of interior and exterior hours of use from the IL Statewide LED Lighting Logger study conducted as part of the PY8/PY9 evaluations of the Ameren Illinois and ComEd Residential Lighting programs, assuming 15% exterior specialty lighting. The distribution of LEDs is based on the on-site lighting inventory conducted as part of the IL Statewide LED Lighting Logger study.

[901] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate. Note efficiency should include duct

| System Type | Age of Equipment | HSPF Estimate | $COP_{HEAT}$ (COP Estimate) = (HSPF/3.413)*0.85 |
|---|---|---|---|
| Heat Pump | Before 2006 | 6.8 | 1.7 |
| | After 2006 - 2014 | 7.7 | 1.92 |
| | 2015 on | 8.2 | 2.04 |
| Resistance | N/A | N/A | 1.00 |
| Unknown[902] | N/A | N/A | 1.28 |

For example, a 13W PAR20 LED is purchased through a ComEd upstream program and installed in place of a 750 lumen PAR20 incandescent screw-in lamp with medium screw base, diameter >2.5" in a single family interior location with a 2016 heat pump:

ΔkWh = - (((45 - 13) / 1000) * 0.840 * (1 – 0.02) * 763 * 0.49) / 2.04

= - 4.83 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = ((WattsBase - WattsEE) / 1000) * ISR * (1-Leakage) * WHFd * CF

Where:

WHFd = Waste heat factor for demand to account for cooling savings from efficient lighting.

| Bulb Location | WHFd |
|---|---|
| Interior single family | 1.11[903] |
| Multifamily in unit | 1.07[904] |
| Exterior or uncooled location | 1.0 |
| Unknown location | 1.083[905] |

Use Multifamily if: Building meets utility's definition for multifamily

CF = Summer Peak Coincidence Factor for measure

= 0.109 for residential and in-unit multifamily bulbs[906], 0.273 for exterior bulbs[907] and 0.117 for

losses. Defaults provided assume 15% duct loss for heat pumps.

902 Calculation assumes 35% Heat Pump and 65% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see "HC6.9 Space Heating in Midwest Region.xls", using average for East North Central Region. Average efficiency of heat pump is based on assumption that 50% are units from before 2006 and 50% from 2006-2014. Program or evaluation data should be used to improve this assumption if available.

903 The value is estimated at 1.11 (calculated as 1 + (0.66 * 0.466 / 2.8)). See footnote relating to WHFe for details. Note the 46.6% factor represents the average Residential cooling coincidence factor calculated by dividing average load during the peak hours divided by the maximum cooling load.

904 As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from "Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009" which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average)

905 Unknown is weighted average of interior v exterior (assuming 15% exterior specialty lighting based on distribution of LEDs from on-site lighting inventory conducted as part of the IL Statewide LED Lighting Logger study) and SF v MF interior based on statewide weighted average of 69% single family and 31% multifamily, based on IL data from 2009 RECS Table HC2.9 Structural and Geographic Characteristics of Homes in Midwest Region, Divisions and States, 2009.

906 Based on the IL Statewide LED Lighting Logger study conducted as part of the PY8/PY9 evaluations of the Ameren Illinois and ComEd Residential Lighting programs.

907 Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation. the IL Statewide LED Lighting Logger study conducted as part of the PY8/PY9 evaluations of the Ameren Illinois and ComEd Residential Lighting programs was unable to provide coincidence factors for specialty LEDs in exterior applications.

unknown[908].

Use Multifamily if: Building meets utility's definition for multifamily

Other factors as defined above

> For example, a 13W PAR20 LED is purchased through a ComEd upstream program and installed in place of a 750 lumen PAR20 incandescent screw-in lamp with medium screw base, diameter >2.5" in a single family interior location:
>
> ΔkW = (((45 - 13) / 1000) * 0.840 * (1 – 0.02) * 1.11* 0.109
>
> = 0.0032 kW

**NATURAL GAS SAVINGS**

Heating penalty if Natural Gas heated home, or if heating fuel is unknown.

Δtherms = - (((WattsBase - WattsEE) / 1000) * ISR * (1-Leakage) * Hours * HF * 0.03412) / ηHeat

Where:

HF = Heating factor, or percentage of lighting savings that must be replaced by heating system.

= 49% [909] for interior

= 0% for exterior location

= 42%[910] for unknown location

0.03412 = Converts kWh to Therms

ηHeat = Average heating system efficiency.

= 0.70 [911]

Other factors as defined above

> For example, a 13W PAR20 LED is purchased through a ComEd upstream program and installed in place of a 750 lumen PAR20 incandescent screw-in lamp with medium screw base, diameter >2.5" in single family interior location with gas heating at 70% total efficiency:
>
> Δtherms = - (((45 - 13) / 1000) * 0.840 * (1 – 0.02) * 763 * 0.49* 0.03412) / 0.70
>
> = - 0.49 therms

[908] Based on a weighted average of coincidence factors in interior and exterior applications, assuming 5% exterior lighting. The distribution of LEDs is based on the on-site lighting inventory conducted as part of the IL Statewide LED Lighting Logger study.

[909] Average result from REMRate modeling of several different configurations and IL locations of homes

[910] Based on a weighted average of interior and exterior hours of use from the IL Statewide LED Lighting Logger study conducted as part of the PY8/PY9 evaluations of the Ameren Illinois and ComEd Residential Lighting programs, assuming 15% exterior specialty lighting. The distribution of LEDs is based on the on-site lighting inventory conducted as part of the IL Statewide LED Lighting Logger study.

[911] This has been estimated assuming that natural gas central furnace heating is typical for Illinois residences (66% of Illinois homes have a Natural Gas Furnace (based on Energy Information Administration, 2009 Residential Energy Consumption Survey) In 2000, 24% of furnaces purchased in Illinois were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 10 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows:
(0.24*0.92) + (0.76*0.8) * (1-0.15) = 0.70

## WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

## DEEMED O&M COST ADJUSTMENT CALCULATION

Bulb replacement costs assumed in the O&M calculations are provided below[912].

| Lamp Type | Installation Year | Standard Incandescent | EISA Compliant Halogen | CFL |
|---|---|---|---|---|
| Decorative | 2019 | $1.74 | N/A | N/A |
| | 2020 | $1.74 | N/A | N/A |
| | 2021 & after | $1.74 | N/A | $2.50 |
| Directional | 2019 | $3.53 | N/A | N/A |
| | 2020 | $3.53 | N/A | N/A |
| | 2021 & after | $3.53 | N/A | $4.50 |

For non-exempt EISA bulb types defined above, in order to account for the shift in baseline due to the Energy Independence and Security Act of 2007, an equivalent annual levelized baseline replacement cost over the lifetime of the LED bulb is calculated. The key assumptions used in this calculation are documented below:

| Installation Location | Specialty LED Measure Hours | Hours of Use per year [913] | Measure Life in Years (capped at 10) |
|---|---|---|---|
| Interior | 15,000 | 763[914] | 10 |
| Exterior | 15,000 | 2,475[915] | 6.1 |
| Unknown | 15,000 | 1,020[916] | 10 |

The NPV for replacement lamps and annual levelized replacement costs using the societal real discount rate of 0.46% are presented below[917].

**Decorative Lamps**

| Location | NPV of replacement costs for period | | | Levelized annual replacement cost savings | | |
|---|---|---|---|---|---|---|
| | 2019 | 2020 | 2021 | 2019 | 2020 | 2021 |
| Interior | $6.15 | $5.03 | $3.92 | $0.63 | $0.52 | $0.40 |
| Exterior | $20.17 | $16.56 | $10.39 | $3.38 | $2.78 | $1.74 |
| Unknown | $6.84 | $5.60 | $4.36 | $0.70 | $0.57 | $0.45 |

[912] Baseline costs are based on field data collected by CLEAResult and provided by ComEd. See ComEd Pricing Projections 06302016.xlsx for analysis.
[913] Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluations.
[914] Based on the IL Statewide LED Lighting Logger study conducted as part of the PY8/PY9 evaluations of the Ameren Illinois and ComEd Residential Lighting programs.
[915] Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation. The IL Statewide LED Lighting Logger study conducted as part of the PY8/PY9 evaluations of the Ameren Illinois and ComEd Residential Lighting programs was unable to provide hours of use for specialty LEDs in exterior applications.
[916] Based on a weighted average of interior and exterior hours of use from the IL Statewide LED Lighting Logger study conducted as part of the PY8/PY9 evaluations of the Ameren Illinois and ComEd Residential Lighting programs, assuming 5% exterior lighting. The distribution of LEDs is based on the on-site lighting inventory conducted as part of the IL Statewide LED Lighting Logger study.
[917] See “Specialty LED EISA compliant O&M Calc_2018_Adj2024.xlsx” for calculation.

**Directional Lamps**

| Location | NPV of replacement costs for period | | | Levelized annual replacement cost savings | | |
|---|---|---|---|---|---|---|
| | 2019 | 2020 | 2021 | 2019 | 2020 | 2021 |
| Interior | $12.26 | $9.96 | $7.65 | $1.26 | $1.02 | $0.78 |
| Exterior | $40.76 | $33.31 | $20.65 | $6.84 | $5.59 | $3.46 |
| Unknown | $13.64 | $11.08 | $8.52 | $1.40 | $1.14 | $0.87 |

It is important to note that for cost-effectiveness screening purposes, the O&M cost adjustments should only be applied in cases where the light bulbs area actually in service and so should be multiplied by the appropriate ISR.

**MEASURE CODE: RS-LTG-LEDD-V09-190101**

**REVIEW DEADLINE: 1/1/2020**

## 5.5.7 LED Exit Signs

### Description

This measure characterizes the savings associated with installing a Light Emitting Diode (LED) exit sign in place of a fluorescent or incandescent exit sign in a MultiFamily building within unit (use 4.5.5 Commercial Exit Signs for multifamily common area exit signs). Light Emitting Diode exit signs have a string of very small, typically red or green, glowing LEDs arranged in a circle or oval. The LEDs may also be arranged in a line on the side, top or bottom of the exit sign. LED exit signs provide the best balance of safety, low maintenance, and very low energy usage compared to other exit sign technologies.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

The efficient equipment is assumed to be an exit sign illuminated by LEDs.

### Definition of Baseline Equipment

The baseline equipment is assumed to be an existing fluorescent or incandescent model.

### Deemed Lifetime of Efficient Equipment

The measure life is assumed to be 5 years[918].

### Deemed Measure Cost

The actual material and labor costs should be used if available. If actual costs are unavailable, assume a total installed cost of at $32.50.[919]

### Loadshape

Loadshape C53 - Flat

### Coincidence Factor

The summer peak coincidence factor for this measure is assumed to be 100%[920].

**Algorithm**

### Calculation of Savings

### Electric Energy Savings

$$\Delta kWh = ((WattsBase - WattsEE) / 1000) * HOURS * WHF_e$$

Where:

WattsBase = Actual wattage if known, if unknown assume the following:

[918] Estimate of remaining life of existing unit being replaced.

[919] Price includes new exit sign/fixture and installation. LED exit cost/unit is $22.50 from the NYSERDA Deemed Savings Database and assuming I labor cost of 15 minutes @ $40/hr.

[920] Assuming continuous operation of an LED exit sign, the Summer Peak Coincidence Factor is assumed to equal 1.0.

| Baseline Type | $Watts_{Base}$ |
|---|---|
| Incandescent | 35W[921] |
| CFL (dual sided) | 14W[922] |
| CFL (single sided) | 7W |
| Unknown | 7W |

WattsEE = Actual wattage if known, if singled sided or unknown assume 2W, if dual sided assume 4W.[923]

HOURS = Annual operating hours

= 8766

$WHF_e$ = Waste heat factor for energy; accounts for cooling savings from efficient lighting.

= 1.04[924]

Default if replacing incandescent fixture

ΔkWh = (35 – 2)/1000 * 8766 * 1.04

= 301 kWh

Default if replacing dual sided fluorescent fixture

ΔkWh = (14 – 4)/1000 * 8766 * 1.04

= 91 kWh

Default if replacing single sided fluorescent (or unknown) fixture

ΔkWh = (7 – 2)/1000 * 8766 * 1.04

= 46 kWh

**HEATING PENALTY**

If electric heated home (if heating fuel is unknown assume gas, see Natural Gas section):

ΔkWh[925] = - (((WattsBase - WattsEE) / 1000) * Hours * HF) / ηHeat

Where:

HF = Heating Factor or percentage of light savings that must be heated

= 49%[926]

---

921 Based on review of available product.

922 Average CFL single sided (5W, 7W, 9W) from Appendix B 2013-14 Table of Standard Fixture Wattages.

923 Average LED single sided (2W) from Appendix B 2013-14 Table of Standard Fixture Wattages.

924 The value is estimated at 1.04 (calculated as 1 + (0.45*(0.27 / 2.8)). Based on cooling loads decreasing by 27% of the lighting savings (average result from REMRate modeling of several different configurations and IL locations of homes), assuming typical cooling system operating efficiency of 3.1 COP (starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm (-0.02 * SEER2) + (1.12 * SEER) (from Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), converted to COP = EER/3.412 = 2.8COP) and estimate of 45% of multi family buildings in Illinois having central cooling (based on data from "Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009" which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average)

925 Negative value because this is an increase in heating consumption due to the efficient lighting.

926 This means that heating loads increase by 49% of the lighting savings. This is based on the average result from REMRate modeling of several different configurations and IL locations of homes.

ηHeat = Efficiency in COP of Heating equipment

= Actual. If not available use: [927]:

| System Type | Age of Equipment | HSPF Estimate | $COP_{HEAT}$ (COP Estimate) = (HSPF/3.413)*0.85 |
|---|---|---|---|
| Heat Pump | Before 2006 | 6.8 | 1.7 |
| | After 2006 - 2014 | 7.7 | 1.92 |
| | 2015 on | 8.2 | 2.04 |
| Resistance | N/A | N/A | 1.00 |
| Unknown[928] | N/A | N/A | 1.28 |

For example, a 2.0 COP (including duct loss) Heat Pump heated building:

If incandescent fixture: ΔkWh = -((35 – 2)/1000 * 8766 * 0.49) / 2

= -71 kWh

If unknown fixture ΔkWh = -((7 – 2)/1000 * 8766 * 0.49) / 2

= -10.7 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$$\Delta kW = ((WattsBase - WattsEE) / 1000) * WHF_d * CF$$

Where:

$WHF_d$ = Waste heat factor for demand to account for cooling savings from efficient lighting. The cooling savings are only added to the summer peak savings.

=1.07[929]

CF = Summer Peak Coincidence Factor for measure

= 1.0

Default if incandescent fixture

ΔkW = (35 – 2)/1000 * 1.07 * 1.0

= 0.035 kW

Default if dual sided fluorescent fixture

ΔkW = (14 – 4)/1000 * 1.07 * 1.0

= 0.0107 kW

[927] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate. Note efficiency should include duct losses. Defaults provided assume 15% duct loss for heat pumps.

[928] Calculation assumes 35% Heat Pump and 65% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see “HC6.9 Space Heating in Midwest Region.xls”, using average for East North Central Region. Average efficiency of heat pump is based on assumption that 50% are units from before 2006 and 50% from 2006-2014. Program or evaluation data should be used to improve this assumption if available.

[929] The value is estimated at 1.11 (calculated as 1 + (0.45 * 0.466 / 2.8)). See footnote relating to WHFe for details. Note the 46.6% factor represents the average Residential cooling coincidence factor calculated by dividing average load during the peak hours divided by the maximum cooling load.

Default if single sided fluorescent fixture

ΔkW = (7 – 2)/1000 * 1.07 * 1.0

= 0.0054 kW

**NATURAL GAS SAVINGS**

Heating penalty if Natural Gas heated building, or if heating fuel is unknown.

ΔTherms = - (((WattsBase - WattsEE) / 1000) * Hours * HF * 0.03412) / ηHeat

Where:

HF = Heating factor, or percentage of lighting savings that must be replaced by heating system.

= 49% [930]

0.03412 = Converts kWh to Therms

ηHeat = Average heating system efficiency.

= 0.70 [931]

Other factors as defined above

Default if incandescent fixture

ΔTherms = - (((35 - 2) / 1000) * 8766 * 0.49* 0.03412) / 0.70

= -6.9 therms

Default if dual sided fluorescent fixture

ΔTherms = - (((14 - 4) / 1000) * 8766 * 0.49* 0.03412) / 0.70

= -2.1 therms

Default if single sided fluorescent fixture

ΔTherms = - (((7 - 2) / 1000) * 8766 * 0.49* 0.03412) / 0.70

= -1.05 therms

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

The annual O&M Cost Adjustment savings should be calculated using the following component costs and lifetimes.

| | Baseline Measures | |
|---|---|---|
| Component | Cost | Life (yrs) |

[930] Average result from REMRate modeling of several different configurations and IL locations of homes
[931] This has been estimated assuming that natural gas central furnace heating is typical for Illinois residences (66% of Illinois homes have a Natural Gas Furnace (based on Energy Information Administration, 2009 Residential Energy Consumption Survey) In 2000, 24% of furnaces purchased in Illinois were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 10 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows:
(0.24*0.92) + (0.76*0.8) * (1-0.15) = 0.70

| | Baseline Measures | |
|---|---|---|
| Lamp | \$12.45[932] | 1.37 years[933] |

**MEASURE CODE: RS-LTG-LEDE-V03-190101**

**REVIEW DEADLINE: 1/1/2024**

[932] Consistent with assumption for a Standard CFL bulb (\$2.45) with an estimated labor cost of \$10 (assuming \$40/hour and a task time of 15 minutes).
[933] Assumes a lamp life of 12,000 hours and 8766 run hours 12000/8766 = 1.37 years.

## 5.5.8 LED Screw Based Omnidirectional Bulbs

### Description

This characterization provides savings assumptions for LED Screw Based Omnidirectional (e.g. A-Type lamps) lamps within the residential and multifamily sectors. This characterization assumes that the LED lamp is installed in a residential location. Where the implementation strategy does not allow for the installation location to be known (e.g. an upstream retail program) a deemed split of 97% Residential and 3% Commercial assumptions should be used[934].

This measure was developed to be applicable to the following program types: TOS, NC, EREP, KITS.

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

In order for this characterization to apply, new lamps must be ENERGY STAR labeled. Note a new ENERGY STAR specification v2.1 became effective on 1/2/2017.

### Definition of Baseline Equipment

In 2012, Federal legislation stemming from the Energy Independence and Security Act of 2007 (EISA) will require all general-purpose light bulbs between 40 watts and 100 watts to have ~30% increased efficiency, essentially phasing out standard incandescent technology. In 2012, the 100 w lamp standards apply; in 2013 the 75 w lamp standards will apply, followed by restrictions on the 60 w and 40 w lamps in 2014. Since measures installed under this TRM all occur after 2014, baseline equipment are the values after EISA. These are shown in the baseline table below.

Additionally, an EISA backstop provision requires replacement baseline lamps to meet an efficacy requirement of 45 lumens/watt or higher beginning on 1/1/2020. Due to expected delay in clearing retail inventory and to account for the operating life of a halogen or incandescent lamp potentially spanning past 1/1/2020, this shift under the EISA backstop provision is assumed to not to occur until 1/1/2021.

The baseline for the early replacement measure is the existing bulb being replaced.

### Deemed Lifetime of Efficient Equipment

The deemed measure life is 6.1 years[935] for exterior application. For all other applications, lifetimes are capped at 10 years[936].

For early replacement measures, if replacing a halogen or incandescent bulb, the remaining life is assumed to be 333 hours. For CFL's, the remaining life is 3,333 hours[937].

### Deemed Measure Cost

The price of LED lamps is falling quickly. Where possible, the actual LED lamp cost should be used and compared to the baseline cost provided below. If the incremental cost is unknown, assume the following[938]:

---

[934] RES v C&I split is based on a weighted (by sales volume) average of ComEd PY7, PY8 and PY9 and Ameren PY8 in store intercept survey results. See 'RESvCI Split_2018.xlsx'.

[935] ENERGY STAR v2.1 requires omnidirectional LED bulbs to be rated for at least 15,000 hours. 15000/2475 (exterior hours of use) = 6.1 years.

[936] Based on recommendation in the Dunsky Energy Consulting, Livingston Energy Innovations and Opinion Dynamics Corporation; NEEP Emerging Technology Research Report, p 6-18.

[937] Representing a third of the expected lamp lifetime.

[938] Baseline and LED lamp costs are based on field data collected by CLEAResult and provided by ComEd. See ComEd Pricing Projections 06302016.xlsx for analysis.

| Year | EISA Compliant Halogen | LED A-Lamp | Incremental Cost |
|---|---|---|---|
| 2019 | $1.25 | $3.11 | $1.86 |
| 2020 and on | | $2.70 | $1.45 |

**LOADSHAPE**

Loadshape R06 – Residential Indoor Lighting

Loadshape R07 – Residential Outdoor Lighting

**COINCIDENCE FACTOR**

The summer peak coincidence factor is assumed to be 0.128 for Residential and in-unit Multi Family bulbs[939], 0.273 for exterior bulbs[940] and 0.135 for unknown[941].

Use Multifamily if: Building meets utility's definition for multifamily

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

$$\Delta kWh = ((Watts_{base} - Watts_{EE})/1000) * ISR * (1-Leakage) * Hours * WH_e$$

Where:

$Watts_{base}$ = Input wattage of the existing or baseline system. Reference the "LED New and Baseline Assumptions" table for default values.

$Watts_{EE}$ = Actual wattage of LED purchased / installed. If unknown, use default provided below:[942]

**LED New and Baseline Assumptions Table**

| Minimum Lumens | Maximum Lumens | Lumens used to calculate LED Wattage (midpoint) | LED Wattage[943] (WattsEE) | Baseline 2014-2020 (WattsBase) | Delta Watts 2014-2020 (WattsEE) | Baseline From 1/1/2021[944] (WattsBase) | Delta Watts From 1/1/2021 (WattsEE) |
|---|---|---|---|---|---|---|---|
| 5280 | 6209 | 5745 | 72.9 | 300.0 | 227.1 | 300.0 | 227.1 |
| 3301 | 5279 | 4290 | 54.5 | 200.0 | 145.5 | 200.0 | 145.5 |
| 2601 | 3300 | 2951 | 37.5 | 150.0 | 112.5 | 65.5 | 28.1 |
| 1490 | 2600 | 2045 | 26.0 | 72.0 | 46.0 | 45.4 | 19.5 |

[939] Based on the IL Statewide LED Lighting Logger study conducted as part of the PY8/PY9 evaluations of the Ameren Illinois and ComEd Residential Lighting programs.

[940] Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation. the IL Statewide LED Lighting Logger study conducted as part of the PY8/PY9 evaluations of the Ameren Illinois and ComEd Residential Lighting programs was unable to provide coincidence factors for screw-based omnidirectional LEDs in exterior applications.

[941] Based on a weighted average of coincidence factors in interior and exterior applications, assuming 5% exterior lighting. The distribution of LEDs is based on the on-site lighting inventory conducted as part of the IL Statewide LED Lighting Logger study.

[942] See file "LED baseline and EE wattage table_2018.xlsx" for details on lamp wattage calculations.

[943] Based on ENERGY STAR V2.1 specs – for omnidirectional <90CRI: 80 lm/W and for omnidirectional >=90 CRI: 70 lm/W. To weight these two criteria, the ENERGY STAR qualified list was reviewed and found to contain 87.8% lamps <90CRI and 12.2% >=90CRI.

[944] Calculated as 45lm/W for all EISA non-exempt bulbs.

| Minimum Lumens | Maximum Lumens | Lumens used to calculate LED Wattage (midpoint) | LED Wattage [943] (WattsEE) | Baseline 2014-2020 (WattsBase) | Delta Watts 2014-2020 (WattsEE) | Baseline From 1/1/2021[944] (WattsBase) | Delta Watts From 1/1/2021 (WattsEE) |
|---|---|---|---|---|---|---|---|
| 1050 | 1489 | 1270 | 16.1 | 53.0 | 36.9 | 28.2 | 12.1 |
| 750 | 1049 | 900 | 11.4 | 43.0 | 31.6 | 20.0 | 8.6 |
| 310 | 749 | 530 | 6.7 | 29.0 | 22.3 | 11.8 | 5.0 |
| 250 | 309 | 280 | 3.5 | 25.0 | 21.5 | 25.0 | 21.5 |

ISR = In Service Rate, the percentage of lamps rebated that are actually in service.

| Program | | Weighted Average 1st year In Service Rate (ISR) | 2nd year Installations | 3rd year Installations | Final Lifetime In Service Rate |
|---|---|---|---|---|---|
| Retail (Time of Sale) | | 78.4%[945] | 10.6% | 9.0% | 98.0%[946] |
| Direct Install | | 96.9%[947] | | | |
| Efficiency Kits[948] | LED Distribution[949] | 59% | 13% | 11% | 83% |
| | School Kits[950] | 60% | 13% | 11% | 84% |
| | Direct Mail Kits[951] | 66% | 14% | 12% | 93% |

Leakage = Adjustment to account for the percentage of program bulbs that move out (and in if deemed appropriate[952]) of the Utility Jurisdiction.

KITS programs = Determined through evaluation

Upstream (TOS) Lighting programs = Use deemed assumptions below[953]:

---

945 1st year in service rate is based upon analysis of ComEd PY7, PY8, and PY9 and Ameren PY8 intercept data (see 'RES Lighting ISR_2018.xlsx' for more information).

946 The 98% Lifetime ISR assumption is based upon the standard CFL measure in the absence of any better reference. This value is based upon review of two evaluations:
'Nexus Market Research, RLW Analytics and GDS Associates study; "New England Residential Lighting Markdown Impact Evaluation, January 20, 2009' and 'KEMA Inc, Feb 2010, Final Evaluation Report:, Upstream Lighting Program, Volume 1.' This implies that only 2% of bulbs purchased are never installed. The second and third year installations are based upon Ameren analysis of the Californian KEMA study showing that 54% of future installs occur in year 2 and 46% in year 3. The 2nd and 3rd year installations should be counted as part of those future program year savings.

947 Based upon Standard CFL assumption in the absence of better data, and is based upon review of the PY2 and PY3 ComEd Direct Install program surveys. This value includes bulb failures in the 1st year to be consistent with the Commission approval of annualization of savings for first year savings claims. ComEd PY2 All Electric Single Family Home Energy Performance Tune-Up Program Evaluation, Navigant Consulting, December 21, 2010.

948 In Service Rates provided are for the bulb within a kit only. Given the significant differences in program design and the level of education provided through Efficiency Kits programs, the evaluators should apply the ISR estimated through evaluations (either past evaluations or the current program year evaluation) of the specific Efficiency Kits program. In cases where program-specific evaluation results for an ISR are unavailable, the default ISR values for Efficiency Kits provide may be used.

949 Free bulbs provided without request, with little or no education. Consistent with Standard CFL assumptions.

950 1st year ISR for school kits based on ComEd PY9 data for the Elementary Energy Education program.

951 Opt-in program to receive kits via mail, with little or no education. Consistent with Standard CFL assumptions.

952 Leakage in is only appropriate to credit to IL utility program savings if it is reasonably expected that the IL utility program marketing efforts played an important role in influencing customer to purchase the light bulbs. Furthermore, consideration that such customers might be free riders should be addressed. If leakage in is assessed, efforts should be made to ensure no double counting of savings occurs if the evaluation is estimating both leakage in and spillover savings of light bulbs.

953 Leakage rate is based upon review of PY7-9 evaluations from ComEd and PY8 for Ameren (see for more information).

ComEd: 0.7%

Ameren: 13.1%

All other programs = 0

Hours = Average hours of use per year

| Installation Location | Hours |
|---|---|
| Residential and in-unit Multi Family | 1,089[954] |
| Exterior | 2,475[955] |
| Unknown | 1,159[956] |

WHFe = Waste heat factor for energy to account for cooling energy savings from efficient lighting

| Bulb Location | WHFe |
|---|---|
| Interior single family | 1.06 [957] |
| Multifamily in unit | 1.04 [958] |
| Exterior or uncooled location | 1.0 |
| Unknown location | 1.051[959] |

**Mid Life Baseline Adjustment**

For non-exempt lamps, an appropriate baseline adjustment should be included to account for the 2020 EISA backstop provision making replacement baseline lamps meet 45 lumens/watt. Due to expected delay in clearing retail inventory and to account for the operating life of a halogen incandescent potentially spanning over 2020, this shift is assumed not to occur until 2021.

For example, for 60W equivalent bulbs installed in 2018, the full savings (as calculated above in the Algorithm) should be claimed for the first three years, but a reduced annual savings (calculated energy savings above multiplied by the adjustment factor in the table below) claimed for the remainder of the measure life.

Note for early replacement measures an additional baseline shift accounting for the replacement of the existing unit with a new baseline lamp should be accounted for.

---

954 Based on the IL Statewide LED Lighting Logger study conducted as part of the PY8/PY9 evaluations of the Ameren Illinois and ComEd Residential Lighting programs.

955 Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation. The IL Statewide LED Lighting Logger study conducted as part of the PY8/PY9 evaluations of the Ameren Illinois and ComEd Residential Lighting programs was unable to provide hours of use for screw-based omnidirectional LEDs in exterior applications.

956 Based on a weighted average of hours of use in interior and exterior applications, assuming 5% exterior lighting. The distribution of LEDs is based on the on-site lighting inventory conducted as part of the IL Statewide LED Lighting Logger study.

957 The value is estimated at 1.06 (calculated as 1 + (0.66*(0.27 / 2.8)). Based on cooling loads decreasing by 27% of the lighting savings (average result from REMRate modeling of several different configurations and IL locations of homes), assuming typical cooling system operating efficiency of 2.8 COP (starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm (-0.02 * SEER2) + (1.12 * SEER) (from Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), converted to COP = EER/3.412 = 2.8COP) and 66% of homes in Illinois having central cooling ("Table HC7.9 Air Conditioning in Homes in Midwest Region, Divisions, and States, 2009 from Energy Information Administration", 2009 Residential Energy Consumption Survey)

958 As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from “Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009” which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average)

959 Unknown is weighted average of interior v exterior (assuming 5% exterior lighting based on distribution of LEDs from on-site lighting inventory conducted as part of the IL Statewide LED Lighting Logger study) and SF v MF interior based on statewide weighted average of 69% single family and 31% multifamily, based on IL data from 2009 RECS Table HC2.9 Structural and Geographic Characteristics of Homes in Midwest Region, Divisions and States, 2009.

| Minimum Lumens | Maximum Lumens | LED Wattage (WattsEE) | Delta Watts 2014-2019 (WattsEE) | Delta Watts From 1/1/2021 (WattsEE) | Mid Life adjustment (made from 01/2021) to first year savings |
|---|---|---|---|---|---|
| 2601 | 3300 | 37.5 | 112.5 | 28.1 | 25.0% |
| 1490 | 2600 | 26.0 | 46.0 | 19.5 | 42.3% |
| 1050 | 1489 | 16.1 | 36.9 | 12.1 | 32.8% |
| 750 | 1049 | 11.4 | 31.6 | 8.6 | 27.1% |
| 310 | 749 | 6.7 | 22.3 | 5.0 | 22.6% |

For example, an 8W LED lamp, 450 lumens, is installed in the interior of a home. The customer purchased the lamp through a ComEd upstream program:

$$\Delta kWh = ((29.0 - 6.7)/1000) * 0.784 * (1 - 0.007) * 1{,}089 * 1.06$$
$$= 20.0 \text{ kWh}$$

This value should be claimed for two years, i.e. 2019-2020, but from 2021 until the end of the measure life for that same bulb, savings should be reduced to (20.0 * 0.226 =) 4.5 kWh for the remainder of the measure life. Note these adjustments should be applied to kW and fuel impacts as well.

**DEFERRED INSTALLS**

As presented above, the characterization assumes that a percentage of bulbs purchased are not installed until Year 2 and Year 3 (see ISR assumption above). The Illinois Technical Advisory Committee has determined the following methodology for calculating the savings of these future installs.

Year 2 and 3 installs: Characterized using delta watts assumption and hours of use from the Install Year i.e. the actual deemed assumptions active in Year 2 and 3 should be applied.

The NTG factor for the Purchase Year should be applied.

Using the example from above, for an 8W LED, 450 Lumens purchased for the interior of a residential homes through a ComEd upstream program.

$$\Delta kWh_{2nd\ year\ installs} = ((29 - 6.7)/1000) * 0.106 * (1 – 0.007) * 1{,}089 * 1.06$$
$$= 2.7 \text{ kWh}$$
$$\Delta kWh_{3rd\ year\ installs} = ((29 - 6.7)/1000) * 0.09 * (1 – 0.007) * 1{,}089 * 1.06$$
$$= 2.3 \text{ kWh}$$

Note: Here we assume no change in hours assumption. NTG value from Purchase year should be applied.

**HEATING PENALTY**

If electric heated home (if heating fuel is unknown assume gas, see Natural Gas section):

$$\Delta kWh^{960} = - (((WattsBase - WattsEE) / 1000) * ISR * (1-Leakage) * Hours * HF) / \eta Heat$$

Where:

HF = Heating Factor or percentage of light savings that must be heated

[960] Negative value because this is an increase in heating consumption due to the efficient lighting.

= 49%[961] for interior

= 0% for exterior or unheated location

= 42%[962] for unknown location

ηHeat = Efficiency in COP of Heating equipment

= actual. If not available use[963]:

| System Type | Age of Equipment | HSPF Estimate | $COP_{HEAT}$ (COP Estimate) = (HSPF/3.413)*0.85 |
|---|---|---|---|
| Heat Pump | Before 2006 | 6.8 | 1.7 |
| | After 2006 - 2014 | 7.7 | 1.92 |
| | 2015 on | 8.2 | 2.04 |
| Resistance | N/A | N/A | 1.00 |
| Unknown[964] | N/A | N/A | 1.28 |

Using the same 8 W LED that is installed in home with 2.0 COP Heat Pump (including duct loss) through a ComEd upstream program:

$\Delta kWh_{1st\ year}$ = - (((29 - 6.7) / 1000) * 0.784 * (1-0.007) * 1,089 * 0.42) / 2.0

= - 4.0 kWh

Second and third year install savings should be calculated using the appropriate ISR and the delta watts and hours from the install year. The appropriate baseline shift adjustment should then be applied to all installs.

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

ΔkW = ((WattsBase - WattsEE) / 1000) * ISR * (1-Leakage) * WHFd * CF

Where:

WHFd = Waste heat factor for demand to account for cooling savings from efficient lighting.

| Bulb Location | WHFd |
|---|---|
| Interior single family | 1.11[965] |
| Multifamily in unit | 1.07[966] |

[961] This means that heating loads increase by 49% of the lighting savings. This is based on the average result from REMRate modeling of several different configurations and IL locations of homes.

[962] Based on a weighted average of interior and exterior hours of use from the IL Statewide LED Lighting Logger study conducted as part of the PY8/PY9 evaluations of the Ameren Illinois and ComEd Residential Lighting programs, assuming 15% exterior specialty lighting. The distribution of LEDs is based on the on-site lighting inventory conducted as part of the IL Statewide LED Lighting Logger study.

[963] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate. Note efficiency should include duct losses. Defaults provided assume 15% duct loss for heat pumps.

[964] Calculation assumes 35% Heat Pump and 65% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see “HC6.9 Space Heating in Midwest Region.xls”, using average for East North Central Region. Average efficiency of heat pump is based on assumption that 50% are units from before 2006 and 50% from 2006-2014. Program or evaluation data should be used to improve this assumption if available.

[965] The value is estimated at 1.11 (calculated as 1 + (0.66 * 0.466 / 2.8)). See footnote relating to WHFe for details. Note the 46.6% factor represents the average Residential cooling coincidence factor calculated by dividing average load during the peak hours divided by the maximum cooling load.

[966] As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from “Table

| Bulb Location | WHFd |
|---|---|
| Exterior or uncooled location | 1.0 |
| Unknown location | 1.093[967] |

CF = Summer Peak Coincidence Factor for measure.

| Bulb Location | CF |
|---|---|
| Interior | 0.128[968] |
| Exterior | 0.273[969] |
| Unknown | 0.135[970] |

Other factors as defined above

For the same 8 W LED that is installed in a single family interior location through a ComEd upstream program:

ΔkW = ((29 - 6.7) / 1000) * 0.784 * (1-0.007) * 1.11 * 0.128

= 0.0025 kW

Second and third year install savings should be calculated using the appropriate ISR and the delta watts and hours from the install year. The appropriate baseline shift adjustment should then be applied to all installs.

**NATURAL GAS SAVINGS**

Heating penalty if Natural Gas heated home, or if heating fuel is unknown.

ΔTherms = - (((WattsBase - WattsEE) / 1000) * ISR * (1-Leakage) * Hours * HF * 0.03412) / ηHeat

Where:

HF = Heating factor, or percentage of lighting savings that must be replaced by heating system.

= 49% [971] for interior

= 0% for exterior location

= 42%[972] for unknown location

HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009" which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average)

[967] Unknown is weighted average of interior v exterior (assuming 5% exterior lighting based on distribution of LEDs from on-site lighting inventory conducted as part of the IL Statewide LED Lighting Logger study) and SF v MF interior based on statewide weighted average of 69% single family and 31% multifamily, based on IL data from 2009 RECS Table HC2.9 Structural and Geographic Characteristics of Homes in Midwest Region, Divisions and States, 2009.

[968] Based on the IL Statewide LED Lighting Logger study conducted as part of the PY8/PY9 evaluations of the Ameren Illinois and ComEd Residential Lighting programs.

[969] Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation. the IL Statewide LED Lighting Logger study conducted as part of the PY8/PY9 evaluations of the Ameren Illinois and ComEd Residential Lighting programs was unable to provide coincidence factors for screw-based omnidirectional LEDs in exterior applications.

[970] Based on a weighted average of coincidence factors in interior and exterior applications, assuming 5% exterior lighting. The distribution of LEDs is based on the on-site lighting inventory conducted as part of the IL Statewide LED Lighting Logger study.

[971] Average result from REMRate modeling of several different configurations and IL locations of homes

[972] Based on a weighted average of interior and exterior hours of use from the IL Statewide LED Lighting Logger study conducted as part of the PY8/PY9 evaluations of the Ameren Illinois and ComEd Residential Lighting programs, assuming 15% exterior specialty lighting. The distribution of LEDs is based on the on-site lighting inventory conducted as part of the IL Statewide LED Lighting Logger study.

0.03412 = Converts kWh to Therms

ηHeat = Average heating system efficiency.

= 0.70 [973]

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

Bulb replacement costs assumed in the O&M calculations are provided below[974].

In order to account for the shift in baseline due to the Energy Independence and Security Act of 2007, an equivalent annual levelized baseline replacement cost over the lifetime of the LED bulb is calculated. The key assumptions used in this calculation are documented below:

| Installation Location | Omnidirectional LED Measure Hours | Hours of Use per year | Measure Life in Years (capped at 10) |
|---|---|---|---|
| Residential and in-unit Multi Family | 15,000 | 1,089[975] | 10 |
| Exterior | 15,000 | 2,475[976] | 6.1 |
| Unknown | 15,000 | 1,159[977] | 10 |

The NPV for replacement lamps and annual levelized replacement costs using the societal real discount rate of 0.46% are presented below[978]. It is important to note that for cost-effectiveness screening purposes, the O&M cost adjustments should only be applied in cases where the light bulbs area actually in service and so should be multiplied by the appropriate ISR:

| Location | Lumen Level | NPV of replacement costs for period | | | Levelized annual replacement cost savings | | |
|---|---|---|---|---|---|---|---|
| | | 2019 | 2020 | 2021 | 2019 | 2020 | 2021 |
| Residential and in-unit Multi Family | Lumens <310 or >3300 (non-EISA compliant) | $4.10 | $4.10 | $4.10 | $0.42 | $0.42 | $0.42 |
| | Lumens ≥ 310 and ≤ 3300 (EISA compliant) | $3.42 | $2.34 | $2.34 | $0.35 | $0.24 | $0.24 |

[973] This has been estimated assuming that natural gas central furnace heating is typical for Illinois residences (66% of Illinois homes have a Natural Gas Furnace (based on Energy Information Administration, 2009 Residential Energy Consumption Survey) In 2000, 24% of furnaces purchased in Illinois were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 10 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows:

(0.24*0.92) + (0.76*0.8) * (1-0.15) = 0.70

[974] Baseline and LED lamp costs are based on field data collected by CLEAResult and provided by ComEd. See ComEd Pricing Projections 06302016.xlsx for analysis.

[975] Based on the IL Statewide LED Lighting Logger study conducted as part of the PY8/PY9 evaluations of the Ameren Illinois and ComEd Residential Lighting programs.

[976] Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation. The IL Statewide LED Lighting Logger study conducted as part of the PY8/PY9 evaluations of the Ameren Illinois and ComEd Residential Lighting programs was unable to provide hours of use for screw-based omnidirectional LEDs in exterior applications.

[977] Based on a weighted average of hours of use in interior and exterior applications, assuming 5% exterior lighting. The distribution of LEDs is based on the on-site lighting inventory conducted as part of the IL Statewide LED Lighting Logger study.

[978] See “LED TRM Examples_2018.xlsx” for calculation.

| Location | Lumen Level | NPV of replacement costs for period | | | Levelized annual replacement cost savings | | |
|---|---|---|---|---|---|---|---|
| | | 2019 | 2020 | 2021 | 2019 | 2020 | 2021 |
| Exterior | Lumens <310 or >3300 (non-EISA compliant) | $5.96 | $5.96 | $5.96 | $1.00 | $1.00 | $1.00 |
| | Lumens ≥ 310 and ≤ 3300 (EISA compliant) | $7.34 | $4.87 | $3.64 | $1.23 | $0.82 | $0.61 |
| Unknown | Lumens <310 or >3300 (non-EISA compliant) | $4.36 | $4.36 | $4.36 | $0.45 | $0.45 | $0.45 |
| | Lumens ≥ 310 and ≤ 3300 (EISA compliant) | $3.64 | $2.49 | $2.49 | $0.37 | $0.25 | $0.25 |

Note incandescent lamps in lumen range <310 and >3300 are exempt from EISA. For halogen bulbs, we assume the same replacement cycle as incandescent bulbs.[979] The replacement cycle is based on the location of the lamp and varies based on the hours of use for that location. Both incandescent and halogen lamps are assumed to last for 1,000 hours before needing replacement.

**MEASURE CODE: RS-LTG-LEDA-V07-190101**

**REVIEW DEADLINE: 1/1/2020**

[979] The manufacturers of the new minimally compliant EISA Halogens are using regular incandescent lamps with halogen fill gas rather than halogen infrared to meet the standard and so the component rated life is equal to the standard incandescent.

## 5.5.9 LED Fixtures

### DESCRIPTION

This characterization provides savings assumptions for LED Fixtures and is broken into four ENERGY STAR fixture types: Indoor Fixtures (including track lighting, wall-wash, sconces, ceiling and fan lights), Task and Under Cabinet Fixtures, Outdoor Fixtures (including flood light, hanging lights, security/path lights, outdoor porch lights), and Downlight Fixtures.

For upstream programs, utilities should develop an assumption of the residential v commercial split and apply the relevant assumptions to each portion. A default deemed split of 97% Residential and 3% Commercial assumptions can be used based on Omnidirectional Bulbs[980].

This measure was developed to be applicable to the following program types: TOS, NC.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, new fixtures must be ENERGY STAR labeled based upon the v2.1 ENERGY STAR specification for luminaires. Specifications are as follows:

| Fixture Category | Lumens/Watt |
|---|---|
| Indoor | 65 |
| Task and Under Cabinet | 50 |
| Outdoor | 60 |
| Downlight | 55 |

### DEFINITION OF BASELINE EQUIPMENT

The baseline condition for this measure is assumed to be an average of EISA-equivalent wattages for ENERGY STAR-qualified products. An EISA backstop provision requires replacement baseline lamps to meet an efficacy requirement of 45 lumens/watt or higher beginning on 1/1/2020. Due to expected delay in clearing retail inventory and to account for the operating life of a halogen or incandescent lamp potentially spanning past 1/1/2020, this shift under the EISA backstop provision is assumed to not to occur until 1/1/2021.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The lifetime of a fixture is a function of its rated life and average hours of use. The rated life is 47,000 hours for indoor and downlight, 45,000 for task and cabinet, and 49,000 for outdoor fixtures[981]. This would imply a lifetime of 51 years for indoor and downlight, 62 years for task and under cabinet, and 20 years for outdoor fixtures. However, all fixture lifetimes are capped at 15 years[982] so a 15 year measure life should be assumed.

### DEEMED MEASURE COST

Wherever possible, actual incremental costs should be used. If unavailable, assume the following incremental costs:

[980] RES v C&I split is based on a weighted (by sales volume) average of ComEd PY7, PY8 and PY9 and Ameren PY8 in store intercept survey results. See 'RESvCI Split_2018.xlsx'.
[981] Average rated lives are based on the average rated lives of fixtures available on the ENERGY STAR qualifying list as of 2/26/2018.
[982] Based on recommendation in the Dunsky Energy Consulting, Livingston Energy Innovations and Opinion Dynamics Corporation; NEEP Emerging Technology Research Report, p 6-18.

| Fixture Category | Incremental Cost |
|---|---|
| Indoor | $26[983] |
| Task /Under Cabinet | $18[984] |
| Outdoor | $26 |
| Downlight | $13 |

### LOADSHAPE

Loadshape R06 - Residential Indoor Lighting

Loadshape R07 - Residential Outdoor Lighting

### COINCIDENCE FACTOR

The summer peak coincidence factor is assumed to be 0.119 for residential and in-unit multifamily fixtures[985], 0.273 for exterior fixtures[986] and 0.127 for unknown[987].

## Algorithm

### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

$$\Delta kWh = ((Watts_{base} - Watts_{EE})/1000) * ISR * (1-Leakage) * Hours * WHF_e$$

Where:

$Watts_{Base}$ = Baseline is an average of lumen-equivalent EISA wattages for ENERGY STAR products within the fixture category;[988] see table below

$Watts_{EE}$ = Actual wattage of LED fixture purchased / installed - If unknown, use default provided below[989]

| Fixture Category | $Watts_{Base}$ | $Watts_{EE}$ |
|---|---|---|
| Indoor | 88.5 | 22.4 |
| Task /Under Cabinet | 45.2 | 11.6 |
| Outdoor | 79.6 | 18.3 |
| Downlight | 72.8 | 20.3 |

ISR = In Service Rate, the percentage of units rebated that are actually in service

[983] Incremental costs for indoor and outdoor fixtures based on ENERGY STAR Light Fixtures and Ceiling Fans Calculator, which cites "EPA research on available products, 2012." ENERGY STAR cost assumptions were reduced by 20% to account for falling LED prices.

[984] Incremental costs for task/under cabinet and downlight fixtures are from the 2018 Michigan Energy Measures Database.

[985] Based on the IL Statewide LED Lighting Logger study conducted as part of the PY8/PY9 evaluations of the Ameren Illinois and ComEd Residential Lighting programs. Average of values for standard and specialty bulbs.

[986] Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation. the IL Statewide LED Lighting Logger study conducted as part of the PY8/PY9 evaluations of the Ameren Illinois and ComEd Residential Lighting programs was unable to provide coincidence factors for screw-based omnidirectional LEDs in exterior applications.

[987]Based on a weighted average of coincidence factors in interior and exterior applications, assuming 5% exterior lighting. The distribution of LEDs is based on the on-site lighting inventory conducted as part of the IL Statewide LED Lighting Logger study.

[988] See "Analysis" tab within file Residential LED Fixtures_Analysis_June 2018.xlsx for baseline calculations.

[989] Average of ENERGY STAR product category watts for products at or above the version 2.1 efficacy specification

= 1.0[990]

Leakage = Adjustment to account for the percentage of program bulbs that move out (and in if deemed appropriate[991]) of the Utility Jurisdiction.

Upstream (TOS) Lighting programs = Use deemed assumptions below[992]:

ComEd: 0.7%

Ameren: 6.6%

All other programs = 0

Hours = Average hours of use per year

| Fixture Category | Hours |
|---|---|
| Indoor and Downlight | 926[993] |
| Task/Under Cabinet | 730[994] |
| Outdoor | 2,475[995] |

WHFe = Waste heat factor for energy to account for cooling energy savings from efficient lighting

| Bulb Location | WHFe |
|---|---|
| Interior single family | 1.06 [996] |
| Multifamily in unit | 1.04 [997] |
| Exterior or uncooled location | 1.0 |
| Unknown location | 1.051[998] |

[990] ISR recommendation for fixtures in the Dunsky Energy Consulting, Livingston Energy Innovations and Opinion Dynamics Corporation; NEEP Emerging Technology Research Report, p 6-22.

[991] Leakage in is only appropriate to credit to IL utility program savings if it is reasonably expected that the IL utility program marketing efforts played an important role in influencing customer to purchase the light bulbs. Furthermore, consideration that such customers might be free riders should be addressed. If leakage in is assessed, efforts should be made to ensure no double counting of savings occurs if the evaluation is estimating both leakage in and spillover savings of light bulbs.

[992] Leakage rate is based upon review of PY7-9 evaluations from ComEd and PY8 for Ameren (see for more information) for LED omnidirectional and specialty lamps. Leakage rates for fixtures are an average of rates for standard and specialty lamps, reduced by half according to TAC agreement.

[993] Assuming 365.25 days/year and average of recommended values for standard LED lamps (2.98) and specialty LED lamps (2.09) in interior locations from the IL Statewide LED Lighting Logger study conducted as part of the PY8/PY9 evaluations of the Ameren Illinois and ComEd Residential Lighting programs

[994] Task/under cabinet hours of use are estimated at 2 hours per day.

[995] Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation. The IL Statewide LED Lighting Logger study conducted as part of the PY8/PY9 evaluations of the Ameren Illinois and ComEd Residential Lighting programs was unable to provide hours of use for screw-based omnidirectional LEDs in exterior applications.

[996] The value is estimated at 1.06 (calculated as 1 + (0.66*(0.27 / 2.8)). Based on cooling loads decreasing by 27% of the lighting savings (average result from REMRate modeling of several different configurations and IL locations of homes), assuming typical cooling system operating efficiency of 2.8 COP (starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm (-0.02 * SEER2) + (1.12 * SEER) (from Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), converted to COP = EER/3.412 = 2.8COP) and 66% of homes in Illinois having central cooling ("Table HC7.9 Air Conditioning in Homes in Midwest Region, Divisions, and States, 2009 from Energy Information Administration", 2009 Residential Energy Consumption Survey)

[997] As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from "Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009" which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average)

[998] Unknown is weighted average of interior v exterior (assuming 5% exterior lighting based on distribution of LEDs from on-site lighting inventory conducted as part of the IL Statewide LED Lighting Logger study) and SF v MF interior based on statewide weighted average of 69% single family and 31% multifamily, based on IL data from 2009 RECS Table HC2.9 Structural and Geographic Characteristics of Homes in Midwest Region, Divisions and States, 2009.

**Mid-Life Baseline Adjustment**

During the lifetime of a standard omnidirectional LED, the baseline incandescent/halogen bulb would need to be replaced multiple times. Since the baseline bulb changes over time (except for <310 and 3300+ lumen lamps) the annual savings claim must be reduced within the life of the measure to account for this baseline shift.

For example, for an LED fixture installed in 2019, the full savings (as calculated above in the algorithm) should be claimed for the first two years, but a reduced annual savings (calculated energy savings above multiplied by the adjustment factor in the table below) claimed for the remainder of the measure life.

| Fixture Category | Lumens/Watt From 1/1/2021[999] | $Watts_{Base}$ From 1//1/2021[1000] | Mid Life adjustment (made from 01/1/2021) to first year savings |
|---|---|---|---|
| Indoor | 45 | 53.3 | 47% |
| Task /Under Cabinet | | 21.6 | 30% |
| Outdoor | | 46.2 | 46% |
| Downlight | | 42.6 | 43% |

For example, an indoor LED fixture is purchased through a ComEd retail program in 2019:

ΔkWh = ((88.5 – 22.4) /1000) * 1.0 * (1 – 0.007) * 926 * 1.06

= 64.4 kWh

This value should be claimed for two years, but from 2021 until the end of the measure life for that same fixture, savings should be reduced to (64.4 * 0.47) = 30.3 kWh for the remainder of the measure life. Note that these adjustments should be applied to kW and fuel impacts as well.

**HEATING PENALTY**

If electric heated home (if heating fuel is unknown assume gas, see Natural Gas section):

ΔkWh[1001] = - (((WattsBase - WattsEE) / 1000) * ISR * (1-Leakage) * Hours * HF) / ηHeat

Where:

HF = Heating Factor or percentage of light savings that must be heated

= 49%[1002] for interior location

= 0% for exterior or unheated location

= 42%[1003] for unknown location

ηHeat = Efficiency in COP of Heating equipment

= actual. If not available use[1004]:

[999] Lumens/watt as of 1/1/2021 is equal to the EISA minimum efficacy requirement for general service lamps in year 2020.

[1000] Baseline post 2020 watts are calculated using the 2020 lumens/watt value.

[1001] Negative value because this is an increase in heating consumption due to the efficient lighting.

[1002] This means that heating loads increase by 49% of the lighting savings. This is based on the average result from REMRate modeling of several different configurations and IL locations of homes.

[1003] Based on a weighted average of interior and exterior hours of use from the IL Statewide LED Lighting Logger study conducted as part of the PY8/PY9 evaluations of the Ameren Illinois and ComEd Residential Lighting programs, assuming 15% exterior specialty lighting. The distribution of LEDs is based on the on-site lighting inventory conducted as part of the IL Statewide LED Lighting Logger study.

[1004] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely

| System Type | Age of Equipment | HSPF Estimate | $COP_{HEAT}$ (COP Estimate) = (HSPF/3.413)*0.85 |
|---|---|---|---|
| Heat Pump | Before 2006 | 6.8 | 1.7 |
| | After 2006 - 2014 | 7.7 | 1.92 |
| | 2015 on | 8.2 | 2.04 |
| Resistance | N/A | N/A | 1.00 |
| Unknown[1005] | N/A | N/A | 1.28 |

Using the same indoor LED fixture that is installed in home with 2.0 COP Heat Pump (including duct loss) through a ComEd retail program in 2019:

$\Delta kWh_{1st\ year}$ = - (((88.5 – 22.4) / 1000) * 1.0 * (1 – 0.007) * 926 * 0.49) / 2.0

= - 14.9 kWh

Second and third year install savings should be calculated using the appropriate ISR and the delta watts and hours from the install year. The appropriate baseline shift adjustment should then be applied to all installs.

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = ((WattsBase - WattsEE) / 1 000) * ISR * (1-Leakage) * WHFd * CF

Where:

WHFd = Waste heat factor for demand to account for cooling savings from efficient lighting.

| Bulb Location | WHFd |
|---|---|
| Interior single family | 1.11[1006] |
| Multifamily in unit | 1.07[1007] |
| Exterior or uncooled location | 1.0 |
| Unknown location | 1.093[1008] |

CF = Summer Peak Coincidence Factor for measure.

| Bulb Location | CF |
|---|---|
| Interior | 0.119[1009] |

degradation of efficiencies over time mean that using the minimum standard is appropriate. Note efficiency should include duct losses. Defaults provided assume 15% duct loss for heat pumps.

[1005] Calculation assumes 35% Heat Pump and 65% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see "HC6.9 Space Heating in Midwest Region.xls", using average for East North Central Region. Average efficiency of heat pump is based on assumption that 50% are units from before 2006 and 50% from 2006-2014. Program or evaluation data should be used to improve this assumption if available.

[1006] The value is estimated at 1.11 (calculated as 1 + (0.66 * 0.466 / 2.8)). See footnote relating to WHFe for details. Note the 46.6% factor represents the average Residential cooling coincidence factor calculated by dividing average load during the peak hours divided by the maximum cooling load.

[1007] As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from "Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009" which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average)

[1008] Unknown is weighted average of interior v exterior (assuming 5% exterior lighting based on distribution of LEDs from on-site lighting inventory conducted as part of the IL Statewide LED Lighting Logger study) and SF v MF interior based on statewide weighted average of 69% single family and 31% multifamily, based on IL data from 2009 RECS Table HC2.9 Structural and Geographic Characteristics of Homes in Midwest Region, Divisions and States, 2009.

[1009] Based on the IL Statewide LED Lighting Logger study conducted as part of the PY8/PY9 evaluations of the Ameren Illinois and ComEd Residential Lighting programs. Average of values for standard and specialty bulbs.

| Bulb Location | CF |
|---|---|
| Exterior | 0.273[1010] |
| Unknown | 0.127[1011] |

Other factors as defined above

For the same indoor LED fixture that is installed in a single family interior location through a ComEd retail program in 2019, the demand savings are:

ΔkW = ((88.5 – 22.4) / 1000) * 1.0 * (1-0.007) * 1.11 * 0.119

= 0.0087 kW

Second and third year install savings should be calculated using the appropriate ISR and the delta watts and hours from the install year. The appropriate baseline shift adjustment should then be applied to all installs.

**NATURAL GAS SAVINGS**

Heating penalty if Natural Gas heated home, or if heating fuel is unknown.

ΔTherms = - (((WattsBase - WattsEE) / 1000) * ISR * (1-Leakage) * Hours * HF * 0.03412) / ηHeat

Where:

HF = Heating factor, or percentage of lighting savings that must be replaced by heating system.

= 49% [1012] for interior or unknown location

= 0% for exterior location

= 42%[1013] for unknown location

0.03412 = Converts kWh to Therms

ηHeat = Average heating system efficiency.

= 0.70 [1014]

[1010] Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation. the IL Statewide LED Lighting Logger study conducted as part of the PY8/PY9 evaluations of the Ameren Illinois and ComEd Residential Lighting programs was unable to provide coincidence factors for screw-based omnidirectional LEDs in exterior applications.

[1011] Based on a weighted average of coincidence factors in interior and exterior applications, assuming 5% exterior lighting. The distribution of LEDs is based on the on-site lighting inventory conducted as part of the IL Statewide LED Lighting Logger study.

[1012] Average result from REMRate modeling of several different configurations and IL locations of homes

[1013] Based on a weighted average of interior and exterior hours of use from the IL Statewide LED Lighting Logger study conducted as part of the PY8/PY9 evaluations of the Ameren Illinois and ComEd Residential Lighting programs, assuming 15% exterior specialty lighting. The distribution of LEDs is based on the on-site lighting inventory conducted as part of the IL Statewide LED Lighting Logger study.

[1014] This has been estimated assuming that natural gas central furnace heating is typical for Illinois residences (66% of Illinois homes have a Natural Gas Furnace (based on Energy Information Administration, 2009 Residential Energy Consumption Survey) In 2000, 24% of furnaces purchased in Illinois were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 10 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows:

(0.24*0.92) + (0.76*0.8) * (1-0.15) = 0.70

### WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

### DEEMED O&M COST ADJUSTMENT CALCULATION

Bulb replacement costs assumed in the O&M calculations are provided below[1015].

| Year | Standard Incandescent | CFL |
|---|---|---|
| 2019 | $1.90 | N/A |
| 2020 | $1.90 | N/A |
| 2021 & after | $1.90 | $3.15 |

In order to account for the shift in baseline due to the Energy Independence and Security Act of 2007, an equivalent annual levelized baseline replacement cost over the lifetime of the LED bulb is calculated. The key assumptions used in this calculation are documented below:

| Fixture Type | Fixture Hours | Hours of Use per year | Measure Life in Years (capped at 15) |
|---|---|---|---|
| Indoor and Downlight | 47,000 | 926[1016] | 15 |
| Task/Under Cabinet | 45,000 | 730[1017] | |
| Outdoor | 49,000 | 2,475[1018] | |

The NPV for replacement lamps and annual levelized replacement costs using the societal real discount rate of 0.46% are presented below[1019]. It is important to note that for cost-effectiveness screening purposes, the O&M cost adjustments should only be applied in cases where the light bulbs area actually in service and so should be multiplied by the appropriate ISR:

| Location | NPV of replacement costs for period | | | Levelized annual replacement cost savings | | |
|---|---|---|---|---|---|---|
| | 2019 | 2020 | 2021 | 2019 | 2020 | 2021 |
| Indoor and Downlight | $5.38 | $3.93 | $3.93 | $0.37 | $0.27 | $0.27 |
| Task/Under Cabinet | $4.24 | $3.10 | $3.10 | $0.29 | $0.21 | $0.21 |
| Outdoor | $17.18 | $13.29 | $10.50 | $1.19 | $0.92 | $0.73 |

[1015] Baseline and LED lamp costs are based on field data collected by CLEAResult and provided by ComEd. See ComEd Pricing Projections 06302016.xlsx for analysis. Costs for standard, decorative, and directional bulbs were averaged.

[1016] Assuming 365.25 days/year and average of recommended values for standard LED lamps (2.98) and specialty LED lamps (2.09) in interior locations from the IL Statewide LED Lighting Logger study conducted as part of the PY8/PY9 evaluations of the Ameren Illinois and ComEd Residential Lighting programs

[1017] Task/under cabinet hours of use are estimated at 2 hours per day.

[1018] Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation. The IL Statewide LED Lighting Logger study conducted as part of the PY8/PY9 evaluations of the Ameren Illinois and ComEd Residential Lighting programs was unable to provide hours of use for screw-based omnidirectional LEDs in exterior applications.

[1019] See "LED TRM Examples_2018.xlsx" for calculation.

**MEASURE CODE: RS-LTG-LDFX-V01-190101**

**REVIEW DEADLINE: 1/1/2020**

## 5.5.10 Holiday String Lighting

### DESCRIPTION

This measure categorizes the savings from customers handing in incandescent string lighting typically used during the holidays and receiving equivalent LED string lighting. LED bulbs on string lights can consume up to 98% less power when compared to incandescent bulbs. Besides less energy to operate, LED string lighting offers many other advantages over incandescent: longer bulb life, a higher brightness, less heat buildup making them safer especially when used indoors on live trees, and better durability since they use a plastic covering over the diode instead of a glass bulb.[1020]

This measure applies to mini, C7, and C9 bulb shape types used in residential locations. Description of the bulb types of string lighting are listed below: [1021, 1022]

Mini: About 1/4" wide x 5/8" high with a shape described as a miniature candle with a pointed tip. The mini is the most common type of string light today and shares about 80% of the market. They have a female-to-male push type base.

C7: Approximately 1" wide x 1-1/2" high with a shape described as a strawberry. The C7 (and C9) are thought of as more "old fashioned" or traditional since they were the first types of string lighting used for decorative purposes. The C7 shares about 7% of the market and has a screw-in E12 candelabra base.

C9: Similar in shape to the C7, the C9 is slightly larger at 1-1/4" wide x 2-1/2" high. The C9 shares about 5% of the market and has a screw-in E17 intermediate base.

A third variant of the "C" bulb exists, which is called C6. However, due to lack of availability of the C6 incandescent from retailers, it is assumed the market has already adopted the LED as the baseline for this bulb shape type and should not be claimed for utility program savings.

The implementation strategy for this measure is only geared towards residential customers. Furthermore, the deemed hours of operation are sourced on residential only. As such, the proposed deemed split of 100% Residential and 0% Commercial assumptions should be used.

This measure was developed to be applicable to the following program types: EREP. To ensure that the baseline is appropriate, the measure is limited to an exchange event where the customer has to turn in a string of inefficient lighting.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, new string lights must be LED and one of the eligible bulb shape categories listed in this measure (mini, C7, C9).

Some manufacturers offer integrated "smart" control of new LED strings; however, these are not included in this measure.

### DEFINITION OF BASELINE EQUIPMENT

The baseline condition is the existing incandescent mini, C7, or C9 string lighting turned in during an exchange event.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The rated lifespan of LED bulbs for string lighting is in the range of 20,000 to 100,000 hours of use. However, the

[1020] See 'Christmas Lights Buying Guide – Hayneedle'.
[1021] See 'Christmas Lights Buying Guide – Hayneedle'.
[1022] See 'Christmas Lights Guide Visual'.

measure lifetime is capped at 7 years due to wear on bulbs and string from weather, sunlight, and annual installation and storage.[1023]

### Deemed Measure Cost

Where possible, the actual, full cost of new LED string lighting should be used. If unavailable, assume the following costs.

| Bulb Type | Measure Cost[1024] |
|---|---|
| Mini | $15.38 |
| C7 | $21.42 |
| C9 | $17.28 |

Loadshape

Loadshape R16; Residential Holiday String Lighting

### Coincidence Factor

Due to the seasonal nature and evening operation of holiday string lights, there is no expected reduction in a utility's peak demand.

## Algorithm

### Calculation of Energy Savings

### Electric Energy Savings

$$\Delta kWh = ((Watts_{base}-Watts_{EE})/1000) * ISR * (1-Leakage) * Hours * WHF_e$$

Where:

$Watts_{base}$ = Total wattage of the existing incandescent string lights = Bulb Wattage * # Bulbs; see table below for baseline bulb wattage assumptions

$Watts_{EE}$ = Actual total wattage of the new LED string lights = Bulb Wattage * # Bulbs. If unknown, assume total wattage of new LED string lights = Bulb Wattage * # Bulbs; see table below for LED bulb wattage assumptions

Where:

Bulb Wattage = Reference the "Bulb Wattage Assumptions" table below.

**Bulb Wattage Assumptions[1025]**

| Type | Incandescent Bulb (Watts) | LED Bulb (Watts) |
|---|---|---|
| Mini | 0.49 | 0.11 |
| C7 | 5.00 | 0.31 |
| C9 | 7.00 | 0.13 |

[1023] LED string lighting lifetime from https://www.christmasdesigners.com/blog/how-long-do-led-christmas-lights-really-last/'How Long Do LED Christmas Lights Really Last Christmas Designers'

[1024] See file Holiday Lights Research and Calcs_2018.xlsx for CLEAResult research on holiday string lighting costs.

[1025] Average wattages provided from market research by CLEAResult. See file Holiday Lights Research and Calcs_2018.xlsx.

| | |
|---|---|
| # Bulbs | = Actual quantity of bulbs on the string. If baseline is unknown, assume same as the new string. |
| ISR | = In Service Rate, or percentage of string lights that get installed. Derive from program evaluation analysis, otherwise assume 100%. |
| Leakage | = Adjustment to account for the percentage of program string lights that move out (and in, if deemed appropriate) of the Utility Jurisdiction. |
| | = For an exchange event, assume 0% if customer is required to be a utility customer. If not, determine leakage rate through evaluation. If customer is not required to be utility customer and if leakage is not determined through evaluation, use the deemed leakage rates LED omnidirectional bulbs sold through Upstream (TOS) programs:[1026]: |

| | |
|---|---|
| ComEd: | 0.7% |
| Ameren: | 13.1% |

| | |
|---|---|
| Hours | = Average hours of use per year |
| | = 210 hours[1027] |
| WHFe | = Waste heat factor for energy to account for cooling energy savings from efficient lighting, assumed value of 1.0 since operation of string lights (if indoors) does not coincide with cooling season and there are no interactive effects for outdoor string lights. |

For example, a customer replaces a 50-bulb mini incandescent string with a 50-bulb mini LED string:

ΔkWh = ((0.49 * 50) – (0.11 * 50))/1000) * 1.00 * (1 - 0) * 210 * 1.0

= 4.0 kWh

**HEATING PENALTY**

If electric heated home (if heating fuel is unknown assume gas, see Natural Gas section):

ΔkWh[1028] = - (((WattsBase - WattsEE)/1000) * ISR * (1-Leakage) * Hours * HF) / ηHeat

Where:

| | |
|---|---|
| HF | = Heating Factor or percentage of light savings that must be heated<br>= 49% for interior or unknown location[1029]<br>= 0% for exterior or unheated location |
| ηHeat | = Efficiency in COP of Heating equipment |
| | = actual. If not available, use:[1030] |

---

[1026] Leakage rate is based upon review of PY7-9 evaluations from ComEd and PY8 for Ameren (see for more information).

[1027] Based on typical holiday lighting hours of use (6 hours per day, 7 days per week for 5 weeks) from California Municipal Utilities Association "TRM 205 LED Holiday Lights."

[1028] Negative value because this is an increase in heating consumption due to the efficient lighting.

[1029] This means that heating loads increase by 49% of the lighting savings. This is based on the average result from REMRate modeling of several different configurations and IL locations of homes.

[1030] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate. Note efficiency should include duct losses. Defaults provided assume 15% duct loss for heat pumps.

| System Type | Age of Equipment | HSPF Estimate | COPheat (COP Estimate) = (HSPF/3.413) * 0.85 |
|---|---|---|---|
| Heat Pump | Before 2006 | 6.8 | 1.7 |
| | After 2006-2014 | 7.7 | 1.92 |
| | 2015 on | 8.2 | 2.04 |
| Resistance | N/A | N/A | 1 |
| Unknown[1031] | N/A | N/A | 1.28 |

Using the same 50-bulb mini LED string that is installed in home with 2.0 COP Heat Pump (including duct loss):

ΔkWh = - ((((0.49 * 50) – (0.11 * 50))/1000) * 1.00 * (1 - 0) * 210 * 0.49) / 2.0

= - 1.0 kWh

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

### NATURAL GAS SAVINGS

Heating penalty if installed in a natural gas heated home, or if heating fuel is unknown.

ΔTherms = - (((WattsBase - WattsEE)/1000) * ISR * (1-Leakage) * Hours * HF * 0.03412) / ηHeat

Where:

HF = Heating factor, or percentage of lighting savings that must be replaced by heating system.

= 49% for interior or unknown location [1032]

= 0% for exterior location

0.03412 = Converts kWh to Therms

ηHeat = Actual heating system efficiency.

= 70% [1033]

[1031] Calculation assumes 35% Heat Pump and 65% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see "HC6.9 Space Heating in Midwest Region.xls", using average for East North Central Region. Average efficiency of heat pump is based on assumption that 50% are units from before 2006 and 50% from 2006-2014. Program or evaluation data should be used to improve this assumption if available.

[1032] Average result from REMRate modeling of several different configurations and IL locations of homes.

[1033] This has been estimated assuming that natural gas central furnace heating is typical for Illinois residences (66% of Illinois homes have a Natural Gas Furnace (based on Energy Information Administration, 2009 Residential Energy Consumption Survey). In 2000, 24% of furnaces purchased in Illinois were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 10 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows:

(0.24*0.92) + (0.76*0.8) * (1-0.15) = 0.70

Using the same 50-bulb mini LED string that is installed in a single family interior location with gas heating at 70% total efficiency:

$$\Delta therms = - ((((0.49 * 50) – (0.11 * 50))/1000) * 1.00 * (1 - 0) * 210 * 0.49 * 0.03412) / 0.70$$

$$= - 0.10 \text{ therms}$$

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-LTG-LEDH-V01-190101**

**REVIEW DEADLINE: 1/1/2022**

## 5.5.11 LED Nightlights

### DESCRIPTION

This measure describes savings from LED nightlights. This characterization assumes that the LED nightlight is installed in a residential location.

This measure was developed to be applicable to the following program types: TOS, NC.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

For this characterization to apply, the high-efficiency equipment must be a qualified LED nightlight.

### DEFINITION OF BASELINE EQUIPMENT

The baseline condition is assumed to be an incandescent/halogen nightlight.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The estimated useful life of the is estimated is 8 years[1034].

### DEEMED MEASURE COST

Where possible, the actual cost should be used and compared to the baseline cost. If the incremental cost is unknown, assume the following[1035]:

| Bulb Type | Year | Incandescent | LED | Incremental Cost |
|---|---|---|---|---|
| Nightlights | All | $2.84 | $6.19 | $3.35 |

### LOADSHAPE

Loadshape R07 - Residential Outdoor Lighting

### COINCIDENCE FACTOR

Demand savings is assumed to be zero for this measure.

## Algorithm

### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

$\Delta kWh$ = ((WattsBase - WattsEE) / 1000) * ISR * (1-Leakage) * Hours * WHFe

Where:

$Watts_{base}$ = Actual wattage if known, if unknown, assume 7W[1036].

[1034] Southern California Edison Company, "LED, Electroluminescent & Fluorescent Night Lights", Work Paper WPSCRELG0029 Rev. 1, February 2009, p. 2. and p.3.
[1035] Average cost data provided in Stanley Mertz, "LED Nightlights Energy Efficiency Retail products programs", March, 2018.
[1036] Based on Stanley Mertz, "LED Nightlights Energy Efficiency Retail products programs", March, 2018.

$Watts_{EE}$ = Actual wattage of LED purchased / installed.

ISR = In Service Rate or the percentage of nightlights rebated that get installed

| Program | Weighted Average 1st year In Service Rate (ISR) | 2nd year Installations | 3rd year Installations | Final Lifetime In Service Rate |
|---|---|---|---|---|
| Retail (Time of Sale) | 84.0%[1037] | 7.6% | 6.4% | 98.0%[1038] |
| Direct Install | 96.9%[1039] | | | |
| School Kits | 60%[1040] | 13% | 11% | 84% |

Leakage = Adjustment to account for the percentage of program bulbs that move out (and in if deemed appropriate[1041]) of the Utility Jurisdiction.

KITS programs = Determined through evaluation

Upstream (TOS) Lighting programs = Use deemed assumptions below[1042]:

ComEd: 2.0%

Ameren: 13.1%

Hours = Average hours of use per year

= 4,380[1043]

WHFe = Waste heat factor for energy to account for cooling savings from efficient lighting

| Bulb Location | WHFe |
|---|---|
| Interior single family | 1.06 [1044] |

1037 1st year in service rate is based upon analysis of ComEd PY7, PY8, and PY9 intercept data (see 'Res Lighting ISR_2018.xlsx' for more information).

1038 The 98% Lifetime ISR assumption is based upon the standard CFL measure in the absence of any better reference. This value is based upon review of two evaluations:
'Nexus Market Research, RLW Analytics and GDS Associates study; "New England Residential Lighting Markdown Impact Evaluation, January 20, 2009' and 'KEMA Inc, Feb 2010, Final Evaluation Report:, Upstream Lighting Program, Volume 1.' This implies that only 2% of bulbs purchased are never installed. The second and third year installations are based upon Ameren analysis of the Californian KEMA study showing that 54% of future installs occur in year 2 and 46% in year 3. The 2nd and 3rd year installations should be counted as part of those future program year savings.

1039 Consistent with assumption for standard CFLs (in the absence of evidence that it should be different for this bulb type). Based upon review of the PY2 and PY3 ComEd Direct Install program surveys. This value includes bulb failures in the 1st year to be consistent with the Commission approval of annualization of savings for first year savings claims. ComEd PY2 All Electric Single Family Home Energy Performance Tune-Up Program Evaluation, Navigant Consulting, December 21, 2010.

1040 1st year ISR for school kits based on ComEd PY9 data for the Elementary Energy Education program.

1041 Leakage in is only appropriate to credit to IL utility program savings if it is reasonably expected that the IL utility program marketing efforts played an important role in influencing customer to purchase the light bulbs. Furthermore, consideration that such customers might be free riders should be addressed. If leakage in is assessed, efforts should be made to ensure no double counting of savings occurs if the evaluation is estimating both leakage in and spillover savings of light bulbs.

1042 Leakage rate is based upon review of PY7-9 evaluations from ComEd and PY5,6 and 8 for Ameren (see for more information).

1043 Assumes nightlight is operating 12 hours per day, consistent with the 2016 Pennsylvania TRM.

1044 The value is estimated at 1.06 (calculated as 1 + (0.66*(0.27 / 2.8)). Based on cooling loads decreasing by 27% of the lighting savings (average result from REMRate modeling of several different configurations and IL locations of homes), assuming typical cooling system operating efficiency of 2.8 COP (starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm (-0.02 * SEER2) + (1.12 * SEER) (from Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), converted to COP = EER/3.412 = 2.8COP) and 66% of homes in Illinois having central cooling ("Table HC7.9 Air Conditioning in Homes in

| Bulb Location | WHFe |
|---|---|
| Multifamily in unit | 1.04 [1045] |
| Unknown location | 1.054 [1046] |

For example, a 0.3W LED nightlight is direct installed in single family interior location within ComEd territory:

ΔkWh = ((7 – 0.3) / 1000) * 0.969 * (1 – 0) * 4380 * 1.06

= 30.1 kWh

### HEATING PENALTY

If electric heated home (if heating fuel is unknown assume gas, see Natural Gas section):

ΔkWh[1047] = - (((WattsBase - WattsEE) / 1000) * ISR * Hours * HF) / ηHeat

Where:

HF = Heating Factor or percentage of light savings that must be heated

= 49%[1048] for interior

ηHeat = Efficiency in COP of Heating equipment

= Actual. If not available use: [1049]:

| System Type | Age of Equipment | HSPF Estimate | $COP_{HEAT}$ (COP Estimate) = (HSPF/3.413)*0.85 |
|---|---|---|---|
| Heat Pump | Before 2006 | 6.8 | 1.69 |
| | After 2006 - 2014 | 7.7 | 1.92 |
| | 2015 on | 8.2 | 2.04 |
| Resistance | N/A | N/A | 1.00 |
| Unknown[1050] | N/A | N/A | 1.28 |

Midwest Region, Divisions, and States, 2009 from Energy Information Administration", 2009 Residential Energy Consumption Survey)

[1045] As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from “Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009” which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average)

[1046] Unknown is based on statewide weighted average of 69% single family and 31% multifamily, based on IL data from 2009 RECS Table HC2.9 Structural and Geographic Characteristics of Homes in Midwest Region, Divisions and States, 2009.

[1047] Negative value because this is an increase in heating consumption due to the efficient lighting.

[1048] This means that heating loads increase by 49% of the lighting savings. This is based on the average result from REMRate modeling of several different configurations and IL locations of homes.

[1049] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate. Note efficiency should include duct losses. Defaults provided assume 15% duct loss for heat pumps.

[1050] Calculation assumes 35% Heat Pump and 65% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see “HC6.9 Space Heating in Midwest Region.xls”, using average for East North Central Region. Average efficiency of heat pump is based on assumption that 50% are units from before 2006 and 50% from 2006-2014. Program or evaluation data should be used to improve this assumption if available.

For example, a 0.3W LED nightlight is direct installed in single family interior location with a 2016 heat pump:

ΔkWh = - (((7 – 0.3) / 1000) * 0.969 * (1-0) * 4380 * 0.49) / 2.04

= - 6.83 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = ((WattsBase - WattsEE) / 1 000) * ISR * (1-Leakage) * WHFd * CF

Where:

WHFd = Waste heat factor for demand to account for cooling savings from efficient lighting.

| Bulb Location | WHFd |
|---|---|
| Interior single family or unknown location | 1.11[1051] |
| Multifamily in unit | 1.07[1052] |
| Unknown location | 1.098[1053] |

CF = Summer Peak Coincidence Factor for measure.

= 0

**NATURAL GAS SAVINGS**

Heating penalty if Natural Gas heated home, or if heating fuel is unknown.

Δtherms = - (((WattsBase - WattsEE) / 1000) * ISR * Hours * HF * 0.03412) / ηHeat

Where:

HF = Heating factor, or percentage of lighting savings that must be replaced by heating system.

= 49% [1054] for interior

0.03412 = Converts kWh to Therms

ηHeat = Average heating system efficiency.

= 0.70 [1055]

Other factors as defined above

[1051] The value is estimated at 1.11 (calculated as 1 + (0.66 * 0.466 / 2.8)). See footnote relating to WHFe for details. Note the 46.6% factor represents the average Residential cooling coincidence factor calculated by dividing average load during the peak hours divided by the maximum cooling load.

[1052] As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from “Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009” which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average)

[1053] Unknown is based on statewide weighted average of 69% single family and 31% multifamily, based on IL data from 2009 RECS Table HC2.9 Structural and Geographic Characteristics of Homes in Midwest Region, Divisions and States, 2009.

[1054] Average result from REMRate modeling of several different configurations and IL locations of homes

[1055] This has been estimated assuming that natural gas central furnace heating is typical for Illinois residences (66% of Illinois homes have a Natural Gas Furnace (based on Energy Information Administration, 2009 Residential Energy Consumption Survey) In 2000, 24% of furnaces purchased in Illinois were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 10 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows:

(0.24*0.92) + (0.76*0.8) * (1-0.15) = 0.70

| |
|---|
| For example, a 0.3W LED nightlight is direct installed in single family interior location with gas heating at 70% total efficiency:<br>$\Delta therms = - (((7 – 0.3) / 1000) * 0.969 * (1-0) * 4380 * 0.49 * 0.03412) / 0.70$<br>$= - 0.68$ therms |

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**MEASURE CODE: RS-LTG-NITL-V01-190101**

**REVIEW DEADLINE: 1/1/2022**

# 5.6 Shell End Use

## 5.6.1 Air Sealing

### Description

Thermal shell air leaks are sealed through strategic use and location of air-tight materials. Leaks are detected and leakage rates measured with the assistance of a blower-door. The algorithm for this measure can be used when the program implementation does not allow for more detailed forecasting through the use of residential modeling software.

Prescriptive savings are provided for use only where a blower door test is not possible (for example in large multi family buildings).

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

Air sealing materials and diagnostic testing should meet all eligibility program qualification criteria. The initial and final tested leakage rates should be performed in such a manner that the identified reductions can be properly discerned, particularly in situations wherein multiple building envelope measures may be implemented simultaneously.

### Definition of Baseline Equipment

The existing air leakage should be determined through approved and appropriate test methods using a blower door. The baseline condition of a building upon first inspection significantly impacts the opportunity for cost-effective energy savings through air-sealing.

### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 20 years.[1056]

Note a mid-life adjustment to account for replacement of HVAC equipment during the measure life should be applied after 10 years or 13 years for boilers[1057]. See section below for detail.

### Deemed Measure Cost

The actual capital cost for this measure should be used in screening.

### Loadshape

Loadshape R08 - Residential Cooling
Loadshape R09 - Residential Electric Space Heat
Loadshape R10 - Residential Electric Heating and Cooling

### Coincidence Factor

The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the *average* savings over the defined summer peak period, and is presented so that savings can be bid into PJM's

[1056] As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.
[1057] This is intentionally longer than the assumptions found in the early replacement measures as the application of this measure will occur in a variety of homes that will not be targeted for early replacement HVAC systems.

Forward Capacity Market.

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Central A/C (during utility peak hour)

= 68%[1058]

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

= 72%%[1059]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period)

= 46.6%[1060]

**Algorithm**

## CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

Preferred methodology unless blower door testing is not possible.

ΔkWh = ΔkWh_cooling + ΔkWh_heating

Where:

ΔkWh_cooling = If central cooling, reduction in annual cooling requirement due to air sealing

= [(((CFM50_existing - CFM50_new)/N_cool) * 60 * 24 * CDD * DUA * 0.018) / (1000 * ηCool) * LM * $ADJ_{AirSealingCool}$]

CFM50_existing = Infiltration at 50 Pascals as measured by blower door before air sealing.

= Actual

CFM50_new = Infiltration at 50 Pascals as measured by blower door after air sealing.

= Actual

N_cool = Conversion factor from leakage at 50 Pascal to leakage at natural conditions

=Dependent on location and number of stories:[1061]

| Climate Zone (City based upon) | N_cool (by # of stories) | | | |
|---|---|---|---|---|
| | 1 | 1.5 | 2 | 3 |
| 1 (Rockford) | 39.5 | 35.0 | 32.1 | 28.4 |
| 2 (Chicago) | 38.9 | 34.4 | 31.6 | 28.0 |
| 3 (Springfield) | 41.2 | 36.5 | 33.4 | 29.6 |
| 4 (St Louis, MO) | 40.4 | 35.8 | 32.9 | 29.1 |
| 5 (Paducah, KY) | 43.6 | 38.6 | 35.4 | 31.3 |

[1058] Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.
[1059] Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC's 2010 system peak; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.
[1060] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.
[1061] N-factor is used to convert 50-pascal blower door air flows to natural air flows and is dependent on geographic location and # of stories. These were developed by applying the LBNL infiltration model (see LBNL paper 21040, *Exegisis of Proposed ASHRAE Standard 119: Air Leakage Performance for Detached Single-Family Residential Buildings*; Sherman, 1986; page v-vi, Appendix page 7-9) to the reported wind speeds and outdoor temperatures provided by the NRDC 30 year climate normals. For more information see Bruce Harley, CLEAResult "Infiltration Factor Calculations Methodology.doc".

60 * 24 = Converts Cubic Feet per Minute to Cubic Feet per Day

CDD = Cooling Degree Days

= Dependent on location[1062]:

| Climate Zone (City based upon) | CDD 65 |
|---|---|
| 1 (Rockford) | 820 |
| 2 (Chicago) | 842 |
| 3 (Springfield) | 1,108 |
| 4 (Belleville) | 1,570 |
| 5 (Marion) | 1,370 |

DUA = Discretionary Use Adjustment (reflects the fact that people do not always operate their AC when conditions may call for it).

= 0.75 [1063]

0.018 = Specific Heat Capacity of Air (Btu/ft$^3$*°F)

1000 = Converts Btu to kBtu

ηCool = Efficiency (SEER) of Air Conditioning equipment (kBtu/kWh)

= Actual (where new or where it is possible to measure or reasonably estimate). If unknown assume the following[1064]:

| Age of Equipment | SEER Estimate |
|---|---|
| Before 2006 | 10 |
| 2006 - 2014 | 13 |
| Central AC After 1/1/2015 | 13 |
| Heat Pump After 1/1/2015 | 14 |

LM = Latent multiplier to account for latent cooling demand[1065]

| Climate Zone (City based upon) | LM |
|---|---|
| 1 (Rockford) | 3.3 |
| 2 (Chicago) | 3.2 |
| 3 (Springfield) | 3.7 |
| 4 (St Louis, MO) | 3.6 |
| 5 (Paducah, KY) | 3.7 |

[1062] National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 65°F.

[1063] This factor's source is: Energy Center of Wisconsin, May 2008 metering study; “Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research”, p31.

[1064] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Central AC was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.

[1065] Derived by calculating the sensible and total loads in each hour. For more information see Bruce Harley, CLEAResult “Infiltration Factor Calculations Methodology.doc”.

$ADJ_{AirSealingCool}$ = Adjustment for cooling savings to account for innacuracies in engineering algorithms[1066]

| Measure | $ADJ_{AirSealingCool}$ |
|---|---|
| Air sealing and attic insulation | 121% |
| Air sealing without attic insulation | 100% |

ΔkWh_heating = If electric heat (resistance or heat pump), reduction in annual electric heating due to air sealing

= ([((CFM50_existing - CFM50_new)/N_heat) * 60 * 24 * HDD * 0.018) / (ηHeat * 3,412)]

N_heat = Conversion factor from leakage at 50 Pascal to leakage at natural conditions

= Based on climate zone, building height and exposure level:[1067]

| Climate Zone (City based upon) | N_heat (by # of stories) | | | |
|---|---|---|---|---|
| | 1 | 1.5 | 2 | 3 |
| 1 (Rockford) | 23.8 | 21.1 | 19.3 | 17.1 |
| 2 (Chicago) | 23.9 | 21.1 | 19.4 | 17.2 |
| 3 (Springfield) | 24.2 | 21.5 | 19.7 | 17.4 |
| 4 (St Louis, MO) | 25.4 | 22.5 | 20.7 | 18.3 |
| 5 (Paducah, KY) | 27.8 | 24.6 | 22.6 | 20.0 |

HDD = Heating Degree Days

= Dependent on location:[1068]

| Climate Zone (City based upon) | HDD 60 |
|---|---|
| 1 (Rockford) | 5,352 |
| 2 (Chicago) | 5,113 |
| 3 (Springfield) | 4,379 |
| 4 (Belleville) | 3,378 |
| 5 (Marion) | 3,438 |

ηHeat = Efficiency of heating system

= Actual (where new or where it is possible to measure or reasonably estimate).. If not available refer to default table below[1069]:

[1066] As demonstrated in air sealing and insulation research by Navigant, see Navigant (2018). C*omEd and Nicor Gas Air Sealing and Insulation Research Report.* Presented to Commonwealth Edison Company and Nicor Gas Company.

[1067] N-factor is used to convert 50-pascal blower door air flows to natural air flows and is dependent on geographic location and # of stories. These were developed by applying the LBNL infiltration model (see LBNL paper 21040, *Exegisis of Proposed ASHRAE Standard 119: Air Leakage Performance for Detached Single-Family Residential Buildings*; Sherman, 1986; page v-vi, Appendix page 7-9) to the reported wind speeds and outdoor temperatures provided by the NRDC 30 year climate normals. For more information see Bruce Harley, CLEAResult "Infiltration Factor Calculations Methodology.doc".

[1068] National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 60°F.

[1069] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time means that using the minimum standard is appropriate. An 85% distribution efficiency is then applied to account for duct losses for heat pumps.

| System Type | Age of Equipment | HSPF Estimate | ηHeat (Effective COP Estimate)= (HSPF/3.413)*0.85 |
|---|---|---|---|
| Heat Pump | Before 2006 | 6.8 | 1.7 |
| | 2006 - 2014 | 7.7 | 1.92 |
| | 2015 on | 8.2 | 2.04 |
| Resistance | N/A | N/A | 1 |

3412 = Converts Btu to kWh

The following example captures energy savings from air sealing. Energy savings for attic insulation are included in a separate example in Section 5.6.5: Ceiling/Attic Insulation.

For example, a 2 story single family home in Chicago completes air sealing, installs attic insulation, has 10.5 SEER central cooling and a heat pump with COP of 2 (1.92 including distribution losses), and has pre and post blower door test results of 3,400 and 2,250:

ΔkWh = ΔkWh_cooling + ΔkWh_heating

= [(((3,400 – 2,250) / 31.6) * 60 * 24 * 842 * 0.75 * 0.018) / (1000 * 10.5) * 3.2 * 121%] + [(((3,400 – 2,250) / 19.4) * 60 * 24 * 5113 * 0.018) / (1.92 * 3,412)]

= 220 + 1,199

= 1,419 kWh

ΔkWh_heating = If gas *furnace* heat, kWh savings for reduction in fan run time

= ΔTherms * $F_e$ * 29.3 * $ADJ_{AirSealingHeatFan}$

$F_e$ = Furnace Fan energy consumption as a percentage of annual fuel consumption

= 3.14%[1070]

29.3 = kWh per therm

$ADJ_{AirSealingHeatFan}$ = Adjustment for fan savings during heating season to account for innacuracies in engineering algorithms[1071]

| Measure | $ADJ_{AirSealingHeatFan}$ |
|---|---|
| Air sealing and attic insulation | 107% |
| Air sealing without attic insulation | 100% |

[1070] $F_e$ is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR version 3 criteria for 2% $F_e$. See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference.

[1071] As demonstrated in air sealing and insulation research by Navigant, see Navigant (2018). C*omEd and Nicor Gas Air Sealing and Insulation Research Report.* Presented to Commonwealth Edison Company and Nicor Gas Company.

The following example captures energy savings from air sealing. Energy savings for attic insulation are included in a separate example in Section 5.6.5: Ceiling/Attic Insulation.

For example, a well shielded, 2 story single family home in Chicago completes air sealing, installs attic insulation, has a gas furnace with system efficiency of 70%, and has pre and post blower door test results of 3,400 and 2,250 (see therm calculation in Natural Gas Savings section):

$\Delta kWh$ = 76.3 * 0.0314 * 29.3 * 107%

= 75.1 kWh

***Methodology 2: Prescriptive Infiltration Reduction Measures***[1072]

Savings shall only be calculated via Methodology 2 if a blower door test is not feasible. Cooling savings are not quantified using Methodology 2.

$\Delta kWh\_heating = (\Delta kWh_{gasket} * n_{gasket} + \Delta kWh_{sweep} * n_{sweep} + \Delta kWh_{sealing} * lf_{sealing} + \Delta kWh_{WX} * lf_{WX}) * ADJ_{RxAirsealing}$

Where:

$\Delta kWh_{gasket}$ = Annual kWh savings from installation of air sealing gasket on an electric outlet

| Climate Zone (City based upon) | $\Delta kWh_{gasket}$ / gasket | |
|---|---|---|
| | Electric Resistance | Heat Pump |
| 1 (Rockford) | 10.5 | 5.3 |
| 2 (Chicago) | 10.2 | 5.1 |
| 3 (Springfield) | 8.8 | 4.4 |
| 4 (Belleville) | 7.0 | 3.5 |
| 5 (Marion) | 7.2 | 3.6 |

$n_{gasket}$ = Number of gaskets installed

$\Delta kWh_{sweep}$ =Annual kWh savings from installation of door sweep

| Climate Zone (City based upon) | $\Delta kWh_{sweep}$ / sweep | |
|---|---|---|
| | Electric Resistance | Heat Pump |
| 1 (Rockford) | 202.4 | 101.2 |
| 2 (Chicago) | 195.3 | 97.6 |
| 3 (Springfield) | 169.3 | 84.7 |
| 4 (Belleville) | 134.9 | 67.5 |
| 5 (Marion) | 137.9 | 68.9 |

$n_{sweep}$ = Number of sweeps installed

$\Delta kWh_{sealing}$ = Annual kWh savings from foot of caulking, sealing, or polyethlylene tape

| Climate Zone (City based upon) | $\Delta kWh_{sealing}$ / ft | |
|---|---|---|
| | Electric Resistance | Heat Pump |
| 1 (Rockford) | 11.6 | 5.8 |

[1072] Prescriptive savings are based upon "Evaluation of the Weatherization Residential Assistance Partnership and Helps Programs (WRAP/Helps)." Middletown, CT: KEMA, 2010. Accessed July 30, 2015, and adjusted for relative HDD of Bridgeport/Hartford CT with the IL climate zones. See 'Rx Airsealing HDD adjustment.xls' for more information.

| Climate Zone (City based upon) | $\Delta kWh_{sealing}$ / ft | |
|---|---|---|
| | Electric Resistance | Heat Pump |
| 2 (Chicago) | 11.2 | 5.6 |
| 3 (Springfield) | 9.7 | 4.8 |
| 4 (Belleville) | 7.7 | 3.9 |
| 5 (Marion) | 7.9 | 3.9 |

$lf_{sealing}$ = linear feet of caulking, sealing, or polyethylene tape

$\Delta kWh_{WX}$ = Annual kWh savings from window weatherstripping or door weatherstripping

| Climate Zone (City based upon) | $\Delta kWh_{WX}$ / ft | |
|---|---|---|
| | Electric Resistance | Heat Pump |
| 1 (Rockford) | 13.5 | 6.7 |
| 2 (Chicago) | 13.0 | 6.5 |
| 3 (Springfield) | 11.3 | 5.6 |
| 4 (Belleville) | 9.0 | 4.5 |
| 5 (Marion) | 9.2 | 4.6 |

$lf_{WX}$ = Linear feet of window weatherstripping or door weatherstripping

$ADJ_{RxAirsealing}$ = Adjustment for air sealing savings to account for prescriptive estimates overclaiming savings[1073].

= 80%

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = (ΔkWh_cooling / FLH_cooling) * CF

Where:

FLH_cooling = Full load hours of air conditioning

= Dependent on location[1074]:

| Climate Zone (City based upon) | Single Family | Multifamily |
|---|---|---|
| 1 (Rockford) | 512 | 467 |
| 2 (Chicago) | 570 | 506 |
| 3 (Springfield) | 730 | 663 |
| 4 (Belleville) | 1,035 | 940 |
| 5 (Marion) | 903 | 820 |

Use Multifamily if: Building has shared HVAC or meets utility's definition for multifamily

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)

[1073] Though we do not have a specific evaluation to point to, modeled savings have often been found to overclaim. Further VEIC reviewed these deemed estimates and consider them to likely be a high estimate. As such an 80% adjustment is applied, and this could be further refined with future evaluations.

[1074] Full load hours for Chicago, Moline and Rockford are provided in "Final Evaluation Report: Central Air Conditioning Efficiency Services (CACES), 2010, Navigant Consulting", p.33. An average FLH/Cooling Degree Day (from NCDC) ratio was calculated for these locations and applied to the CDD of the other locations in order to estimate FLH.

= 68%[1075]

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

= 72%%[1076]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Central A/C (average during peak period)

= 46.6%[1077]

Other factors as defined above

The following example captures energy savings from air sealing. Energy savings for attic insulation are included in a separate example in Section 5.6.5: Ceiling/Attic Insulation.

For example, a well shielded, 2 story single family home in Chicago completes air sealing, installs attic insulation, has 10.5 SEER central cooling and a heat pump with COP of 2.0, and has pre and post blower door test results of 3,400 and 2,250:

$\Delta kW_{SSP}$ = 220 / 570 * 0.68

= 0.26 kW

$\Delta kW_{PJM}$ = 220 / 570 * 0.466

= 0.18 kW

**NATURAL GAS SAVINGS**

***Methodology 1: Blower Door Test***

Preferred methodology unless blower door testing is not possible.

If Natural Gas heating:

$$\Delta Therms = (((CFM50\_existing - CFM50\_new)/N\_heat) * 60 * 24 * HDD * 0.018) / (\eta Heat * 100{,}000) * ADJ_{AirSealingGasHeat}$$

Where:

N_heat = Conversion factor from leakage at 50 Pascal to leakage at natural conditions

= Based on climate zone and building height[1078]

| Climate Zone (City based upon) | N_heat (by # of stories) | | | |
|---|---|---|---|---|
| | 1 | 1.5 | 2 | 3 |
| 1 (Rockford) | 23.8 | 21.1 | 19.3 | 17.1 |
| 2 (Chicago) | 23.9 | 21.1 | 19.4 | 17.2 |
| 3 (Springfield) | 24.2 | 21.5 | 19.7 | 17.4 |
| 4 (St Louis, MO) | 25.4 | 22.5 | 20.7 | 18.3 |
| 5 (Paducah, KY) | 27.8 | 24.6 | 22.6 | 20.0 |

1075 Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

1076 Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC's 2010 system peak; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.

1077 Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.

1078 N-factor is used to convert 50-pascal blower door air flows to natural air flows and is dependent on geographic location and # of stories. These were developed by applying the LBNL infiltration model (see LBNL paper 21040, *Exegisis of Proposed ASHRAE Standard 119: Air Leakage Performance for Detached Single-Family Residential Buildings*; Sherman, 1986; page v-vi, Appendix page 7-9) to the reported wind speeds and outdoor temperatures provided by the NRDC 30 year climate normals. For more information see Bruce Harley, CLEAResult "Infiltration Factor Calculations Methodology.doc".

HDD = Heating Degree Days

= dependent on location[1079]:

| Climate Zone (City based upon) | HDD 60 |
|---|---|
| 1 (Rockford) | 5,352 |
| 2 (Chicago) | 5,113 |
| 3 (Springfield) | 4,379 |
| 4 (Belleville) | 3,378 |
| 5 (Marion) | 3,438 |

ηHeat = Efficiency of heating system

= Equipment efficiency * distribution efficiency

= Actual[1080] (where new or where it is possible to measure or reasonably estimate). If not available use 72% for existing system efficiency[1081].

$ADJ_{AirSealingGasHeat}$ = Adjustment for gas heating savings to account for inaccuracies in engineering algorithms[1082]

| Measure | $ADJ_{AirSealingGasHeat}$ |
|---|---|
| Air sealing and attic insulation | 72% |
| Air sealing without attic insulation | 100% |

Other factors as defined above

The following example captures energy savings from air sealing. Energy savings for attic insulation are included in a separate example in Section 5.6.5: Ceiling/Attic Insulation.

For example, a 2 story single family home in Chicago completes air sealing, installs attic insulation, has a gas furnace with system efficiency of 70%, and has pre and post blower door test results of 3,400 and 2,250:

ΔTherms = (((3,400 – 2,250)/19.4) * 60 * 24 * 5113 * 0.018) / (0.72 * 100,000) * 72%

= 78.5 therms

***Methodology 2: Prescriptive Infiltration Reduction Measures[1083]***

Savings shall only be calculated via Methodology 2 if a blower door test is not feasible.

[1079] National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 60°F, consistent with the findings of Belzer and Cort, Pacific Northwest National Laboratory in "Statistical Analysis of Historical State-Level Residential Energy Consumption Trends," 2004..

[1080] Ideally, the System Efficiency should be obtained either by recording the AFUE of the unit, or performing a steady state efficiency test. The Distribution Efficiency can be estimated via a visual inspection and by referring to a look up table such as that provided by the Building Performance Institute: (see 'BPI Distribution Efficiency Table') or by performing duct blaster testing.

[1081] Based on average Nicor PY4 nameplate efficiencies derated by 15% for distribution losses.

[1082] As demonstrated in air sealing and insulation research by Navigant, see Navigant (2018). C*omEd and Nicor Gas Air Sealing and Insulation Research Report.* Presented to Commonwealth Edison Company and Nicor Gas Company.

[1083] Prescriptive savings are based upon "Evaluation of the Weatherization Residential Assistance Partnership and Helps Programs (WRAP/Helps)." Middletown, CT: KEMA, 2010. Accessed July 30, 2015, and adjusted for relative HDD of Bridgeport/Hartford CT with the IL climate zones. See 'Rx Airsealing HDD adjustment.xls' for more information.

$\Delta therms$ = $(\Delta therms_{gasket} * n_{gasket} + \Delta therms_{sweep} * n_{sweep} + \Delta therms_{sealing} * lf_{sealing} + \Delta therms_{WX} * lf_{WX}) * ADJ_{RxAirsealing}$

Where:

$\Delta therms_{gasket}$ = Annual therm savings from installation of air sealing gasket on an electric outlet

| Climate Zone (City based upon) | $\Delta therms_{gasket}$ / gasket Gas Heat |
|---|---|
| 1 (Rockford) | 0.49 |
| 2 (Chicago) | 0.47 |
| 3 (Springfield) | 0.41 |
| 4 (Belleville) | 0.33 |
| 5 (Marion) | 0.33 |

$n_{gasket}$ = Number of gaskets installed

$\Delta therms_{sweep}$ = Annual therm savings from installation of door sweep

| Climate Zone (City based upon) | $\Delta therms_{sweep}$ / sweep Gas Heat |
|---|---|
| 1 (Rockford) | 9.46 |
| 2 (Chicago) | 9.13 |
| 3 (Springfield) | 7.92 |
| 4 (Belleville) | 6.31 |
| 5 (Marion) | 6.45 |

$n_{sweep}$ = Number of sweeps installed

$\Delta therms_{sealing}$ = Annual therm savings from foot of caulking, sealing, or polyethlylene tape

| Climate Zone (City based upon) | $\Delta therms_{sealing}$ / ft Gas Heat |
|---|---|
| 1 (Rockford) | 0.54 |
| 2 (Chicago) | 0.52 |
| 3 (Springfield) | 0.45 |
| 4 (Belleville) | 0.36 |
| 5 (Marion) | 0.37 |

$lf_{sealing}$ = linear feet of caulking, sealing, or polyethylene tape

$\Delta therms_{WX}$ = Annual therm savings from window weatherstripping or door weatherstripping

| Climate Zone (City based upon) | $\Delta therms_{sx}$ / ft Gas Heat |
|---|---|
| 1 (Rockford) | 0.63 |
| 2 (Chicago) | 0.61 |
| 3 (Springfield) | 0.53 |
| 4 (Belleville) | 0.42 |
| 5 (Marion) | 0.43 |

$lf_{WX}$ = Linear feet of window weatherstripping or door weatherstripping

$ADJ_{RxAirsealing}$ = Adjustment for air sealing savings to account for prescriptive estimates overclaiming savings[1084].

= 80%

**Mid-Life adjustment**

In order to account for the likely replacement of existing heating and cooling equipment during the life time of this measure, a mid-life adjustment should be applied. To calculate the adjustment, re-calculate the savings above using the following new baseline system efficiency assumptions:

| Efficiency Assumption | System Type | New Baseline Efficiency |
|---|---|---|
| ηCool | Central AC | 13 SEER |
| | Heat Pump | 14 SEER |
| ηHeat | Electric Resistance | 1.0 COP |
| | Heat Pump<br>(8.2HSPF/3.413)*0.85 | 2.04 COP |
| | Furnace<br>90% AFUE * 0.85 | 76.5% AFUE |
| | Boiler | 82% AFUE |

This reduced annual savings should be applied following the assumed remaining useful life of the existing equipment, estimate to be 10 years or 13 years for boilers[1085].

## WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

## DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

## MEASURE CODE: RS-SHL-AIRS-V07-190101

## REVIEW DEADLINE: 1/1/2022

[1084] Though we do not have a specific evaluation to point to, modeled savings have often been found to overclaim. Further VEIC reviewed these deemed estimates and consider them to likely be a high estimate. As such an 80% adjustment is applied, and this could be further refined with future evaluations.

[1085] This is intentionally longer than the assumptions found in the early replacement measures as the application of this measure will occur in a variety of homes that will not be targeted for early replacement HVAC systems.

## 5.6.2. Basement Sidewall Insulation

### DESCRIPTION

Insulation is added to a basement or crawl space. Insulation added above ground in conditioned space is modeled the same as wall insulation. Below ground insulation is adjusted with an approximation of the thermal resistance of the ground. Insulation in unconditioned spaces is modeled by reducing the degree days to reflect the smaller but non-zero contribution to heating and cooling load. Cooling savings only consider above grade insulation, as below grade has little temperature difference during the cooling season.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

This measure requires a member of the implementation staff or a participating contractor to evaluate the pre and post R-values and measure surface areas. The requirements for participation in the program will be defined by the utilities.

### DEFINITION OF BASELINE EQUIPMENT

The existing condition will be evaluated by implementation staff or a participating contractor and is likely to be no basement wall or ceiling insulation.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 20 years.[1086]

Note a mid-life adjustment to account for replacement of HVAC equipment during the measure life should be applied after 10 years or 13 years for boilers[1087]. See section below for detail.

### DEEMED MEASURE COST

The actual installed cost for this measure should be used in screening.

### DEEMED O&M COST ADJUSTMENTS

N/A

### LOADSHAPE

Loadshape R08 - Residential Cooling

Loadshape R09 - Residential Electric Space Heat

Loadshape R10 - Residential Electric Heating and Cooling

### COINCIDENCE FACTOR

The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the *average* savings over the defined summer peak period, and is presented so that savings can be bid into PJM's Forward Capacity Market.

---

[1086] As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.

[1087] This is intentionally longer than the assumptions found in the early replacement measures as the application of this measure will occur in a variety of homes that will not be targeted for early replacement HVAC systems.

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Central A/C (during utility peak hour)

= 68%[1088]

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

= 72%%[1089]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period)

= 46.6%[1090]

## Algorithm

### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

Where available savings from shell insulation measures should be determined through a custom analysis. When that is not feasible for the program the following engineering algorithms can be used with the inclusion of an adjustment factor to de-rate the heating savings.

ΔkWh = (ΔkWh_cooling + ΔkWh_heating)

Where:

ΔkWh_cooling = If central cooling, reduction in annual cooling requirement due to insulation

= ((((1/R_old_AG - 1/(R_added+R_old_AG)) * L_basement_wall_total * H_basement_wall_AG * (1-Framing_factor)) * 24 * CDD * DUA) / (1000 * ηCool))) * $ADJ_{BasementCool}$

R_added = R-value of additional spray foam, rigid foam, or cavity insulation.

R_old_AG = R-value value of foundation wall above grade.

= Actual, if unknown assume 1.0[1091]

L_basement_wall_total = Length of basement wall around the entire insulated perimeter (ft)

H_basement_wall_AG = Height of insulated basement wall above grade (ft)

Framing_factor = Adjustment to account for area of framing when cavity insulation is used

= 0% if Spray Foam or External Rigid Foam

= 25% if studs and cavity insulation[1092]

24 = Converts hours to days

CDD = Cooling Degree Days

= Dependent on location and whether basement is conditioned:[1093]

---

[1088] Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

[1089] Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC's 2010 system peak; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.

[1090] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.

[1091] ORNL Builders Foundation Handbook, crawl space data from Table 5-5: Initial Effective R-values for Uninsulated Foundation System and Adjacent Soil, 1991.

[1092] ASHRAE, 2001, "Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP)," Table 7.1

[1093] National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 65°F. There is a county

| Climate Zone (City based upon) | Conditioned CDD 65 | Unconditioned CDD 65[1094] |
|---|---|---|
| 1 (Rockford) | 820 | 263 |
| 2 (Chicago) | 842 | 281 |
| 3 (Springfield) | 1,108 | 436 |
| 4 (Belleville) | 1,570 | 538 |
| 5 (Marion) | 1,370 | 570 |
| Weighted Average[1095] | 947 | 325 |

DUA = Discretionary Use Adjustment (reflects the fact that people do not always operate their AC when conditions may call for it).

= 0.75 [1096]

1000 = Converts Btu to kBtu

ηCool = Seasonal Energy Efficiency Ratio of cooling system (kBtu/kWh)

= Actual (where new or where it is possible to measure or reasonably estimate). If unknown assume the following:[1097]

| Age of Equipment | ηCool Estimate |
|---|---|
| Before 2006 | 10 |
| 2006 - 2014 | 13 |
| Central AC After 1/1/2015 | 13 |
| Heat Pump After 1/1/2015 | 14 |

$ADJ_{BasementCool}$ = Adjustment for cooling savings from basement wall insulation to account for prescriptive engineering algorithms overclaiming savings[1098].

= 80%

ΔkWh_heating = If electric heat (resistance or heat pump), reduction in annual electric heating due to insulation

= ([((1/R_old_AG - 1/(R_added+R_old_AG)) * L_basement_wall_total * H_basement_wall_AG * (1-Framing_factor)) + ((1/(R_old_BG - 1/(R_added+R_old_BG)) * L_basement_wall_total * (H_basement_wall_total - H_basement_wall_AG) * (1-Framing_factor))] * 24 * HDD) / (3,412 * ηHeat)) * $ADJ_{BasementHeat}$

Where

R_old_BG = R-value value of foundation wall below grade (including thermal resistance of

mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

[1094] Five year average cooling degree days with 75F base temp from DegreeDays.net were used in this table because the 30 year climate normals from NCDC used elsewhere are not available at base temps above 72F.

[1095] Weighted based on number of occupied residential housing units in each zone.

[1096] This factor's source is: Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research", p31.

[1097] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Central AC was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.

[1098] As demonstrated in two years of metering evaluation by Opinion Dynamics, see Memo "Results for AIC PY6 HPwES Billing Analysis", dated February 20, 2015. TAC negotiated adjustment factor is 80%.

the earth) [1099]

= dependent on depth of foundation (H_basement_wall_total – H_basement_wall_AG):

= Actual R-value of wall plus average earth R-value by depth in table below

| Below Grade R-value | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Depth below grade (ft) | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Earth R-value (°F-ft$^2$-h/Btu) | 2.44 | 4.50 | 6.30 | 8.40 | 10.44 | 12.66 | 14.49 | 17.00 | 20.00 |
| Average Earth R-value (°F-ft2-h/Btu) | 2.44 | 3.47 | 4.41 | 5.41 | 6.42 | 7.46 | 8.46 | 9.53 | 10.69 |
| Total BG R-value (earth + R-1.0 foundation) default | 3.44 | 4.47 | 5.41 | 6.41 | 7.42 | 8.46 | 9.46 | 10.53 | 11.69 |

H_basement_wall_total = Total height of basement wall (ft)

HDD = Heating Degree Days

= dependent on location and whether basement is conditioned:[1100]

| Climate Zone (City based upon) | Conditioned HDD 60 | Unconditioned HDD 50 |
|---|---|---|
| 1 (Rockford) | 5,352 | 3,322 |
| 2 (Chicago) | 5,113 | 3,079 |
| 3 (Springfield) | 4,379 | 2,550 |
| 4 (Belleville) | 3,378 | 1,789 |
| 5 (Marion) | 3,438 | 1,796 |
| Weighted Average[1101] | 4,860 | 2,895 |

ηHeat = Efficiency of heating system

= Actual (where new or where it is possible to measure or reasonably estimate). If not available refer to default table below:[1102]

| System Type | Age of Equipment | HSPF Estimate | ηHeat (Effective COP Estimate) (HSPF/3.413)*0.85 |
|---|---|---|---|
| Heat Pump | Before 2006 | 6.8 | 1.7 |
| | After 2006 - 2014 | 7.7 | 1.92 |
| | 2015 on | 8.2 | 2.04 |

[1099] Adapted from Table 1, page 24.4, of the 1977 ASHRAE Fundamentals Handbook
[1100] National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 60°F for a conditioned basement and 50°F for an unconditioned basement), consistent with the findings of Belzer and Cort, Pacific Northwest National Laboratory in "Statistical Analysis of Historical State-Level Residential Energy Consumption Trends," 2004. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.
[1101] Weighted based on number of occupied residential housing units in each zone.
[1102] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time means that using the minimum standard is appropriate. An 85% distribution efficiency is then applied to account for duct losses for heat pumps.

| System Type | Age of Equipment | HSPF Estimate | ηHeat (Effective COP Estimate) (HSPF/3.413)*0.85 |
|---|---|---|---|
| Resistance | N/A | N/A | 1 |

$ADJ_{BasementHeat}$ = Adjustment for basement wall insulation to account for prescriptive engineering algorithms overclaiming savings[1103].

= 60%

For example, a single family home in Chicago with a 20 by 25 by 7 foot R-2.25 basement, with 3 feet above grade, insulated with R-13 of interior spray foam, 10.5 SEER Central AC and 2.26 COP Heat Pump:

ΔkWh = (ΔkWh_cooling + ΔkWh_heating)

= [((((1/2.25 - 1/(13 + 2.25))*(20+25+20+25) * 3 * (1 - 0)) * 24 * 281 * 0.75)/(1000 * 10.5)) * 0.8] + [(((((1/2.25 - 1/(13 + 2.25)) * (20+25+20+25) * 3 * (1-0)) + ((1 / (2.25 + 6.42) – 1 / (13 + 2.25 + 6.42)) * (20+25+20+25) * 4 * (1-0))) * 24 * 3079) / (3412 * 1.92)) * 0.6]

= (39.4 + 860.9)

= 900.3 kWh

ΔkWh_heating = If gas *furnace* heat, kWh savings for reduction in fan run time

= ΔTherms * $F_e$ * 29.3

$F_e$ = Furnace Fan energy consumption as a percentage of annual fuel consumption

= 3.14%[1104]

29.3 = kWh per therm

For example, a single family home in Chicago with a 20 by 25 by 7 foot unconditioned basement, with 3 feet above grade, insulated with R-13 of interior spray foam, and a 70% efficient furnace (for therm calculation see Natural Gas Savings section :

= 78.3 * 0.0314 * 29.3

= 72.0 kWh

**SUMMER COINCIDENT PEAK DEMAND**

ΔkW = (ΔkWh_cooling / FLH_cooling) * CF

Where:

FLH_cooling = Full load hours of air conditioning

= dependent on location[1105]:

---

[1103] As demonstrated in two years of metering evaluation by Opinion Dynamics, see Memo "Results for AIC PY6 HPwES Billing Analysis", dated February 20, 2015. TAC negotiated adjustment factor is 60%.

[1104] $F_e$ is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR version 3 criteria for 2% $F_e$. See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference.

[1105] Full load hours for Chicago, Moline and Rockford are provided in "Final Evaluation Report: Central Air Conditioning Efficiency Services (CACES), 2010, Navigant Consulting", p.33. An average FLH/Cooling Degree Day (from NCDC) ratio was calculated for these locations and applied to the CDD of the other locations in order to estimate FLH. There is a county mapping

| Climate Zone (City based upon) | Single Family | Multifamily |
|---|---|---|
| 1 (Rockford) | 512 | 467 |
| 2 (Chicago) | 570 | 506 |
| 3 (Springfield) | 730 | 663 |
| 4 (Belleville) | 1,035 | 940 |
| 5 (Marion) | 903 | 820 |
| Weighted Average[1106] | 629 | 564 |

Use Multifamily if: Building has shared HVAC or meets utility's definition for multifamily

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)

= 68%[1107]

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

= 72%%[1108]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Central A/C (average during peak period)

= 46.6%[1109]

For example, a single family home in Chicago with a 20 by 25 by 7 foot unconditioned basement, with 3 feet above grade, insulated with R-13 of interior spray foam, 10.5 SEER Central AC and 2.26 COP Heat Pump:

$\Delta kW_{SSP}$ = 39.4 / 570 * 0.68

= 0.047 kW

$\Delta kW_{PJM}$ = 39.4 / 570 * 0.466

= 0.032 kW

**NATURAL GAS SAVINGS**

If Natural Gas heating:

ΔTherms = [(([((1/R_old_AG - 1/(R_added+R_old_AG)) * L_basement_wall_total * H_basement_wall_AG * (1-Framing_factor) + (1/(R_old_BG - 1/(R_added+R_old_BG)) * L_basement_wall_total * (H_basement_wall_total - H_basement_wall_AG) * (1-Framing_factor)] * 24 * HDD) / (ηHeat * 100,000)] * $ADJ_{BasementHeat}$

ηHeat = Efficiency of heating system

= Equipment efficiency * distribution efficiency

= Actual (where new or where it is possible to measure or reasonably estimate). If unknown assume 72% for existing system efficiency[1110]

Other factors as defined above

---

table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

[1106] Weighted based on number of occupied residential housing units in each zone.

[1107] Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

[1108] Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC's 2010 system peak; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.

[1109] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.

[1110] Based on average Nicor PY4 nameplate efficiencies derated by 15% for distribution losses.

For example, a single family home in Chicago with a 20 by 25 by 7 foot R-2.25 basement, with 3 feet above grade, insulated with R-13 of interior spray foam, and a 72% efficient furnace:

= (((1/2.25 - 1/(13 + 2.25)) * (20+25+20+25) * 3 * (1-0) + (1/8.67 - 1/(13 + 8.67)) * (20+25+20+25) * 4 * (1 - 0)) * 24 * 3079) / (0.72 * 100,000) * 0.60

= 78.3 therms

**Mid-Life adjustment**

In order to account for the likely replacement of existing heating and cooling equipment during the lifetime of this measure, a mid-life adjustment should be applied. To calculate the adjustment, re-calculate the savings above using the following new baseline system efficiency assumptions:

| Efficiency Assumption | System Type | New Baseline Efficiency |
|---|---|---|
| ηCool | Central AC | 13 SEER |
| | Heat Pump | 14 SEER |
| ηHeat | Electric Resistance | 1.0 COP |
| | Heat Pump (8.2HSPF/3.413)*0.85 | 2.04 COP |
| | Furnace 90% AFUE * 0.85 | 76.5% AFUE |
| | Boiler | 82% AFUE |

This reduced annual savings should be applied following the assumed remaining useful life of the existing equipment, estimate to be 10 years or 13 years for boilers [1111].

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-SHL-BINS-V09-190101**

**REVIEW DEADLINE: 1/1/2020**

[1111] This is intentionally longer than the assumption found in the early replacement measures as the application of this measure will occur in a variety of homes and will not be targeting those homes appropriate for early replacement HVAC systems.

## 5.6.3. Floor Insulation Above Crawlspace

### DESCRIPTION

Insulation is added to the floor above a vented crawl space that does not contain pipes or HVAC equipment. If there are pipes, HVAC, or a basement, it is desirable to keep them within the conditioned space by insulating the crawl space walls and ground. Insulating the floor separates the conditioned space above from the space below the floor, and is only acceptable when there is nothing underneath that could freeze or would operate less efficiently in an environment resembling the outdoors. Even in the case of an empty, unvented crawl space, it is still considered best practice to seal and insulate the crawl space perimeter rather than the floor. Not only is there generally less area to insulate this way, but there are also moisture control benefits. There is a “Basement Insulation” measure for perimeter sealing and insulation. This measure assumes the insulation is installed above an unvented crawl space and should not be used in other situations.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

This measure requires a member of the implementation staff or a participating contractor to evaluate the pre and post R-values and measure surface areas. The requirements for participation in the program will be defined by the utilities.

### DEFINITION OF BASELINE EQUIPMENT

The existing condition will be evaluated by implementation staff or a participating contractor and is likely to be no insulation on any surface surrounding a crawl space.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 20 years.[1112]

Note a mid-life adjustment to account for replacement of HVAC equipment during the measure life should be applied after 10 years or 13 years for boilers[1113]. See section below for detail.

### DEEMED MEASURE COST

The actual installed cost for this measure should be used in screening.

### DEEMED O&M COST ADJUSTMENTS

N/A

### LOADSHAPE

Loadshape R08 - Residential Cooling

Loadshape R09 - Residential Electric Space Heat

Loadshape R10 - Residential Electric Heating and Cooling

### COINCIDENCE FACTOR

The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate

[1112] As recommended in Navigant ‘ComEd Effective Useful Life Research Report’, May 2018.

[1113] This is intentionally longer than the assumptions found in the early replacement measures as the application of this measure will occur in a variety of homes that will not be targeted for early replacement HVAC systems.

peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the *average* savings over the defined summer peak period, and is presented so that savings can be bid into PJM's Forward Capacity Market.

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Central A/C (during utility peak hour)

= 68%[1114]

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

= 72%%[1115]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period)

= 46.6%[1116]

**Algorithm**

## CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

Where available savings from shell insulation measures should be determined through a custom analysis. When that is not feasible for the program the following engineering algorithms can be used with the inclusion of an adjustment factor to de-rate the heating savings.

ΔkWh = (ΔkWh_cooling + ΔkWh_heating)

Where:

ΔkWh_cooling = If central cooling, reduction in annual cooling requirement due to insulation

= ((((1/R_old - 1/(R_added+R_old)) * Area * (1-Framing_factor)) * 24 * CDD * DUA) / (1000 * ηCool))) * $ADJ_{FloorCool}$

R_old = R-value value of floor before insulation, assuming 3/4" plywood subfloor and carpet with pad

= Actual. If unknown assume 3.96 [1117]

R_added = R-value of additional spray foam, rigid foam, or cavity insulation.

Area = Total floor area to be insulated

Framing_factor = Adjustment to account for area of framing

= 12% [1118]

24 = Converts hours to days

CDD = Cooling Degree Days

[1114] Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

[1115] Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC's 2010 system peak; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.

[1116] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.

[1117] Based on 2005 ASHRAE Handbook – Fundamentals: assuming 2x8 joists, 16" OC, ¾" subfloor, ½" carpet with rubber pad, and accounting for a still air film above and below: 1/ [(0.85 cavity share of area / (0.68 + 0.94 + 1.23 + 0.68)) + (0.15 framing share / (0.68 + 7.5" * 1.25 R/in + 0.94 + 1.23 + 0.68))] = 3.96

[1118] ASHRAE, 2001, "Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP)," Table 7.1

| Climate Zone (City based upon) | Unconditioned CDD[1119] |
|---|---|
| 1 (Rockford) | 263 |
| 2 (Chicago) | 281 |
| 3 (Springfield) | 436 |
| 4 (Belleville) | 538 |
| 5 (Marion) | 570 |
| Weighted Average[1120] | 325 |

DUA = Discretionary Use Adjustment (reflects the fact that people do not always operate their AC when conditions may call for it).

= 0.75 [1121]

1000 = Converts Btu to kBtu

ηCool = Seasonal Energy Efficiency Ratio of cooling system (kBtu/kWh)

= Actual (where it is possible to measure or reasonably estimate). If unknown assume the following:[1122]

| Age of Equipment | ηCool Estimate |
|---|---|
| Before 2006 | 10 |
| 2006 - 2014 | 13 |
| Central AC After 1/1/2015 | 13 |
| Heat Pump After 1/1/2015 | 14 |

$ADJ_{FloorCool}$ = Adjustment for cooling savings from floor to account for prescriptive engineering algorithms overclaiming savings[1123].

= 80%

ΔkWh_heating = If electric heat (resistance or heat pump), reduction in annual electric heating due to insulation

= ((((1/R_old - 1/(R_added + R_old)) * Area * (1-Framing_factor) * 24 * HDD)/ (3,412 * ηHeat)) * $ADJ_{FloorHeat}$

HDD = Heating Degree Days:[1124]

---

1119 Five year average cooling degree days with 75F base temp from DegreeDays.net were used in this table because the 30 year climate normals from NCDC used elsewhere are not available at base temps above 72F.

1120 Weighted based on number of occupied residential housing units in each zone.

1121 Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research", p31.

1122 These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Central AC was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.

1123 As demonstrated in two years of metering evaluation by Opinion Dynamics, see Memo "Results for AIC PY6 HPwES Billing Analysis", dated February 20, 2015. TAC negotiated adjustment factor is 80%.

1124 National Climatic Data Center, Heating Degree Days with a base temp of 50°F to account for lower impact of unconditioned space on heating system. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

| Climate Zone (City based upon) | Unconditioned HDD |
|---|---|
| 1 (Rockford) | 3,322 |
| 2 (Chicago) | 3,079 |
| 3 (Springfield) | 2,550 |
| 4 (Belleville) | 1,789 |
| 5 (Marion) | 1,796 |
| Weighted Average[1125] | 2,895 |

ηHeat = Efficiency of heating system

= Actual.If not available refer to default table below:[1126]

| System Type | Age of Equipment | HSPF Estimate | ηHeat (Effective COP Estimate) (HSPF/3.413)*0.85 |
|---|---|---|---|
| Heat Pump | Before 2006 | 6.8 | 1.7 |
| | 2006 - 2014 | 7.7 | 1.92 |
| | 2015 on | 8.2 | 2.04 |
| Resistance | N/A | N/A | 1 |

$ADJ_{FloorHeat}$ = Adjustment for floor insulation to account for prescriptive engineering algorithms overclaiming savings[1127].

= 60%

Other factors as defined above

For example, a single family home in Chicago with a 20 by 25 footprint, insulated with R-30 spray foam above the crawlspace, a 10.5 SEER Central AC and a newer heat pump:

ΔkWh = (ΔkWh_cooling + ΔkWh_heating)

= ((((1/3.96 -1/(30+3.96))*(20*25)*(1-0.12)* 24 * 281*0.75)/(1000*10.5)) * 0.8 + (((1/3.96 - 1/(30+3.96))*(20*25)*(1-0.15) * 24 * 3079)/(3412*1.92)) * 0.6)

= (37.8 + 641.7)

= 679.5 kWh

ΔkWh_heating = If gas *furnace* heat, kWh savings for reduction in fan run time

= ΔTherms * $F_e$ * 29.3

$F_e$ = Furnace Fan energy consumption as a percentage of annual fuel consumption

= 3.14%[1128]

---

[1125] Weighted based on number of occupied residential housing units in each zone.

[1126] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time means that using the minimum standard is appropriate. An 85% distribution efficiency is then applied to account for duct losses for heat pumps.

[1127] As demonstrated in two years of metering evaluation by Opinion Dynamics, see Memo "Results for AIC PY6 HPwES Billing Analysis", dated February 20, 2015. TAC negotiated adjustment factor is 60%.

[1128] $F_e$ is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample

29.3 = kWh per therm

For example, a single family home in Chicago with a 20 by 25 footprint, insulated with R-30 spray foam above the crawlspace, and a 70% efficient furnace (for therm calculation see Natural Gas Savings section):

ΔkWh = 60.4 * 0.0314 * 29.3

= 55.6 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = (ΔkWh_cooling / FLH_cooling) * CF

Where:

FLH_cooling = Full load hours of air conditioning

= Dependent on location:[1129]

| Climate Zone (City based upon) | Single Family | Multifamily |
|---|---|---|
| 1 (Rockford) | 512 | 467 |
| 2 (Chicago) | 570 | 506 |
| 3 (Springfield) | 730 | 663 |
| 4 (Belleville) | 1,035 | 940 |
| 5 (Marion) | 903 | 820 |
| Weighted Average[1130] | 629 | 564 |

Use Multifamily if: Building has shared HVAC or meets utility's definition for multifamily

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)

= 68%[1131]

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

= 72%%[1132]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Central A/C (average during peak period)

= 46.6%[1133]

(non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR version 3 criteria for 2% $F_e$. See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference.

1129 Full load hours for Chicago, Moline and Rockford are provided in "Final Evaluation Report: Central Air Conditioning Efficiency Services (CACES), 2010, Navigant Consulting", p.33. An average FLH/Cooling Degree Day (from NCDC) ratio was calculated for these locations and applied to the CDD of the other locations in order to estimate FLH. There is a county mapping table Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

1130 Weighted based on number of occupied residential housing units in each zone.

1131 Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

1132 Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC's 2010 system peak; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.

1133 Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.

For example, a single family home in Chicago with a 20 by 25 footprint, insulated with R-30 spray foam above the crawlspace, a 10.5 SEER Central AC and a newer heat pump:

$\Delta kW_{SSP}$ = 37.8 / 570 * 0.68

= 0.045 kW

$\Delta kW_{SSP}$ = 37.8 / 570 * 0.466

= 0.031 kW

**NATURAL GAS SAVINGS**

If Natural Gas heating:

$$\Delta Therms = (1/R\_old - 1/(R\_added+R\_old)) * Area * (1-Framing\_factor)) * 24 * HDD) / (100{,}000 * \eta Heat) * ADJ_{FloorHeat}$$

Where

ηHeat = Efficiency of heating system

= Equipment efficiency * distribution efficiency

= Actual (where new or where it is possible to measure or reasonably estimate). If unknown assume 72% for existing system efficiency[1134]

Other factors as defined above

For example, a single family home in Chicago with a 20 by 25 footprint, insulated with R-30 spray foam above the crawlspace, and a 72% efficient furnace:

$\Delta Therms = ((1 / 3.96 – 1 /(30 + 3.96))*(20 * 25) * (1 - 0.12) * 24 * 3079) / (100{,}000 * 0.72) * 0.60$

= 60.4 therms

**Mid-Life adjustment**

In order to account for the likely replacement of existing heating and cooling equipment during the lifetime of this measure, a mid-life adjustment should be applied. To calculate the adjustment, re-calculate the savings above using the following new baseline system efficiency assumptions:

| Efficiency Assumption | System Type | New Baseline Efficiency |
|---|---|---|
| ηCool | Central AC | 13 SEER |
| | Heat Pump | 14 SEER |
| ηHeat | Electric Resistance | 1.0 COP |
| | Heat Pump (8.2HSPF/3.413)*0.85 | 2.04 COP |
| | Furnace 90% AFUE * 0.85 | 76.5% AFUE |
| | Boiler | 82% AFUE |

This reduced annual savings should be applied following the assumed remaining useful life of the existing equipment, estimate to be 10 years or 13 years for boilers [1135].

[1134] Based on average Nicor PY4 nameplate efficiencies derated by 15% for distribution losses.

[1135] This is intentionally longer than the assumption found in the early replacement measures as the application of this measure will occur in a variety of homes and will not be targeting those homes appropriate for early replacement HVAC systems.

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-SHL-FINS-V09-190101**

**REVIEW DEADLINE: 1/1/2020**

## 5.6.4. Wall Insulation

### DESCRIPTION

Insulation is added to wall cavities. This measure requires a member of the implementation staff evaluating the pre and post R-values and measure surface areas. The efficiency of the heating and cooling equipment in the home should also be evaluated if possible.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

This measure requires a member of the implementation staff or a participating contractor to evaluate the pre and post R-values and measure surface areas. The requirements for participation in the program will be defined by the utilities.

### DEFINITION OF BASELINE EQUIPMENT

The existing condition will be evaluated by implementation staff or a participating contractor and is likely to be empty wall cavities.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 20 years.[1136]

Note a mid-life adjustment to account for replacement of HVAC equipment during the measure life should be applied after 10 years or 13 years for boilers[1137]. See section below for detail.

### DEEMED MEASURE COST

The actual installed cost for this measure should be used in screening.

### LOADSHAPE

Loadshape R08 - Residential Cooling

Loadshape R09 - Residential Electric Space Heat

Loadshape R10 - Residential Electric Heating and Cooling

### COINCIDENCE FACTOR

The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the *average* savings over the defined summer peak period, and is presented so that savings can be bid into PJM's Forward Capacity Market.

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Central A/C (during utility peak hour)

= 68%[1138]

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

1136 As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.

1137 This is intentionally longer than the assumptions found in the early replacement measures as the application of this measure will occur in a variety of homes that will not be targeted for early replacement HVAC systems.

1138 Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

= 72%%[1139]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period)

= 46.6%[1140]

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

Where available savings from shell insulation measures should be determined through a custom analysis. When that is not feasible for the program the following engineering algorithms can be used with the inclusion of an adjustment factor to de-rate the heating savings.

ΔkWh = (ΔkWh_cooling + ΔkWh_heating)

Where

ΔkWh_cooling = If central cooling, reduction in annual cooling requirement due to wall insulation

= ((((1/R_old - 1/R_wall) * A_wall * (1-Framing_factor_wall)) * 24 * CDD * DUA) / (1000 * ηCool)) * $ADJ_{WallCool}$

R_wall = R-value of new wall assembly (including all layers between inside air and outside air).

R_old = R-value value of existing assembly and any existing insulation.

(Minimum of R-5 for uninsulated assemblies[1141])

A_wall = Net area of insulated wall ($ft^2$)

Framing_factor_wall = Adjustment to account for area of framing

= 25%[1142]

24 = Converts hours to days

CDD = Cooling Degree Days

= dependent on location:[1143]

| Climate Zone (City based upon) | CDD 65 |
|---|---|
| 1 (Rockford) | 820 |
| 2 (Chicago) | 842 |
| 3 (Springfield) | 1,108 |
| 4 (Belleville) | 1,570 |
| 5 (Marion) | 1,370 |

1139 Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC's 2010 system peak; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.

1140 Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.

1141 An estimate based on review of Madison Gas and Electric, Exterior Wall Insulation, R-value for no insulation in walls, and NREL's Building Energy Simulation Test for Existing Homes (BESTEST-EX).

1142 ASHRAE, 2001, "Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP)," Table 7.1

1143 National Climatic Data Center, Cooling Degree Days are based on a base temp of 65°F. There is a county mapping table Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

| Climate Zone (City based upon) | CDD 65 |
|---|---|
| Weighted Average[1144] | 947 |

DUA = Discretionary Use Adjustment (reflects the fact that people do not always operate their AC when conditions may call for it).

= 0.75 [1145]

1000 = Converts Btu to kBtu

ηCool = Seasonal Energy Efficiency Ratio of cooling system (kBtu/kWh)

= Actual (where new or where it is possible to measure or reasonably estimate). If unknown assume the following:[1146]

| Age of Equipment | ηCool Estimate |
|---|---|
| Before 2006 | 10 |
| 2006 - 2014 | 13 |
| Central AC After 1/1/2015 | 13 |
| Heat Pump After 1/1/2015 | 14 |

$ADJ_{WallCool}$ = Adjustment for cooling savings from wall insulation to account for inaccuracies in prescriptive engineering algorithms[1147]

= 80%

kWh_heating = If electric heat (resistance or heat pump), reduction in annual electric heating due to wall insulation

= ((((1/R_old - 1/R_wall) * A_wall * (1-Framing_factor_wall)) * 24 * HDD) / (ηHeat * 3412)) * $ADJ_{WallHeat}$

HDD = Heating Degree Days

= Dependent on location:[1148]

| Climate Zone (City based upon) | HDD 60 |
|---|---|
| 1 (Rockford) | 5,352 |
| 2 (Chicago) | 5,113 |
| 3 (Springfield) | 4,379 |

[1144] Weighted based on number of occupied residential housing units in each zone.
[1145] This factor's source is: Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research", p31.
[1146] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Central AC was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.
[1147] As demonstrated in two years of metering evaluation by Opinion Dynamics, see Memo "Results for AIC PY6 HPwES Billing Analysis", dated February 20, 2015. TAC negotiated adjustment factor is 80%.
[1148] National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 60°F, consistent with the findings of Belzer and Cort, Pacific Northwest National Laboratory in "Statistical Analysis of Historical State-Level Residential Energy Consumption Trends," 2004. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

| Climate Zone (City based upon) | HDD 60 |
|---|---|
| 4 (Belleville) | 3,378 |
| 5 (Marion) | 3,438 |
| Weighted Average[1149] | 4,860 |

ηHeat = Efficiency of heating system

= Actual (where new or where it is possible to measure or reasonably estimate). If not available refer to default table below:[1150]

| System Type | Age of Equipment | HSPF Estimate | ηHeat (Effective COP Estimate) (HSPF/3.413)*0.85 |
|---|---|---|---|
| Heat Pump | Before 2006 | 6.8 | 1.7 |
| | 2006 - 2014 | 7.7 | 1.92 |
| | 2015 on | 8.2 | 2.04 |
| Resistance | N/A | N/A | 1 |

3412 = Converts Btu to kWh

$ADJ_{WallHeat}$ = Adjustment for heating savings to account for inaccuracies in prescriptive engineering algorithms.[1151]

= 60%

For example, a single family home in Chicago with 990 ft$^2$ of R-5 walls insulated to R-11, 10.5 SEER Central AC and 2.26 (1.92 including distribution losses) COP Heat Pump:

ΔkWh = (ΔkWh_cooling + ΔkWh_heating)

= (((((1/5 - 1/11) * 990 * (1-0.25)) * 842 * 0.75 * 24)/ (1000 * 10.5)) * 80%) + (((((1/5 - 1/11) * 990 * (1-0.25)) * 5113 * 24) / (1.92 * 3412)) * 60%)

= 93.5 + 910

= 1,004 kWh

ΔkWh_heating = If gas *furnace* heat, kWh savings for reduction in fan run time

= ΔTherms * $F_e$ * 29.3

$F_e$ = Furnace Fan energy consumption as a percentage of annual fuel consumption

[1149] Weighted based on number of occupied residential housing units in each zone.

[1150] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time means that using the minimum standard is appropriate. An 85% distribution efficiency is then applied to account for duct losses for heat pumps.

[1151] As demonstrated in two years of metering evaluation by Opinion Dynamics, see Memo "Results for AIC PY6 HPwES Billing Analysis", dated February 20, 2015. TAC negotiated adjustment factor is 60%.[1152] $F_e$ is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR version 3 criteria for 2% $F_e$. See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference.

= 3.14%[1152]

29.3 = kWh per therm

For example, a single family home in Chicago with 990 $ft^2$ of R-5 walls insulated to R-11 with a gas furnace with system efficiency of 66% (for therm calculation see Natural Gas Savings section):

ΔkWh = 90.3 * 0.0314 * 29.3

= 83.1 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = (ΔkWh_cooling / FLH_cooling) * CF

Where:

FLH_cooling = Full load hours of air conditioning

= Dependent on location as below:[1153]

| Climate Zone (City based upon) | Single Family | Multifamily |
|---|---|---|
| 1 (Rockford) | 512 | 467 |
| 2 (Chicago) | 570 | 506 |
| 3 (Springfield) | 730 | 663 |
| 4 (Belleville) | 1,035 | 940 |
| 5 (Marion) | 903 | 820 |
| Weighted Average[1154] | 629 | 564 |

Use Multifamily if: Building has shared HVAC or meets utility's definition for multifamily

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)

= 68%[1155]

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

72%%[1156]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Central A/C (average during peak period)

= 46.6%[1157]

1152 $F_e$ is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR version 3 criteria for 2% $F_e$. See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference.

1153 Based on Full Load Hours from ENERGY STAR with adjustments made in a Navigant Evaluation, other cities were scaled using those results and CDD. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

1154 Weighted based on number of occupied residential housing units in each zone.

1155 Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

1156 Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC's 2010 system peak; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.

1157 Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.

For example, a single family home in Chicago with 990 $ft^2$ of R-5 walls insulated to R-11, 10.5 SEER Central AC, and 2.26 COP Heat Pump:

$\Delta kW_{SSP}$ = 93.5 / 570 * 0.68

= 0.11 kW

$\Delta kW_{PJM}$ = 93.5 / 570 * 0.466

= 0.08 kW

**NATURAL GAS SAVINGS**

If Natural Gas heating:

ΔTherms = ((((1/R_old - 1/R_wall) * A_wall * (1-Framing_factor_wall)) * 24 * HDD) / (ηHeat * 100,000 Btu/therm) * $ADJ_{WallHeat}$

Where:

HDD = Heating Degree Days

= Dependent on location:[1158]

| Climate Zone (City based upon) | HDD 60 |
|---|---|
| 1 (Rockford) | 5,352 |
| 2 (Chicago) | 5,113 |
| 3 (Springfield) | 4,379 |
| 4 (Belleville) | 3,378 |
| 5 (Marion) | 3,438 |
| Weighted Average[1159] | 4,860 |

ηHeat = Efficiency of heating system

= Equipment efficiency * distribution efficiency

= Actual (where new or where it is possible to measure or reasonably estimate).[1160] If unknown assume 72% for existing system efficiency.[1161]

Other factors as defined above

For example, a single family home in Chicago with 990 $ft^2$ of R-5 walls insulated to R-11, with a gas furnace with system efficiency of 66%:

ΔTherms = ((((1/5 - 1/11) * 990 * (1-0.25)) * 24 * 5113) / (0.66 * 100,000)) * 60%

= 90.4 therms

[1158] National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 60°F, consistent with the findings of Belzer and Cort, Pacific Northwest National Laboratory in "Statistical Analysis of Historical State-Level Residential Energy Consumption Trends," 2004. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

[1159] Weighted based on number of occupied residential housing units in each zone.

[1160] Ideally, the System Efficiency should be obtained either by recording the AFUE of the unit, or performing a steady state efficiency test. The Distribution Efficiency can be estimated via a visual inspection and by referring to a look up table such as that provided by the Building Performance Institute: (see 'BPI Distribution Efficiency Table') or by performing duct blaster testing.

[1161] Based on average Nicor PY4 nameplate efficiencies derated by 15% for distribution losses.

**Mid-Life adjustment**

In order to account for the likely replacement of existing heating and cooling equipment during the lifetime of this measure, a mid-life adjustment should be applied. To calculate the adjustment, re-calculate the savings above using the following new baseline system efficiency assumptions:

| Efficiency Assumption | System Type | New Baseline Efficiency |
|---|---|---|
| ηCool | Central AC | 13 SEER |
| | Heat Pump | 14 SEER |
| ηHeat | Electric Resistance | 1.0 COP |
| | Heat Pump<br>(8.2HSPF/3.413)*0.85 | 2.04 COP |
| | Furnace<br>90% AFUE * 0.85 | 76.5% AFUE |
| | Boiler | 82% AFUE |

This reduced annual savings should be applied following the assumed remaining useful life of the existing equipment, estimate to be 10 years or 13 years for boilers [1162].

## Water Impact Descriptions and Calculation

N/A

## Deemed O&M Cost Adjustment Calculation

N/A

**MEASURE CODE: RS-SHL-WINS-V08-190101**

**REVIEW DEADLINE: 1/1/2022**

[1162] This is intentionally longer than the assumption found in the early replacement measures as the application of this measure will occur in a variety of homes and will not be targeting those homes appropriate for early replacement HVAC systems.

## 5.6.5. Ceiling/Attic Insulation

### Description

Insulation is added to attic. This measure requires a member of the implementation staff evaluating the pre and post R-values and measure surface areas. The efficiency of the heating and cooling equipment in the home should also be evaluated if possible.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

This measure requires a member of the implementation staff or a participating contractor to evaluate the pre and post R-values and measure surface areas. The requirements for participation in the program will be defined by the utilities.

### Definition of Baseline Equipment

The existing condition will be evaluated by implementation staff or a participating contractor and is likely to be little or no attic insulation.

### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 20 years.[1163]

Note a mid-life adjustment to account for replacement of HVAC equipment during the measure life should be applied after 10 years or 13 years for boilers[1164]. See section below for detail.

### Deemed Measure Cost

The actual installed cost for this measure should be used in screening.

### Loadshape

Loadshape R08 - Residential Cooling

Loadshape R09 - Residential Electric Space Heat

Loadshape R10 - Residential Electric Heating and Cooling

### Coincidence Factor

The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the *average* savings over the defined summer peak period, and is presented so that savings can be bid into PJM's Forward Capacity Market.

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Central A/C (during utility peak hour)

= 68%[1165]

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

[1163] As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.
[1164] This is intentionally longer than the assumptions found in the early replacement measures as the application of this measure will occur in a variety of homes that will not be targeted for early replacement HVAC systems.
[1165] Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

= 72%%[1166]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period)

= 46.6%[1167]

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

Where available savings from shell insulation measures should be determined through a custom analysis. When that is not feasible for the program the following engineering algorithms can be used with the inclusion of an adjustment factor to de-rate the heating savings.

ΔkWh = (ΔkWh_cooling + ΔkWh_heating)

Where

ΔkWh_cooling = If central cooling, reduction in annual cooling requirement due to celing/attic insulation

= ((((1/R_old - 1/R_attic) * A_attic * (1-Framing_factor_attic)) * 24 * CDD * DUA) / (1000 * ηCool)) * $ADJ_{AtticCool}$

R_attic = R-value of new attic assembly (including all layers between inside air and outside air).

R_old = R-value value of existing assembly and any existing insulation.

(Minimum of R-5 for uninsulated assemblies[1168])

A_attic = Total area of insulated ceiling/attic ($ft^2$)

Framing_factor_attic = Adjustment to account for area of framing

= 7%[1169]

24 = Converts hours to days

CDD = Cooling Degree Days

= dependent on location:[1170]

| Climate Zone (City based upon) | CDD 65 |
|---|---|
| 1 (Rockford) | 820 |
| 2 (Chicago) | 842 |
| 3 (Springfield) | 1,108 |
| 4 (Belleville) | 1,570 |
| 5 (Marion) | 1,370 |

[1166] Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC's 2010 system peak; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.
[1167] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.
[1168] An estimate based on review of Madison Gas and Electric, Exterior Wall Insulation, R-value for no insulation in walls, and NREL's Building Energy Simulation Test for Existing Homes (BESTEST-EX).
[1169] Ibid.
[1170] National Climatic Data Center, Cooling Degree Days are based on a base temp of 65°F. There is a county mapping table Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

| Climate Zone (City based upon) | CDD 65 |
|---|---|
| Weighted Average[1171] | 947 |

DUA = Discretionary Use Adjustment (reflects the fact that people do not always operate their AC when conditions may call for it).

= 0.75 [1172]

1000 = Converts Btu to kBtu

ηCool = Seasonal Energy Efficiency Ratio of cooling system (kBtu/kWh)

= Actual (where new or where it is possible to measure or reasonably estimate). If unknown assume the following[1173]:

| Age of Equipment | SEER Estimate |
|---|---|
| Before 2006 | 10 |
| 2006 - 2014 | 13 |
| Central AC After 1/1/2015 | 13 |
| Heat Pump After 1/1/2015 | 14 |

$ADJ_{AtticCool}$ = Adjustment for cooling savings to account for inaccuracies in engineering algorithms[1174]

= 121%

kWh_heating = If electric heat (resistance or heat pump), reduction in annual electric heating due to attic insulation

= ((((1/R_old - 1/R_attic) * A_attic * (1-Framing_factor_attic)) * 24 * HDD) / (ηHeat * 3412)) * $ADJ_{AtticElectricHeat}$

HDD = Heating Degree Days

= Dependent on location:[1175]

| Climate Zone (City based upon) | HDD 60 |
|---|---|
| 1 (Rockford) | 5,352 |
| 2 (Chicago) | 5,113 |
| 3 (Springfield) | 4,379 |

[1171] Weighted based on number of occupied residential housing units in each zone.

[1172] This factor's source is: Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research", p31.

[1173] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Central AC was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.

[1174] As demonstrated in air sealing and insulation research by Navigant, see Navigant (2018). C*omEd and Nicor Gas Air Sealing and Insulation Research Report.* Presented to Commonwealth Edison Company and Nicor Gas Company.

[1175] National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 60°F, consistent with the findings of Belzer and Cort, Pacific Northwest National Laboratory in "Statistical Analysis of Historical State-Level Residential Energy Consumption Trends," 2004. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

| Climate Zone (City based upon) | HDD 60 |
|---|---|
| 4 (Belleville) | 3,378 |
| 5 (Marion) | 3,438 |
| Weighted Average[1176] | 4,860 |

ηHeat = Efficiency of heating system

= Actual (where new or where it is possible to measure or reasonably estimate). If not available refer to default table below[1177]:

| System Type | Age of Equipment | HSPF Estimate | ηHeat (Effective COP Estimate)= (HSPF/3.413)*0.85 |
|---|---|---|---|
| Heat Pump | Before 2006 | 6.8 | 1.7 |
| | 2006 - 2014 | 7.7 | 1.92 |
| | 2015 on | 8.2 | 2.04 |
| Resistance | N/A | N/A | 1 |

3412 = Converts Btu to kWh

$ADJ_{AtticElectricHeat}$ = Adjustment for electric heating savings to account for inaccuracies in engineering algorithms[1178]

= 60%

The following example captures energy savings from ceiling/attic insulation. Energy savings for air sealing are included in a separate example in Section 5.6.1: Air Sealing.

For example, a single family home in Chicago installs 700 ft$^2$ of attic insulation, completes air sealing, has 10.5 SEER Central AC and 2.26 (1.92 including distribution losses) COP Heat Pump, and has pre and post attic insulation R-values of R-5 and R-38, respectively:

ΔkWh = (ΔkWh_cooling + ΔkWh_heating)

= (((((1/5 - 1/38) * 700 * (1-0.07)) * 842 * 0.75 * 24)/ (1000 * 10.5)) * 121%) + (((((1/5 - 1/38) * 700 * (1-0.07)) * 5113 * 24) / (1.92 * 3412)) * 60%)

= 197 + 1,271

= 1,468 kWh

ΔkWh_heating = If gas *furnace* heat, kWh savings for reduction in fan run time

= ΔTherms * $F_e$ * 29.3 * $ADJ_{AtticHeatFan}$

$F_e$ = Furnace Fan energy consumption as a percentage of annual fuel consumption

= 3.14%[1179]

[1176] Weighted based on number of occupied residential housing units in each zone.

[1177] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time means that using the minimum standard is appropriate. An 85% distribution efficiency is then applied to account for duct losses for heat pumps.

[1178] As demonstrated in air sealing and insulation research by Navigant, Navigant (2018). C*omEd and Nicor Gas Air Sealing and Insulation Research Report.* Presented to Commonwealth Edison Company and Nicor Gas Company.

[1179] $F_e$ is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a

29.3 = kWh per therm

$ADJ_{AtticHeatFan}$ = Adjustment for fan savings to account for innacuracies in engineering algorithms[1180]

= 107%

The following example captures energy savings from ceiling/attic insulation. Energy savings for air sealing are included in a separate example in Section 5.6.1: Air Sealing.

For example, a single family home in Chicago installs 700 $ft^2$ of attic insulation, completes air sealing, has a gas furnace with system efficiency of 66% (for therm calculation see Natural Gas Savings section), and has pre and post attic insulation R-values of R-5 and R-38, respectively:

ΔkWh = 147 * 0.0314 * 29.3 * 107%

= 145 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = (ΔkWh_cooling / FLH_cooling) * CF

Where:

FLH_cooling = Full load hours of air conditioning

= Dependent on location as below:[1181]

| Climate Zone (City based upon) | Single Family | Multifamily |
|---|---|---|
| 1 (Rockford) | 512 | 467 |
| 2 (Chicago) | 570 | 506 |
| 3 (Springfield) | 730 | 663 |
| 4 (Belleville) | 1,035 | 940 |
| 5 (Marion) | 903 | 820 |
| Weighted Average[1182] | 629 | 564 |

Use Multifamily if: Building has shared HVAC or meets utility's definition for multifamily

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)

= 68%[1183]

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

72%%[1184]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Central A/C (average during peak period)

calculation based on the certified values for fuel energy (Ef in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR version 3 criteria for 2% $F_e$. See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference.

1180 As demonstrated in air sealing and insulation research by Navigant, see Navigant (2018). C*omEd and Nicor Gas Air Sealing and Insulation Research Report.* Presented to Commonwealth Edison Company and Nicor Gas Company.

1181 Based on Full Load Hours from ENERGY STAR with adjustments made in a Navigant Evaluation, other cities were scaled using those results and CDD. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

1182 Weighted based on number of occupied residential housing units in each zone.

1183 Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

1184 Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC's 2010 system peak; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.

= 46.6%[1185]

The following example captures energy savings from ceiling/attic insulation. Energy savings for air sealing are included in a separate example in Section 5.6.1: Air Sealing.

For example, a single family home in Chicago installs 700 ft² of attic insulation, has 10.5 SEER Central AC and 2.26 COP Heat Pump, and has pre and post attic insulation R-values of R-5 and R-38, respectively:

$\Delta kW_{SSP}$ = 197 / 570 * 0.68

= 0.24 kW

$\Delta kW_{PJM}$ = 168 / 570 * 0.466

= 0.16 kW

**NATURAL GAS SAVINGS**

If Natural Gas heating:

$$\Delta Therms = ((((1/R\_old - 1/R\_attic) * A\_attic * (1-Framing\_factor\_attic)) * 24 * HDD) / (\eta Heat * 100{,}000\ Btu/therm) * ADJ_{AtticGasHeat}$$

Where:

HDD = Heating Degree Days

= Dependent on location:[1186]

| Climate Zone (City based upon) | HDD 60 |
|---|---|
| 1 (Rockford) | 5,352 |
| 2 (Chicago) | 5,113 |
| 3 (Springfield) | 4,379 |
| 4 (Belleville) | 3,378 |
| 5 (Marion) | 3,438 |
| Weighted Average[1187] | 4,860 |

ηHeat = Efficiency of heating system

= Equipment efficiency * distribution efficiency

= Actual[1188] (where new or where it is possible to measure or reasonably estimate). If not available use 72% for existing system efficiency[1189].

$ADJ_{AtticGasHeat}$ = Adjustment for gas heating savings to account for inaccuracies in engineering algorithms[1190]

[1185] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.

[1186] National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 60°F, consistent with the findings of Belzer and Cort, Pacific Northwest National Laboratory in "Statistical Analysis of Historical State-Level Residential Energy Consumption Trends," 2004. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

[1187] Weighted based on number of occupied residential housing units in each zone.

[1188] Ideally, the System Efficiency should be obtained either by recording the AFUE of the unit, or performing a steady state efficiency test. The Distribution Efficiency can be estimated via a visual inspection and by referring to a look up table such as that provided by the Building Performance Institute: (see 'BPI Distribution Efficiency Table') or by performing duct blaster testing.

[1189] Based on average Nicor PY4 nameplate efficiencies derated by 15% for distribution losses.

[1190] As demonstrated in air sealing and insulation research by Navigant, Navigant (2018). C*omEd and Nicor Gas Air Sealing and*

= 72%

Other factors as defined above

The following example captures energy savings from ceiling/attic insulation. Energy savings for air sealing are included in a separate example in Section 5.6.1: Air Sealing.

For example, a single family home in Chicago installs 700 $ft^2$ of attic insulation, has a gas furnace with system efficiency of 66%, and has pre and post attic insulation R-values of R-5 and R-38, respectively:

ΔTherms = ((((1/5 - 1/38) * 700 * (1-0.07)) * 24 * 5113) / (0.66 * 100,000)) * 72%

= 151 therms

**Mid-Life adjustment**

In order to account for the likely replacement of existing heating and cooling equipment during the lifetime of this measure, a mid-life adjustment should be applied. To calculate the adjustment, re-calculate the savings above using the following new baseline system efficiency assumptions:

| Efficiency Assumption | System Type | New Baseline Efficiency |
|---|---|---|
| ηCool | Central AC | 13 SEER |
| | Heat Pump | 14 SEER |
| ηHeat | Electric Resistance | 1.0 COP |
| | Heat Pump<br>(8.2HSPF/3.413)*0.85 | 2.04 COP |
| | Furnace<br>90% AFUE * 0.85 | 76.5% AFUE |
| | Boiler | 82% AFUE |

This reduced annual savings should be applied following the assumed remaining useful life of the existing equipment, estimate to be 10 years or 13 years for boilers [1191].

## WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

## DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

## MEASURE CODE: RS-SHL-AINS-V01-190101

## REVIEW DEADLINE: 1/1/2022

*Insulation Research Report.* Presented to Commonwealth Edison Company and Nicor Gas Company.

[1191] This is intentionally longer than the assumption found in the early replacement measures as the application of this measure will occur in a variety of homes and will not be targeting those homes appropriate for early replacement HVAC systems.

## 5.6.6. Rim/Band Joist Insulation

### Description

This measure describes savings from adding insulation (either rigid or spray foam) to rim/band joist cavities. This measure requires a member of the implementation staff evaluating the pre- and post-project R-values and to measure surface areas. The efficiency of the heating and cooling equipment in the home should also be evaluated if possible.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

### Definition of Efficient Equipment

This measure requires a member of the implementation staff or a participating contractor to evaluate the pre and post R-values and measure surface areas. The requirements for participation in the program will be defined by the utilities.

### Definition of Baseline Equipment

The existing condition will be evaluated by implementation staff or a participating contractor and is likely to be empty wall cavities and little or no attic insulation.

### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 20 years.[1192]

Note a mid-life adjustment to account for replacement of HVAC equipment during the measure life should be applied after 10 years or 13 years for boilers[1193]. See section below for detail.

### Deemed Measure Cost

The actual installed cost for this measure should be used in screening.

### Loadshape

Loadshape R08 - Residential Cooling

Loadshape R09 - Residential Electric Space Heat

Loadshape R10 - Residential Electric Heating and Cooling

### Coincidence Factor

The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the *average* savings over the defined summer peak period, and is presented so that savings can be bid into PJM's Forward Capacity Market.

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Central A/C (during utility peak hour)

= 68%[1194]

[1192] As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.

[1193] This is intentionally longer than the assumptions found in the early replacement measures as the application of this measure will occur in a variety of homes that will not be targeted for early replacement HVAC systems.

[1194] Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

= 72%%[1195]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period)

= 46.6%[1196]

**Algorithm**

### CALCULATION OF SAVINGS

### ELECTRIC ENERGY SAVINGS

Where available savings from shell insulation measures should be determined through a custom analysis. When that is not feasible for the program the following engineering algorithms can be used with the inclusion of an adjustment factor to de-rate the heating savings.

ΔkWh = (ΔkWh_cooling + ΔkWh_heating)

Where

ΔkWh_cooling = If central cooling, reduction in annual cooling requirement due to insulation

$$= \frac{\left(\frac{1}{R_{Old}} - \frac{1}{R_{Rim}}\right) * A_{Rim} * (1 - FramingFactor_{Rim}) * CDD * 24 * DUA * ADJ_{BasementCool}}{(1000 * \eta Cool)}$$

$R_{Rim}$ = R-value of new rim/band joist assembly (including all layers between inside air and outside air).

$R_{old}$ = R-value value of existing assembly and any existing insulation.

(Minimum of R-5 for uninsulated assemblies[1197])

$A_{Rim}$ = Net area of insulated rim/band joist ($ft^2$)

$FramingFactor_{Rim}$ = Adjustment to account for area of framing

= 5%[1198]

24 = Converts hours to days

CDD = Cooling Degree Days

= dependent on location:[1199]

| Climate Zone (City based upon) | Conditioned CDD 65 | Unconditioned CDD 75[1200] |
|---|---|---|
| 1 (Rockford) | 820 | 263 |

[1195] Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC's 2010 system peak; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.

[1196] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.

[1197] An estimate based on review of Madison Gas and Electric, Exterior Wall Insulation, R-value for no insulation in walls, and NREL's Building Energy Simulation Test for Existing Homes (BESTEST-EX).

[1198] Assumes the average framing factor for joists running from front-to-back (0.094) and from side-to-side (0). The front-to-back FF was calculated based on 1.5" joists for every 16" (1.5"/16" = 0.094). The side-to-side FF is 0 since joists are continuous and uninterrupted.

[1199] National Climatic Data Center, Cooling Degree Days are based on a base temp of 65°F. There is a county mapping table Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

[1200] Five year average cooling degree days with 75F base temp from DegreeDays.net were used in this table because the 30 year

| Climate Zone (City based upon) | Conditioned CDD 65 | Unconditioned CDD 75[1200] |
|---|---|---|
| 2 (Chicago) | 842 | 281 |
| 3 (Springfield) | 1,108 | 436 |
| 4 (Belleville) | 1,570 | 538 |
| 5 (Marion) | 1,370 | 570 |
| Weighted Average[1201] | 947 | 325 |

DUA = Discretionary Use Adjustment (reflects the fact that people do not always operate their AC when conditions may call for it).

= 0.75 [1202]

1000 = Converts Btu to kBtu

ηCool = Seasonal Energy Efficiency Ratio of cooling system (kBtu/kWh)

= Actual (where new or where it is possible to measure or reasonably estimate). If unknown assume the following[1203]:

| Age of Equipment | SEER Estimate |
|---|---|
| Before 2006 | 10 |
| 2006 - 2014 | 13 |
| Central AC After 1/1/2015 | 13 |
| Heat Pump After 1/1/2015 | 14 |

$ADJ_{BasementCool}$ = Adjustment for cooling savings from basement wall and rim/band joist insulation to account for prescriptive engineering algorithms overclaiming savings[1204].

= 80%

kWh_heating = If electric heat (resistance or heat pump), reduction in annual electric heating due to insulation

$$= \frac{\left(\frac{1}{R_{old}} - \frac{1}{R_{Rim}}\right) * A_{Rim} * (1 - FramingFactor_{Rim}) * HDD * 24 * ADJ_{BasementHeat}}{(\eta Heat * 3412)}$$

HDD = Heating Degree Days

= Dependent on location:[1205]

climate normals from NCDC used elsewhere are not available at base temps above 72F.

1201 Weighted based on number of occupied residential housing units in each zone.

1202 This factor's source is: Energy Center of Wisconsin, May 2008 metering study; “Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research”, p31.

1203 These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Central AC was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.

1204 As demonstrated in two years of metering evaluation by Opinion Dynamics, see Memo “Results for AIC PY6 HPwES Billing Analysis”, dated February 20, 2015. TAC negotiated adjustment factor is 80%.

1205 National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 60°F for a conditioned basement and 50°F for an unconditioned basement, consistent with the findings of Belzer and Cort, Pacific Northwest National Laboratory in “Statistical Analysis of Historical State-Level Residential Energy Consumption Trends,” 2004. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

| Climate Zone (City based upon) | Conditioned HDD 60 | Unconditioned HDD 50 |
|---|---|---|
| 1 (Rockford) | 5,352 | 3,322 |
| 2 (Chicago) | 5,113 | 3,079 |
| 3 (Springfield) | 4,379 | 2,550 |
| 4 (Belleville) | 3,378 | 1,789 |
| 5 (Marion) | 3,438 | 1,796 |
| Weighted Average[1206] | 4,860 | 2,895 |

ηHeat = Efficiency of heating system

= Actual (where new or where it is possible to measure or reasonably estimate). If not available refer to default table below[1207]:

| System Type | Age of Equipment | HSPF Estimate | ηHeat (Effective COP Estimate)= (HSPF/3.413)*0.85 |
|---|---|---|---|
| Heat Pump | Before 2006 | 6.8 | 1.7 |
| | 2006 - 2014 | 7.7 | 1.92 |
| | 2015 on | 8.2 | 2.04 |
| Resistance | N/A | N/A | 1 |

3412 = Converts Btu to kWh

$ADJ_{BasementHeat}$ = Adjustment for basement wall and rim/band joist insulation to account for prescriptive engineering algorithms overclaiming savings[1208].

= 60%

For example, a single family home in Chicago with 100 $ft^2$ of uninsulated rim joist cavities in an unconditioned basement that is insulated to R-13. The home has 10.5 SEER Central AC and 2.26 (1.92 including distribution losses) COP Heat Pump:

ΔkWh = (ΔkWh_cooling + ΔkWh_heating)

= (((1/5 - 1/13) * 100 * (1-0.05) * 281 * 24 * 0.75) / (1000 * 10.5)) + (((1/5 - 1/13) * 100 * (1-0.05) * 3079 * 24 * 0.60) / (1.92 * 3412))

= 5.6 + 79.1

= 84.7 kWh

ΔkWh_heating = If gas *furnace* heat, kWh savings for reduction in fan run time

[1206] Weighted based on number of occupied residential housing units in each zone.

[1207] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time means that using the minimum standard is appropriate. An 85% distribution efficiency is then applied to account for duct losses for heat pumps.

[1208] As demonstrated in two years of metering evaluation by Opinion Dynamics, see Memo "Results for AIC PY6 HPwES Billing Analysis", dated February 20, 2015. TAC negotiated adjustment factor is 60%.

= ΔTherms * $F_e$ * 29.3

$F_e$ = Furnace Fan energy consumption as a percentage of annual fuel consumption

= 3.14%[1209]

29.3 = kWh per therm

> For example, a single family home in Chicago with 100 ft$^2$ of uninsulated rim joist cavities in an unconditioned basement that is insulated to R-13. The home has a gas furnace with system efficiency of 66% (for therm calculation see Natural Gas Savings section):
>
> ΔkWh = 7.85 * 0.0314 * 29.3
>
> = 7.2 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = (ΔkWh_cooling / FLH_cooling) * CF

Where:

FLH_cooling = Full load hours of air conditioning

= Dependent on location as below:[1210]

| Climate Zone (City based upon) | Single Family | Multifamily |
|---|---|---|
| 1 (Rockford) | 512 | 467 |
| 2 (Chicago) | 570 | 506 |
| 3 (Springfield) | 730 | 663 |
| 4 (Belleville) | 1,035 | 940 |
| 5 (Marion) | 903 | 820 |
| Weighted Average[1211] | 629 | 564 |

Use Multifamily if: Building has shared HVAC or meets utility's definition for multifamily

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)

= 68%[1212]

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

72%%[1213]

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Central A/C (average during peak period)

---

[1209] $F_e$ is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the ENERGY STAR version 3 criteria for 2% $F_e$. See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference.

[1210] Based on Full Load Hours from ENERGY STAR with adjustments made in a Navigant Evaluation, other cities were scaled using those results and CDD. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

[1211] Weighted based on number of occupied residential housing units in each zone.

[1212] Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

[1213] Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC's 2010 system peak; 'Impact and Process Evaluation of Ameren Illinois Company's Residential HVAC Program (PY5)'.

= 46.6%[1214]

> For example, a single family home in Chicago with 100 ft$^2$ of uninsulated rim joist cavities in an unconditioned basement that is insulated to R-13. The home has 10.5 SEER Central AC and 2.26 (1.92 including distribution losses) COP Heat Pump:
>
> $\Delta kW_{SSP}$ = 5.6 / 570 * 0.68
>
> = 0.0067 kW
>
> $\Delta kW_{PJM}$ = 5.6 / 570 * 0.466
>
> = 0.0046 kW

**NATURAL GAS SAVINGS**

If Natural Gas heating:

$$= \frac{\left(\frac{1}{R_{old}} - \frac{1}{R_{Rim}}\right) * A_{Rim} * (1 - FramingFactor_{Rim}) * HDD * 24 * ADJ_{BasementHeat}}{(\eta Heat * 100{,}000)}$$

Where:

ηHeat = Efficiency of heating system

= Equipment efficiency * distribution efficiency

= Actual[1215] (where new or where it is possible to measure or reasonably estimate). If not available use 72% for existing system efficiency[1216].

Other factors as defined above

> For example, a single family home in Chicago with 100 ft$^2$ of uninsulated rim joist cavities in an unconditioned basement that is insulated to R-13. The home has a gas furnace with system efficiency of 66%:
>
> ΔTherms = ((1/5 - 1/13) * 100 * (1-0.05) * 3079 * 24 * 0.60) / (0.66 * 100,000)
>
> = 7.85 therms

**Mid-Life adjustment**

In order to account for the likely replacement of existing heating and cooling equipment during the lifetime of this measure, a mid-life adjustment should be applied. To calculate the adjustment, re-calculate the savings above using the following new baseline system efficiency assumptions:

| Efficiency Assumption | System Type | New Baseline Efficiency |
|---|---|---|
| ηCool | Central AC | 13 SEER |
| | Heat Pump | 14 SEER |
| ηHeat | Electric Resistance | 1.0 COP |
| | Heat Pump (8.2HSPF/3.413)*0.85 | 2.04 COP |
| | Furnace | 76.5% AFUE |

[1214] Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.

[1215] Ideally, the System Efficiency should be obtained either by recording the AFUE of the unit, or performing a steady state efficiency test. The Distribution Efficiency can be estimated via a visual inspection and by referring to a look up table such as that provided by the Building Performance Institute: (see 'BPI Distribution Efficiency Table') or by performing duct blaster testing.

[1216] Based on average Nicor PY4 nameplate efficiencies derated by 15% for distribution losses.

| Efficiency Assumption | System Type | New Baseline Efficiency |
|---|---|---|
| | 90% AFUE * 0.85 | |
| | Boiler | 82% AFUE |

This reduced annual savings should be applied following the assumed remaining useful life of the existing equipment, estimate to be 10 years or 13 years for boilers [1217].

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-SHL-RINS-V01-190101**

**REVIEW DEADLINE: 1/1/2024**

[1217] This is intentionally longer than the assumption found in the early replacement measures as the application of this measure will occur in a variety of homes and will not be targeting those homes appropriate for early replacement HVAC systems.

# 5.7 Miscellaneous

## 5.7.1 High Efficiency Pool Pumps

### DESCRIPTION

Conventional residential outdoor pool pumps are single speed, often oversized, and run frequently at constant flow regardless of load. Single speed pool pumps require that the motor be sized for the task that requires the highest speed. As such, energy is wasted performing low speed tasks at high speed. Two speed and variable speed pool pumps reduce speed when less flow is required, such as when filtering is needed but not cleaning, and have timers that encourage programming for fewer on-hours. Variable speed pool pumps use advanced motor technologies to achieve efficiency ratings of 90% while the average single speed pump will have efficiency ratings between 30% and 70%[1218]. This measure is the characterization of the purchasing and installing of an efficient two speed or variable speed residential pool pump motor in place of a standard single speed motor of equivalent horsepower.

This measure was developed to be applicable to the following program types: TOS, NC, RF.

If applied to other program types, the measure savings should be verified.

### DEFINITION OF EFFICIENT EQUIPMENT

The high efficiency equipment is a two speed or variable speed residential pool pump meeting the ENERGY STAR minimum qualifications for either in-ground or above ground pools. ENERGY STAR version 2.0 specification takes effect on January 1, 2019 and version 3.0 has an effective date of July 19, 2021.

| Pump Sub-Type | Size Class | ENERGY STAR Version 2.0 Energy Efficiency Level (Effective 1/1/2019) | ENERGY STAR Version 3.0 Energy Efficiency Level (Effective 7/19/2021) |
|---|---|---|---|
| Self-Priming (Inground) Pool Pumps | Extra Small (hhp ≤ 0.13) | WEF ≥ 7.60 | WEF ≥ 13.40 |
| | Small (hhp > 0.13 and < 0.711) | WEF ≥ -1.30 x ln (hhp) + 4.95 | WEF ≥ -2.45 x ln (hhp) + 8.40 |
| | Standard Size (hhp ≥ 0.711) | WEF ≥ -2.30 x ln (hhp) + 6.59 | WEF ≥ -2.45 x ln (hhp) + 8.40 |
| Non-Self Priming (Aboveground) Pool Pumps | Extra Small (hhp ≤ 0.13) | WEF ≥ 4.92 | WEF ≥ 4.92 |
| | Standard Size (hhp > 0.13) | WEF ≥ -1.00 x ln (hhp) + 3.85 | WEF ≥ -1.00 x ln (hhp) + 3.85 |

### DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a single speed residential pool pump.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The estimated useful life for a two speed or variable speed pool pump is 7 years[1219].

### DEEMED MEASURE COST

The incremental costs for in-ground pool pumps are estimated as $235 for a two speed motor and $549 for a variable speed motor[1220].

The incremental costs for above ground pool pumps are estimated as $200 for a two speed motor and $1,130 for a

[1218] U.S. DOE, 2012. Measure Guideline: Replacing Single-Speed Pool Pumps with Variable Speed Pumps for Energy Savings. Report No. DOE/GO-102012-3534.
[1219] As recommended in Navigant 'ComEd Effective Useful Life Research Report', May 2018.
[1220] ENERGY STAR Pool Pump Calculator.

variable speed motor.[1221]

**LOADSHAPE**

Loadshape R15 – Residential Pool Pumps

**COINCIDENCE FACTOR**

The coincidence factor for this measure is assumed to be 0.831[1222].

## Algorithm

**CALCULATION OF ENERGY SAVINGS**

**ELECTRIC ENERGY SAVINGS[1223]**

$\Delta kWh_{two\ speed} = (((Hrs/Day_{base} * GPM_{base} * 60)/EF_{base}) - (((Hrs/Day_{2spH} * GPM_{2spH} * 60) + (Hrs/Day_{2spL} * GPM_{2spL} * 60))/WEF_{2sp}))/1000 * Days$

$\Delta kWh_{variable\ speed} = (((Hrs/Day_{base} * GPM_{base} * 60)/EF_{base}) - (((Hrs/Day_{vsH} * GPM_{vsH} * 60)/ + (Hrs/Day_{vsL} * GPM_{vsL} * 60)/)/WEF_{vs}))/1000 * Days$

Where:

$Hrs/Day_{base}$ = run hours of single speed pump

= 11.4 hours for in-ground pools

= 7.0 hours for above ground pools

$GPM_{base}$ = flow of single speed pump (gal/min)

= 64.4 gal/min for in-ground pools

= 36 gal/min for above ground pools

60 = minutes per hour

$EF_{base}$ = Energy Factor of baseline single speed pump (gal/Wh)

= 2.1

$Hrs/Day_{2spH}$ = run hours of two speed pump at high speed

= 2 hours for in-ground pools

= 1.2 hours for above ground pools

$GPM_{2spH}$ = flow of two speed pump at high speed (gal/min)

= 56 gal/min for in-ground pools

= 31 gal/min for above ground pools

1221 CEE Efficient Residential Swimming Pool Initiative, December 2012, page 18.

1222 Based on assumptions of daily load pattern through pool season. Assumption was developed for Efficiency Vermont but is considered a reasonable estimate for Illinois.

1223 The methodology and all assumptions are sourced from the ENERGY STAR Pool Pump Calculator and assume a nameplate horsepower of 1.5 and a pool size of 22,000 gallons, with 2.0 turnovers per day in the base case and 1.6 turnovers per day in the efficient case. For above ground pools, the turnover ratios were kept the same with the pool size being 7,540 gallons. The volume of the above ground pool is sourced from the California Urban Water Council Evaluation of Potential Best Management Practices for Pools, Spas, and Fountains for the average above ground residential pool.

$Hrs/Day_{2spL}$ = run hours of two speed pump at low speed

= 15.7 hours for in-ground pools

= 9.6 hours for above ground pools

$GPM_{2spL}$ = flow of two speed pump at low speed (gal/min)

= 31 gal/min for in-ground pools

= 17 gal/min for above ground pools

WEF = Weighted Energy Factor of the efficient pump (gal/Wh), dependent on the pool application and motor designation, as detailed in the table below[1224]:

| Pump Sub-Type | Motor Design | ENERGY STAR Version 2.0 WEF (gal/Wh) | ENERGY STAR Version 3.0 WEF (gal/Wh) |
|---|---|---|---|
| Self-Priming (Inground) Pool Pumps | Multi-speed ($WEF_{2sp}$) | 5.31 | 8.44 |
| | Variable-speed ($WEF_{vs}$) | 6.6 | 11.05 |
| Non-Self Priming (Aboveground) Pool Pumps | Multi-speed ($WEF_{2sp}$) | 3.55 | 3.55 |
| | Variable-speed ($WEF_{vs}$) | 4.21 | 4.21 |

$Hrs/Day_{vsH}$ = run hours of variable speed pump at high speed

= 2 hours for in-ground pools

= 1.2 hours for above ground pools

$GPM_{vsH}$ = flow of variable speed pump at high speed (gal/min)

= 50 gal/min for in-ground pools

= 28 gal/min for above ground pools

$Hrs/Day_{vsL}$ = run hours of variable speed pump at low speed

= 16 hours for in-ground pools

= 9.8 hours for above ground pools

$GPM_{vsL}$ = flow of variable speed pump at low speed (gal/min)

= 30.6 gal/min for in-ground pools

= 17 gal/min for above ground pools

Days = Number of days per year that the swimming pool is operational

= 125[1225]

Based on the pool/pump application and the motor designation, the annual energy savings (ΔkWh) are detailed in the table below:

[1224] The efficient Weighted Energy Factor is sourced from a weighted average of products meeting the ENERGY STAR minimum qualifications and listed on their Qualified Products List (QPL), as accessed on 04/26/2018. As pump applications were not designated in the ENERGY STAR QPL, equipment sizes and horsepower were assumed similar between aboveground and inground pools.

[1225] Assumes 50% of pools operated from Memorial Day through Labor Day (100 days) and 50% of pools operate for a longer span, typically the 5 month period between May and September (150 days), due to their ability to heat the pool.

| Pump Sub-Type | Motor Design | Annual Energy Savings (ΔkWh) ENERGY STAR Version 2.0 | Annual Energy Savings (ΔkWh) ENERGY STAR Version 3.0 |
|---|---|---|---|
| Self-Priming (Inground) Pool Pumps | Multi-speed | 1,776 | 2,090 |
| | Variable-speed | 1,952 | 2,222 |
| Non-Self Priming (Aboveground) Pool Pumps | Multi-speed | 465 | 465 |
| | Variable-speed | 539 | 539 |

**SUMMER COINCIDENT PEAK DEMAND SAVINGS** [1226]

ΔkW two speed = $((kWh/day_{base})/(Hrs/day_{base}) - (kWh/day_{2sp})/(Hr/day_{2sp})) * CF$

ΔkW variable speed = $((kWh/day_{base})/(Hrs/day_{base}) - (kWh/day_{vr})/(Hr/day_{vr})) * CF$

Where:

$kWh/day_{base}$ = daily energy consumption of baseline pump, as defined above

= 20.98 kWh/day for in-ground pools

= 7.19 kWh/day for above ground pools

$Hrs/day_{base}$ = daily run hours of single speed pump

= 11.4 hours for in-ground pools

= 7.0 hours for above ground pools

| kWh/day = daily energy consumption of the efficient pump, dependent on the pool application and motor designation, as detailed in the table below: **Pump Sub-Type** | Motor Design | Daily Energy Consumption (kWh/day) ENERGY STAR Version 2.0 | Daily Energy Consumption (kWh/day) ENERGY STAR Version 3.0 |
|---|---|---|---|
| Self-Priming (Inground) Pool Pumps | Multi-speed ($kWh/day_{2sp}$) | 6.76 | 4.26 |
| | Variable-speed ($kWh/day_{vs}$) | 5.36 | 3.20 |
| Non-Self Priming (Aboveground) Pool Pumps | Multi-speed ($kWh/day_{2sp}$) | 3.47 | 3.47 |
| | Variable-speed ($kWh/day_{vs}$) | 2.88 | 2.88 |

$Hr/day_{2sp}$ = run hours of two speed pump

= 17.7 hours for in-ground pools

= 10.9 hours for above ground pools

$Hr/day_{var}$ = run hours of variable speed pump

= 18 hours for in-ground pools

= 11 hours for above ground pools

CF = Summer Peak Coincidence Factor for measure

[1226] The methodology and all assumptions are sourced from the ENERGY STAR Pool Pump Calculator and assume a nameplate horsepower of 1.5 and a pool size of 22,000 gallons, with 2.0 turnovers per day in the base case and 1.5 turnovers per day in the efficient case.

= 0.831[1227]

Based on the pool/pump application and the motor designation, the summer coincident peak demand savings (ΔkW) are detailed in the table below:

| Pump Sub-Type | Motor Design | Summer Peak Coincident Demand Savings (ΔkW) ENERGY STAR Version 2.0 | Summer Peak Coincident Demand Savings (ΔkW) ENERGY STAR Version 3.0 |
|---|---|---|---|
| Self-Priming (Inground) Pool Pumps | Multi-speed | 1.211 | 1.329 |
| | Variable-speed | 1.282 | 1.381 |
| Non-Self Priming (Aboveground) Pool Pumps | Multi-speed | 0.589 | 0.589 |
| | Variable-speed | 0.638 | 0.638 |

**NATURAL GAS SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-MSC-RPLP-V02-190101**

**REVIEW DEADLINE: 1/1/2021**

[1227] Based on assumptions of daily load pattern through pool season. Assumption was developed for Efficiency Vermont but is considered a reasonable estimate for Illinois.

# 2019 Illinois Statewide Technical Reference Manual for Energy Efficiency

# Version 7.0

# Volume 4: Cross-Cutting Measures and Attachments

## FINAL

## September 28, 2018

## Effective:

## January 1, 2019

# Table of Contents

## Table of Figures



## Table of Tables

# 6 Cross-Cutting Measures

## 6.1 Behavior

### 6.1.1 Adjustments to Behavior Savings to Account for Persistence

**DESCRIPTION**

Energy efficiency program administrators are increasingly including behavior programs as part of their portfolios. These programs are characterized by various kinds of outreach, education, and customer engagement designed to motivate increases in conservation and energy management behaviors, and most commonly include participant-specific energy usage information. Savings impacts are evaluated by ex-post billing analysis comparing consumption before and after (or with and without) program intervention, and require M&V methods that include customer-specific energy usage regression analysis and randomized controlled trial (RCT) experimental designs, among others (see Behavioral protocol set forth in the IL-TRM Attachment A: Illinois Statewide Net-to-Gross Methodologies for more information). As such, initial calculation of savings is treated as a custom protocol[1].

An important issue for many stakeholders is whether energy savings from behavior programs continue over time (i.e., whether they persist beyond the initial program year). Behavior programs have now been delivered for a number of years in many jurisdictions. The weight of evaluation evidence indicates that the energy-saving behaviors influenced through these programs can persist beyond the initial period of program intervention, even without continued program participation[2]. This post-treatment savings persistence has implications for calculations of first-year savings, measure life, and cost-effectiveness testing. Accounting for persistence will yield savings and cost-effectiveness estimates that more accurately reflect the true benefits of these programs. Because annual goals are based on first-year savings, programs should only count savings attributable to first-year spending. The effect of persistence of savings beyond the first year should be included in any lifetime savings calculations (including cumulative persistent annual savings) and cost-effectiveness testing.

The protocol below was developed to outline the adjustments that should be made to account for the persistence of savings beyond the year of program delivery. This protocol is applicable to behavior programs of any type, delivered to residential or C&I customers, that have evaluated evidence of program persistence; however, the persistence values in this version of the protocol are specific to residential home energy reports (HERs)-type programs[3]. This general protocol should be used for any type of behavior program once supportable assumptions for persistence exist as measured by multi-year, rigorous evaluation studies; persistence factors for those behavioral programs may differ from the specific factors provided in this measure for HERs-type programs.

Currently, evaluations calculate a custom value on an annual basis to estimate yearly savings. Evaluators typically use a regression analysis to estimate program effects. These regression analyses provide what is called an average treatment effect on the treated (ATT) estimate of program savings. The ATT approach takes advantage of the presence of a randomly assigned control group for each cohort that received reports in the service territory. These regressions use various methods to account for household-specific usage patterns[4]. Because of the experimental design, we can assume that the treatment and control groups experienced similar historical, political, economic, and

[1] The protocol outlined here assumes that adjustments to remove the effects of savings from program lift (participation in other utility programs), including legacy uplift, to account for move-outs and opt-outs, to normalize for effects of weather, and any other appropriate adjustments, have been made as part of the custom calculation of savings – this final savings value is referred to as "Measured Savings" in the calculations below.

[2] Long-Run Savings and Cost-Effectiveness of Home Energy Reports Programs, Cadmus, October 2014. Also see additional sources in the REFERENCE TABLE below.

[3] Residential HERs-type programs: programs that regularly deliver home energy reports to residential customers through direct mail or email channels using a random control trial (RCT) experimental design. At a minimum, the reports include customer-specific usage information used for a comparison to similar households and individualized energy savings tips.

[4] For example, a linear fixed-effects regression (LFER) model includes a household-specific intercept to account for time-invariant, household-level factors affecting energy use, and a post program regression (PPR) model uses energy use lags to account for household-specific usage in the year prior to the program.

other events that had comparable effects on their energy use. Moreover, because these groups experienced generally similar weather conditions, it is not necessary to measure or include weather in the RCT model specification to calculate initial annual savings related to the program.

However, in the case of comparing and summing savings year over year, exogenous factors, such as weather, are likely to make annual estimates non-equivalent. In particular, weather is likely to play an important role in driving behavioral effects, affecting savings magnitude (e.g., a constant percentage change in consumption will result in more cooling savings during a hotter-than-average summer), as well as savings rate (e.g., the percentage change in consumption is likely to be higher during hotter-than-average summers. As such, for this framework, evaluators will adjust for effects related to weather as part of the custom inputs to this protocol. Each evaluator will choose the most appropriate method for weather normalization. For example, one method would be to provide savings using a model specification that incorporates standard weather year inputs (e.g., HDD and CDD), to be used as the initial input into the calculation of annual savings, as well as inputs for cost effectiveness, as outlined below. This input will approximate average savings for a standard weather year based upon historical data.[5] Adjusting savings to a standard weather year is consistent with how other weather-sensitive TRM measures are specified, and will remove weather risk from performance goals and cost-effectiveness testing.[6]

The protocol will become effective for residential HERs-type programs as of January 1, 2018. All ongoing programs will undergo a “reset” upon institution of this protocol[7]. Regardless of any previous history of behavior program delivery, the program year ending December 31, 2018 will be assumed to be Year 1 for all HERs-type programs underway at that time for the purpose of the incorporation of multiyear measure life/savings persistence into cost-effectiveness calculations and for the application of the adjustments to annual savings as outlined below. Should any additional new programs (referred to as “waves” in the calculations below) be established in 2018 or in subsequent years, their first year will be assumed to be Year 1 for that wave – that is, each wave is tracked separately and savings are calculated separately using the approach outlined here. Waves that existed prior to the program year ending December 31, 2018 will continue to be tracked separately for each wave. All residential HERs-type programs implemented prior to January 1, 2018 will assume a one-year measure life; the assumptions and protocols outlined below will not be applied retrospectively to any utility programs. Updates to persistence factors from future evaluations, once incorporated into the IL-TRM, will be used when available for calculation of annual savings values for applicable program years but will not be applied retrospectively to previous years’ first-year savings calculations. All other types of behavior programs will continue to use a one-year measure life until supportable evidence exists for savings persistence, at which time this adjustment protocol can be used with appropriate persistence factors.

**DETERMINATION OF EFFICIENT BEHAVIOR**

Behavior programs focus primarily on reducing electricity and natural gas consumption through behavioral changes; this reduction is generally measured through ex-post billing analysis after program intervention. Specific energy conservation and management behaviors are not usually directly observable. The specific definition of the efficient case is part of the design of behavioral programs and is included as part of the custom saving protocol, which will include any adjustment necessary to remove effects of program-related investments in efficient equipment.

---

[5] In the future, this approach could be empirically tested by comparing actual savings calculated in future program years against standard weather year results, producing a ‘realization rate’ between planned and actual savings results. Standard weather years could potentially be enhanced to better reflect these differences.

[6] We acknowledge that this approach is a proxy for estimating actual savings to allow for prospective calculation of lifetime savings. However, a substantial limitation to this approach is the issue of unobserved behavioral ramp-up that is likely to occur for future waves of participants.

[7] It is understood that this approach does not accurately take into account that programs have been in place prior to this date, and the fact that customers at that time will have been receiving reports for variable amounts of time, with varied associated actual savings persistence from these earlier program efforts. The difficulties of trying to “phase in” persistence adjustments to reflect this history have been recognized, and the approach outlined here has been recommended by the Illinois TAC members as a reasonable approximation.

### DETERMINATION OF BASELINE BEHAVIOR

The ideal baseline for behavior programs is the energy usage without the program intervention. Various types of experimental, quasi-experimental, and/or regression-based EM&V approaches are used to present statistically valid approximations to this without-program baseline[8]. The specific definition of the baseline case is part of the design of behavioral programs and is included as part of the custom saving protocol.

### DEEMED LIFETIME/PERSISTENCE OF SAVINGS

Evaluations in Illinois have shown that savings from residential HERs-type behavior programs can persist into at least the first and second year following discontinuation of program delivery[9], though on-going savings levels decay in the second year. For other residential RCT programs evaluated to date, savings have been shown to persist for at least 3 years year following program delivery[10], and industry expectations are that savings likely persist beyond that. We assume here that savings persist at some level for 5 years[11]. On-going savings over those 5 years are not equal, however; it is preferable that actual levels of ongoing savings should be calculated by future year as outlined below (see Application of Persistence for Cost-effectiveness) and used in cost-effectiveness and lifetime savings calculations[12]. For other behavior program types without evaluations that quantify levels of persistence, measure life is assumed = 1 year.

### DEEMED MEASURE COST

It is assumed that most behavior changes in residential settings can be accomplished with homeowner labor only and without investment in new equipment; therefore, without evidence to the contrary, measure costs in such residential programs focused on motivating changes in customer behavior may be defined as $0[13]. Costs for C&I programs may include additional staffing, software purchases, etc. Cost for such programs is therefore program specific and is determined on a custom basis.

### LOADSHAPE AND COINCIDENCE FACTOR

While there is evidence from analysis of AMI data that the savings loadshape for residential HERs-type programs

---

[8] See the Illinois Behavioral protocol set forth in the IL-TRM Attachment A: IL-NTG Methods for more information concerning randomized control trials and quasi-experimental evaluation methods for non-randomized designs for behavior programs.

[9] ComEd Home Energy Report Opower Program Decay Rate and Persistence Study DRAFT-Navigant, presented to Commonwealth Edison Company, January 29, 2016; ComEd Home Energy Report Program Decay Rate and Persistence Study, Year Two DRAFT - Navigant, Presented to Commonwealth Edison Company, July 20, 2016; Behavioral Energy Savings Programs: Home Energy Reports Persistence Study Part 2 – April 2015 to September 2015 FINAL – Navigant, Prepared for Nicor Gas, September 21, 2016.

[10] Long-Run Savings and Cost-Effectiveness of Home Energy Reports Programs, Cadmus, October 2014. Also see additional sources in the REFERENCE TABLE below. Given the limited persistence studies available, we acknowledge that using an average of these studies by fuel type may be the best approximation of persistence rates. However, moving forward, the TAC will incorporate additional study values and develop the most appropriate persistence factors, taking into account participant characteristics, such as the duration of exposure, the frequency of reports, baseline usage, as well as the amount of time that has persisted since receiving their final report, and the shape of the persistence curve.

[11] Determined as a reasonable preliminary assumption by Illinois TAC members. This assumption should be updated as additional research is conducted on these types of programs, and additional evaluation should be undertaken to assess the reasonableness of this assumption for Illinois-specific programs.

[12] This method of applying calculated values for future year benefits is preferred. Alternatively, an effective measure life can be calculated as Effective Measure Life = Total Discounted Lifetime Savings / First Year Savings.

[13] Future evaluation of costs of behavior change is encouraged to help clarify this assumption. In addition, as noted earlier in this measure characterization, in order to ensure double counting of savings does not occur, the protocol outlined here assumes that adjustments to remove the effects of program lift have been made as part of the custom calculation of savings. In a similar manner, given the savings accounted for by other utility programs are removed from the savings claims and cost-effectiveness for the behavior program, the incremental costs associated with such utility program incentivized measures should also be excluded from the behavior program cost-effectiveness analysis, so as to help ensure double counting of costs does not occur in the utility portfolio cost-effectiveness analysis.

mirrors the whole-house electric energy load pattern, there are not yet enough data to develop a behavior-specific loadshape. Indications from several unpublished analyses[14] show that these behavior savings occur in a general pattern most closely approximated by the Residential Electric Heating and Cooling Loadshape (R10) than any other current residential measure loadshape; this is therefore recommended as the most reasonable approximation for use until more-specific data are available. Loadshapes and coincidence factors will need to be determined for other types of behavior programs once sufficient data are in hand.

**Algorithm**

### CALCULATION OF SAVINGS

Throughout these protocols, Year T refers to the current reporting year for which annual savings are being determined[15].

### ELECTRIC ENERGY SAVINGS

The algorithm shown below for this measure was developed to calculate the annual persistence-adjusted electric savings in to be reported in year T after adjustment to account for the proportion of the measured savings for that program year that actually reflects any persistent savings from prior years' program activities (Years T-1, T-2, T-3, and T-4)[16].

$$\Delta kWh_{T\ Adjusted} = \Delta kWh_{T\ Measured} - (\Delta kWh_{T-1\ Adjusted} * RR_{T-1,T} * PFE_1) - (\Delta kWh_{T-2\ Adjusted} * RR_{T-2,T} * PFE_2) - (\Delta kWh_{T-3\ Adjusted} * RR_{T-3,T} * PFE_3) - (\Delta kWh_{T-4\ Adjusted} * RR_{T-4,T} * PFE_4)$$

Where:

$\Delta kWh_{x\ Adjusted}$ = total program annual savings for year X after adjustments to account for persistence (calculated value)

$\Delta kWh_{x\ Measured}$ = measured kWh savings: total program savings as determined from custom calculation/billing analysis[17] of participants in program during year X (input value)

$RR_{Y,X}$ = Program retention rate in year X from year Y participation[18]

= % of program participants in year Y that are still in program in year X (input value:

[14] Based on communication from Mathias Bell based on (currently unpublished) studies done by Opower, Cadmus, and LBNL. Also see DTE Energy: Behavior Program Measures for Submission to 2015 MEMD - Year Three Energy Savings - Demand Savings. Energy Optimization, April 15, 2014. http://www.michigan.gov/documents/mpsc/memd_2015_453673_7.pdf

[15] Calculation algorithms account for attrition of customers out of the service territory, as well as persistence decay. It has been noted that there may also be a need to adjust for cross-year effects of large differences in weather conditions or economic impacts. Custom savings inputs therefore are adjusted for standard year weather.

[16] This calculation should be carried out separately for each "wave" of behavior programs, where a wave is defined as a newly launched program. For simplicity, any new wave is assumed to start at the beginning of a program year (Year 1) and may include multiple different treatment types such as usage groups, report frequency, etc. For example, any wave added after 2018, will be considered Year 1 in the year they are launched.

[17] All appropriate adjustments to remove effects of participation in other utility programs, move-outs, opt-outs, to normalize for effects related to weather, and other adjustments as determined by the program experimental design, are assumed to have been made to result in this value for "measured savings". This value has been adjusted for standard year weather terms.

[18] It is possible that some savings related to behavioral programs persist even after participants move and are therefore dropped from the program. Such persistent savings could potentially occur in two ways. First, some proportion of program savings likely comes from efficient measures installed on the premises and not otherwise identified through other direct program participation; this component of saving would likely persist even under new building ownership. Second, participants who move might exhibit changes in energy usage even in a new setting; this could continue to provide savings to the program administrator if the move was within the same utility territory. As of this time, no definitive information exists as to the level of program savings related to installed measures vs. behavioral changes, making determination of these effects highly uncertain. As such, this protocol assumes no persistent savings related to customers who move. Future evaluation related to this assumption is encouraged in order to make this determination more precise.

calculated as # participants still in program in year X / # participants in year Y))

$PFE_Z$ = Persistence factor - electric (deemed value)

= % savings that persist Z years after savings were initially measured, where Z is a number from 1 - 4

= use table below to select the appropriate value

**Electric Persistence Factors**[19]

| Program Type | Program Year T - record 100% of adjusted savings ($\Delta kWh_{TAdjusted}$ above) | Percent adjusted savings from Year T activities that persist 1 year after year T | Percent adjusted savings from Year T activities that persist 2 years after year T | Percent adjusted savings from Year T activities that persist 3 years after year T | Percent adjusted savings from Year T activities that persist 4 years after year T |
|---|---|---|---|---|---|
| | | $PFE_1$ | $PFE_2$ | $PFE_3$ | $PFE_4$ |
| Residential HERs-type (RCT) | 100% | 80% | 54% | 31% | 15% |

[19] See REFERENCE TABLES below for sources.

**Example of Adjusted Annual Savings Calculations:**

Assume the following information on participation and measured savings for the following program years (all adjustments have been made to remove effects of program lift, weather, etc. within the custom savings calculations). Assume 2018 is the first year of all programs (or is the "reset" year).

| | Reporting Year | | | | | |
|---|---|---|---|---|---|---|
| | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 |
| **Input data from program information and custom savings analysis** | | | | | | |
| # Participants (households) | 120,000 | 109,000 | 103,000 | 99,000 | 94,000 | 90,000 |
| kWh per participant (household) | 200 | 250 | 245 | 250 | 250 | 265 |
| Measured kWh savings (custom) | 24,000,000 | 27,250,000 | 25,235,000 | 24,750,000 | 23,500,000 | 23,850,000 |

**Calculation of Retention Rates:**

For use in 2019:

$RR_{2018, 2019}$ = 109,000/120,000 = 0.908

For use in 2020:

$RR_{2018, 2020}$ = 103,000/120,000 = 0.858

$RR_{2019, 2020}$ = 103,000/109,000 = 0.945

For use in 2021:

$RR_{2018, 2021}$ = 99,000/120,000 = 0.825

$RR_{2019, 2021}$ = 99,000/109,000 = 0.908

$RR_{2020, 2021}$ = 99,000/103,000 = 0.961

For use in 2022:

$RR_{2018, 2022}$ = 94,000/120,000 = 0.783

$RR_{2019, 2022}$ = 94,000/109,000 = 0.862

$RR_{2020, 2022}$ = 94,000/103,000 = 0.913

$RR_{2021, 2022}$ = 94,000/99,000 = 0.949

For use in 2023:

$RR_{2019, 2023}$ = 90,000/109,000 = 0.826

$RR_{2020, 2023}$ = 90,000/103,000 = 0.874

$RR_{2021, 2023}$ = 90,000/99,000 = 0.909

$RR_{2022, 2023}$ = 90,000/94,000 = 0.957

**Calculation of Adjusted Annual Savings:**

$\Delta kWh_{2018\ Adjusted}$ = 24,000,000 kWh

$\Delta kWh_{2019\ Adjusted}$ = 27,250,000 – (24,000,000 * 0.908 * 0.80)
= 9,816,400 kWh

$\Delta kWh_{2020\ Adjusted}$ = 25,235,000 – (9,816,400 * 0.945 * 0.80) – (24,000,000 * 0.858 * 0.54)
= 6,694,122 kWh

$\Delta kWh_{2021\ Adjusted}$ = 24,750,000 – (6,694,122 * 0.961 * 0.80) – (9,816,400 * 0.908 * 0.54) – (24,000,000 * 0.825 * 0.31)
= 8,652,382 kWh

$\Delta kWh_{2022\ Adjusted}$ = 23,500,000 – (8,652,382 * 0.949 * 0.80) – (6,694,122 * 0.913 * 0.54) – (9,816,400 * 0.862 * 0.31) – (24,000,000 * 0.783 * 0.15)
= 8,188,837 kWh

$\Delta kWh_{2023\ Adjusted}$ = 23,850,000 – (8,188,837 * 0.957 * 0.80) – (8,652,382 * 0.909 * 0.54) – (6,694,122 * 0.874 * 0.31) – (9,816,400 * 0.826 * 0.15)
= 10,303,561 kWh

Apply the same approach to calculate adjusted annual kW and Therms.

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

Coincident peak demand savings in year T should also be adjusted to account for persistence from previous years using a similar algorithm[20].

If peak demand is measured directly by the custom savings analysis:

$$kW_{T\ Adjusted} = \Delta kW_{T\ Measured} - (\Delta kW_{T-1\ Adjusted} * RR_{T-1,T} * PFE_1) - (\Delta kW_{T-2\ Adjusted} * RR_{T-2,T} * PFE_2)$$

[20] While there are no current studies that evaluate the persistence of peak savings, without more-specific information on the actual behaviors undertaken by program participants and their corresponding peak savings, it seems reasonable to assume that peak savings will also persist in a similar pattern; both of the approaches given assume persistence in peak savings. Further evaluation should be undertaken to clarify this point and determine appropriate peak-specific persistence values.

$– (\Delta kW_{T\text{-}3\ Adjusted} * RR_{T\text{-}3,T} * PFE_3) – (\Delta kW_{T\text{-}4\ Adjusted} * RR_{T\text{-}4,T} * PFE_4)$

Where:

$\Delta kW_{X\ Adjusted}$ = total program demand savings for year X after adjustments to account for persistence (calculated value)

$\Delta kW_{X\ Measured}$ = total program demand savings as determined from custom calculation /billing analysis[21] of participants in program during year X (input value)

Other variables as defined above

If peak demand is not measured directly by the custom savings analysis, peak demand should be calculated as follows:

$\Delta kW_{T\ Adjusted}$ = ($\Delta kWh_{T\ Adjusted\ Summer}$ / #summer hours) * peak adjustment factor

Where:

$\Delta kWh_{T\ Adjusted\ Summer}$ = average adjusted electric energy savings (calculated above) for peak summer months

= $\Delta kWh_{T\ Adjusted}$ * 0.42 * (3/5)

= $\Delta kWh_{T\ Adjusted}$ * 0.25

Where:

0.42 = Summer Loadshape % for May – Sept

3/5 = proportion of May-Sept hours that fall in June, July, and Aug

# summer hours = # hours in June, July, and Aug

= 8760 / 4

Where: 8760 = Hours per year

peak adjustment factor = adjustment for peak k/w over average kW for these hours

= 1.5[22]

**NATURAL GAS ENERGY SAVINGS**

The algorithm shown below for this measure was developed to calculate the annual persistence-adjusted Therm savings in to be reported in year T after adjustment to account for the proportion of the measured savings for that program year that actually reflects any persistent savings from prior years' program activities (Years T-1, T-2, T-3, and T-4).[23]

$\Delta Therms_{T\ Adjusted} = \Delta Therms_{T\ Measured} – (\Delta Therms_{T\text{-}1\ Adjusted} * RR_{T\text{-}1,T} * PFG_1) – (\Delta Therms_{T\text{-}2\ Adjusted} * RR_{T\text{-}2,T} * PFG_2)$
$– (\Delta Therms_{T\text{-}3\ Adjusted} * RR_{T\text{-}3,T} * PFG_3) – (\Delta Therms_{T\text{-}4\ Adjusted} * RR_{T\text{-}4,T} * PFG_4)$

Where:

[21] All appropriate adjustments to remove effects of participation in other utility programs, move-outs, opt-outs, to normalize for effects related to weather, and other adjustments as determined by the program experimental design, are assumed to have been made to result in this value for "measured savings". This value has been adjusted for standard year weather terms.

[22] Based on an approach used in Michigan that gives resulting values supported by evaluation claims. Also see DTE Energy: Behavior Program Measures for Submission to 2015 MEMD - Year Three Energy Savings - Demand Savings. Energy Optimization, April 15, 2014. http://www.michigan.gov/documents/mpsc/memd_2015_453673_7.pdf

[23] This calculation should be carried out separately for each "wave" of behavior programs, where a wave is defined as a newly launched program. For simplicity, any new wave is assumed to start at the beginning of a program year (Year 1) and may include multiple different treatment types such as usage groups, report frequency, etc.

$\Delta Therms_{x\ Adjusted}$ = total program annual savings for year X after adjustments to account for persistence (calculated value)

$\Delta Therms_{x\ Measured}$ = total program savings as determined from custom calculation/billing analysis[24] of participants in program during year X (input value)

$PFG_Z$ = Persistence factor - gas (deemed value)

= % savings that persist Z years after savings were initially measured, where Z is a number from 1 - 4

= use table below to select the appropriate value

Other variables as defined above

**Gas Persistence Factors[25]**

| Program Type | Program Year T - record 100% of calculated savings ($\Delta Therms_{TAdjusted}$ above) | Percent adjusted savings from Year T activities that persist 1 year after year T | Percent adjusted savings from Year T activities that persist 2 years after year T | Percent adjusted savings from Year T activities that persist 3 years after year T | Percent adjusted savings from Year T activities that persist 4 years after year T |
|---|---|---|---|---|---|
| | | $PFG_1$ | $PFG_2$ | $PFG_3$ | $PFG_4$ |
| Residential HERs-type (RCT) | 100% | 45% | 20% | 9% | 4% |

**APPLICATION OF PERSISTENCE FOR PROSPECTIVE CALCULATIONS**

For determination of prospective savings related to programs delivered in year T (including cost-effectiveness, lifetime savings, and cumulative prospective annual savings (CPAS)), future years' savings related to the current year activities should be recorded for this measure as savings for each specific year calculated using the table below. Because of the potentially confounding effects of differences in weather in future years, the savings inputs used ($\Delta kWh_{TAdjusted}$, $\Delta kW_{TAdjusted}$, $\Delta Therms_{TAdjusted}$) for these future-year savings calculations have been determined using weather normalized inputs. This input (to be provided by program evaluators) will approximate average savings for a standard weather year based upon historical data.[26]

| Program Year T - record 100% of adjusted annual savings as calculated above | Percent savings from Year T activities that persist 1 year after year T | Percent savings from Year T activities that persist 2 years after year T | Percent savings from Year T activities that persist 3 years after year T | Percent savings from Year T activities that persist 4 years after year T |
|---|---|---|---|---|
| $\Delta kWh_{TAdjusted}$<br>$\Delta kW_{TAdjusted}$<br>$\Delta Therms_{TAdjusted}$ | $\Delta kWh_{TAdjusted} * PFE_1 * RR_{Utility}$<br>$\Delta kW_{TAdjusted} * PFE_1 * RR_{Utility}$<br>$\Delta Therms_{TAdjusted} * PFG_1 * RR_{Utility}$ | $\Delta kWh_{TAdjusted} * PFE_2 * RR_{Utility}^2$<br>$\Delta kW_{TAdjusted} * PFE_2 * RR_{Utility}^2$<br>$\Delta Therms_{TAdjusted} * PFG_2 * RR_{Utility}^2$ | $\Delta kWh_{TAdjusted} * PFE_3 * RR_{Utility}^3$<br>$\Delta kW_{TAdjusted} * PFE_3 * RR_{Utility}^3$<br>$\Delta Therms_{TAdjusted} * PFG_3 * RR_{Utility}^3$ | $\Delta kWh_{TAdjusted} * PFE_4 * RR_{Utility}^4$<br>$\Delta kW_{TAdjusted} * PFE_4 * RR_{Utility}^4$<br>$\Delta Therms_{TAdjusted} * PFG_4 * RR_{Utility}^4$ |

[24] All appropriate adjustments to remove effects of participation in other utility programs, move-outs, opt-outs, to normalize for effects related to weather, and other adjustments as determined by the program experimental design, are assumed to have been made to result in this value for "measured savings". This value has been adjusted for standard year weather terms.

[25] See REFERENCE TABLES below for sources.

[26] In the future, this approach could be empirically tested by comparing actual savings calculated in future program years against standard weather year results, producing a 'realization rate' between planned and actual savings results. Standard weather years could potentially be enhanced to better reflect these differences.

Where:

$RR_{Utility}$ = a utility-specific estimated retention rate for the program[27,28]

Other variables as defined above

[27] This retention rate should be an historical average, based on multiple years of data, that applies across all program waves for a given utility. The retention rate should be updated on a regular basis (for example, with the program planning cycles) to make sure it remains reflective of current program and economic conditions. Evaluators will decide for each utility what population the retention rate should be based on (for example: all residential customers; the entire population eligible for the program; the current program population). In making this decision, evaluators should consider data availability, expected changes in the program population in the planning cycle, and the eligible population for the program.

[28] It is possible that some savings related to behavioral programs persist even after participants move and are therefore dropped from the program. Such persistent savings could potentially occur in two ways. First, some proportion of program savings likely comes from efficient measures installed on the premises and not otherwise identified through other direct program participation; this component of saving would likely persist even under new building ownership. Second, participants who move might exhibit changes in energy usage even in a new setting; this could continue to provide savings to the program administrator if the move was within the same utility territory. As of this time, no definitive information exists as to the level of program savings related to installed measures vs. behavioral changes, making determination of these effects highly uncertain. As such, this protocol assumes no persistent savings related to customers who move. Future evaluation related to this assumption is encouraged in order to make this determination more precise.

**Example of Calculation of Cost-effectiveness Inputs – for Electric Savings:**

Assume the same information as was used in the Example of Adjusted Annual Savings Calculations.

| | Reporting Year T | | | | | |
|---|---|---|---|---|---|---|
| | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 |
| **Annual Savings** = Adj. kWh savings (previously calculated) = $\Delta kWh_{TAdjusted}$ | 24,000,000 | 9,816,400 | 4,634,922 | 5,384,166 | 4,683,858 | 11,741,354 |
| $RR_{Utility}$ = 0.908 | | | | | | |

**For calculating cost effectiveness in 2018:**

Cost-effectiveness benefit of 2018 savings in 2019 = $\Delta kWh_{2018\ Adjusted}$ * $PFE_1$* $RR_{Utility}$ = 24,000,000 * 0.80 * 0.908 = 17,433,600 kWh

Cost-effectiveness benefit of 2018 savings in 2020 = $\Delta kWh_{2018\ Adjusted}$ * $PFE_2$*$RR_{Utility}^2$ = 24,000,000 * 0.54 * $0.908^2$ = 10,685,053 kWh

Cost-effectiveness benefit of 2018 savings in 2021 = $\Delta kWh_{2018\ Adjusted}$ * $PFE_3$*$RR_{Utility}^3$ = 24,000,000 * 0.31 * $0.908^3$ = 5,569,683 kWh

Cost-effectiveness benefit of 2018 savings in 2022 = $\Delta kWh_{2018\ Adjusted}$ * $PFE_4$*$RR_{Utility}^4$ = 24,000,000 * 0.15 * $0.908^4$ = 2,447,067 kWh

**For calculating cost effectiveness in 2019:**

Cost-effectiveness benefit of 2019 savings in 2020 = $\Delta kWh_{2019\ Adjusted}$ * $PFE_1$*$RR_{Utility}$ = 9,816,400 * 0.80 * 0.908 = 7,130,633 kWh

Cost-effectiveness benefit of 2019 savings in 2021 = $\Delta kWh_{2019\ Adjusted}$ * $PFE_2$*$RR_{Utility}^2$ = 9,816,400 * 0.54 * $0.908^2$ = 4,370,365 kWh

Cost-effectiveness benefit of 2019 savings in 2022 = $\Delta kWh_{2019\ Adjusted}$ * $PFE_3$*$RR_{Utility}^3$ = 9,816,400 * 0.31 * $0.908^3$ = 2,278,093 kWh

Cost-effectiveness benefit of 2019 savings in 2023 = $\Delta kWh_{2019\ Adjusted}$ * $PFE_4$*$RR_{Utility}^4$ = 9,816,400 * 0.15 * $0.908^4$ = 1,000,891 kWh

**For calculating cost effectiveness in 2020:**

Cost-effectiveness benefit of 2020 savings in 2021 = $\Delta kWh_{2020\ Adjusted}$ * $PFE_1$*$RR_{Utility}$ = 6,694,122 * 0.80 * 0.908 = 4,862,610 kWh

Cost-effectiveness benefit of 2020 savings in 2022 = $\Delta kWh_{2020\ Adjusted}$ * $PFE_2$*$RR_{Utility}^2$ = 6,694,122 * 0.54 * $0.908^2$ = 2,980,294 kWh

Cost-effectiveness benefit of 2020 savings in 2023 = $\Delta kWh_{2020\ Adjusted}$ * $PFE_3$*$RR_{Utility}^3$ = 6,694,122 * 0.31 * $0.908^3$ = 1,553,506 kWh

Cost-effectiveness benefit of 2020 savings in 2024 = $\Delta kWh_{2020\ Adjusted}$ * $PFE_4$*$RR_{Utility}^4$ = 6,694,122 * 0.15 * $0.908^4$ = 682,540 kWh

**Etc.**

Apply the same approach to calculate cost-effectiveness inputs for kW and for Therms.

## WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

## DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

## REFERENCE TABLES

Persistence studies done to date for HERs-type programs capture effects only through a limited time frame and only for the specific program characteristics of the programs studied. They may not accurately represent conditions in Illinois or those for all Illinois programs. The Illinois TAC has determined that an average annual persistence rate across the studies done to date (Table 1 below) is the best currently available data to approximate persistence for the first year for the general class of residential HERs-type programs. Additional information about the rate of decay in the following years is limited. Most studies done to date that assess decay after more than one year do not specifically evaluate after each individual year and instead just calculate an average annual decay across the years studied. This is true of persistence studies for gas HERs-type programs. For them, this protocol assumes a linear on-going rate of decay for five years based on the average annual persistence in Table 1.

Navigant has recently undertaken an evaluation of the ComEd electric HERs program specifically designed to determine the first and second year persistence rate separately for each individual year. The results, shown in Table 2 below, indicate an average increase in the year-over-year persistence factor from year 1 to year 2 of 15%. This level of non-linear increase in the persistence factor is assumed to hold for the five years of electric savings persistence for HERs-type programs and is used to calculate persistence factors used in this protocol. The average annual persistence rate from Table 1 is used for the first year.

It is recommended that the persistence values and the shape of the decay function used in this protocol continue to be updated regularly as further longer term and Illinois-specific evaluations are undertaken.

**Table 1: Annual Persistence Rate for Residential HERs-type (RCT) Programs: Reference Studies**

| Utility/Location | Frequency of Reports when in program | Number of Months in Program Before Terminated | Number of Post-Treatment Savings Analysis Months | Average Annual savings decay | Persistence (= 100% - decay) | Source | Electric or Gas |
|---|---|---|---|---|---|---|---|
| Upper Midwest | Monthly & quarterly | 24-25 | 26 | 21% | 79% | 1 | Electric |
| West Coast | Monthly & quarterly | 24 | 29 | 18% | 82% | 1 | Electric |
| West Coast | Monthly & quarterly | 25-28 | 34 | 15% | 85% | 1 | Electric |
| SMUD | Monthly & quarterly | 27 | 12 | 32% | 68% | 1 | Electric |
| Puget Sound Energy | Monthly & quarterly | 24 | 36 | 11% | 89% | 1 | Electric |
| MASS | Monthly & quarterly | 26 | 15 | 33% | 67% | 2 | Electric |
| Illinois (ComEd): First Year | Bimonthly | 16-52 | 12 | 10% | 90% | 3 | Electric |
| **Average Annual Electric Savings Persistence:** | | | | | **80%** | | |
| | | | | | | | |
| MASS | Monthly & quarterly | 15 | 17 | 64% | 36% | 2 | Gas |
| Illinois (Nicor) | Bimonthly | 12 | 12 | 46% | 54% | 4 | Gas |
| **Average Annual Gas Savings Persistence:** | | | | | **45%** | | |

Sources:
1: http://www.cadmusgroup.com/wp-content/uploads/2014/11/Cadmus_Home_Energy_Reports_Winter2014.pdf
2: http://ma-eeac.org/wordpress/wp-content/uploads/Home-Energy-Report-Savings-Decay-Analysis-Final-Report1.pdf
3:http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_5/Sources/ComEd_HER_Opower_Persistence_and_Decay_Study_DRAFT_2016-01-28.pdf
4:http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_6/Evaluation_Documents/Nicor_Gas_HER_Persistence_Study_Part_2_Final_2016-09-21.pdf

**Table 2: Year-over-Year Persistence Factors for ComEd Residential HERs Programs**

| | **Annual Persistence Factor** | | | | **Implied Year-over-Year Persistence** | **Change in Year-over-Year Persistence** |
|---|---|---|---|---|---|---|
| | **Wave 1** | **Wave 3** | **Wave 5 Non-AMI** | **Average** | | |
| Year 1: 11/2013-10/2014 | 96% | 98% | 78% | 90% | 90% | |
| Year 2: 11/2014-10/2015 | 85% | 83% | 40% | 69% | 77% | 15% |

Source:
http://ilsagfiles.org/SAG_files/Evaluation_Documents/Draft%20Reports%20for%20Comment/ComEd_EPY7/ComEd_HER_Year_

Two_Persistence_and_Decay_Study_2016-07-20_Draft.pdf This evaluation extends the analysis of the ComEd program waves reviewed in the 2016 study (#3 above) to the second year after reports were terminated. The study shows an increased rate of decay in year two, indicating that a linear decay rate assumption may not be accurate, at least for the first two years. This assessment of a non-liner decay rate will be reviewed, and the rate as it extends beyond the first two years, will be revisited when there have been additional studies designed to explicitly assess the shape of the decay curve across several years.

**MEASURE CODE: CC-BEH-BEHP-V03-190101**

**REVIEW DEADLINE: 1/1/2021**

# 2019 Illinois Statewide Technical Reference Manual for Energy Efficiency Version 7.0

# Attachment A

# Illinois Statewide Net-to-Gross Methodologies

# Effective for Evaluation

All NTG data collection and analysis activities for the program types covered by this document shall conform to the NTG methods set forth herein.

# Attachment A: Illinois Statewide Net-to-Gross Methodologies

## Policy Context for this Information

The Illinois Evaluation Teams (ADM Associates, Cadmus Group, Itron, Navigant Consulting, Opinion Dynamics, Ridge & Associates) are working with the Illinois Stakeholder Advisory Group (SAG) to create an Illinois Statewide Net-to-Gross (NTG) Methodologies document (IL-NTG Methods). The IL-NTG Methods document is included as an attachment to the Illinois Statewide Technical Reference Manual for Energy Efficiency (IL-TRM). Through five different dockets, the Illinois Commerce Commission (ICC) has directed the Evaluation Teams to compile and formalize standard NTG methods for use in Illinois energy efficiency (EE) evaluation, measurement, and verification (EM&V) work. The ICC EE dockets are shown in the following table.

**Table 1-1. ICC Energy Efficiency Dockets**

| ICC Order Docket No. and Date | Program Administrator | NTG Discussion – Order Pages | ICC Link |
|---|---|---|---|
| **13-0495 (1/28/14)** | Commonwealth Edison Company (ComEd) | 129-130 | http://www.icc.illinois.gov/downloads/public/edocket/367591.pdf |
| **13-0498 (1/28/14)** | Ameren Illinois Company (Ameren) | 167, 171 | http://www.icc.illinois.gov/downloads/public/edocket/367603.pdf |
| **13-0499 (1/28/14)** | Illinois Department of Commerce & Economic Opportunity (Department of Commerce) | 20, 23, 49 | http://www.icc.illinois.gov/downloads/public/edocket/367581.pdf |
| **13-0549 (5/20/14)** | Nicor Gas Company (Nicor) | 41-42, 78 | http://www.icc.illinois.gov/downloads/public/edocket/378494.pdf |
| **13-0550 (5/20/14)** | North Shore Gas Company (North Shore Gas) and The Peoples Gas Light and Coke Company (Peoples Gas) (collectively, PG&NSG) | 54-55, 66 | http://www.icc.illinois.gov/downloads/public/edocket/378495.pdf |

To provide clarity to the ICC directives, the relevant section on IL-NTG Methods is shown in its entirety from the Nicor Gas Order (Docket No. 13-0549). The Nicor Gas Order provides the most detail on the ICC NTG directive in comparison to the other EE orders. The Nicor language is as follows:

> The Commission believes that Staff's recommendations concerning Commission adoption of consistent statewide net-to-gross methodologies ("IL-NTG Methods") for use by the evaluators are reasonable and will aid in future evaluation of the energy efficiency programs. To help ensure the independence of the evaluators, to improve efficiency in the evaluation process, and to ensure programs across the state as delivered by the various Program Administrators can be meaningfully and consistently evaluated, the Commission hereby adopts Staff's recommendation that consistent IL-NTG Methods be established for use in the evaluations of comparable energy efficiency programs offered by different Illinois Program Administrators. The Commission notes that Section 8-104(k) of the Act encourages statewide coordination and consistency between the gas and electric energy efficiency programs and Staff's proposal would help ensure consistency in the evaluation of program performance. The Commission notes that this directive is not to create entirely "new" NTG methodologies for every energy efficiency program, but rather to assess NTG methodologies and survey instruments that have been used to evaluate energy efficiency programs offered in Illinois, and to compile the most justifiable and well-vetted methodologies (or potentially combine certain components from the existing approaches to better represent the most justifiable and well-vetted method consistent with best practices) in an attachment to the Updated IL-TRM that would get submitted to the Commission for approval. The Commission notes that the IL-NTG Methods will be

flexible and adaptable to multiple program designs and budgets and tailored to appropriately assess the specifics of each of the Program Administrators' energy efficiency programs, consistent with standard NTG methodologies adopted in other states that were filed in this proceeding. The Commission agrees with Staff that in the interest of efficiency, the current program evaluators should take the lead in compiling and formalizing standard methodologies for NTG in Illinois taking into consideration SAG input. Because the existing Plan 1 evaluators are under contract with the Company for the evaluation of the program year three energy efficiency programs, it is appropriate for these existing evaluators to work on and complete the compilation of the IL-NTG Methods over the next year. The Commission recognizes that each year considerable time may be spent vetting NTG methodologies for each program evaluation separately for each utility under the existing evaluation plan review practices; adoption of IL-NTG Methods would save on these limited evaluation resources by having a common reference document for the evaluators to use in estimating net savings for Illinois.

The Commission hereby directs the Company to require its evaluators to collaborate with the other Illinois evaluators and the SAG to use best efforts to reach consensus on the approaches used in assessing NTG in particular markets for both residential and non-residential energy efficiency programs in a manner consistent with the direction described herein. (Pages 41-42)

(16) Northern Illinois Gas Company shall require its evaluators to collaborate with the other Illinois evaluators and the SAG to reach consensus on the most defensible and well-vetted methodologies for assessing net-to-gross ratios in particular markets for both residential and non-residential energy efficiency programs in a manner consistent with the direction provided herein;

(17) ICC Staff shall file the agreed-upon consensus statewide NTG methodologies with the Commission as an attachment to the Updated IL-TRM, and if consensus is not reached on a certain component of the statewide NTG methodologies, that particular non-consensus component should be submitted in a manner consistent with the approach used for non-consensus IL-TRM Updates; (Page 78)

## 1.2 Programs Currently Covered in this Document

This document is intended to cover the majority of residential and non-residential programs offered in Illinois.[29] Programs covered as of the writing of this document are listed in tables at the beginning of Section 3: Commercial, Industrial, and Public Sector Protocols and Section 4: Residential and Low Income Sector Protocols. If the design of a given program changes significantly, then it may mean that the NTG protocol listed for that program in this document is no longer appropriate. If that happens, the evaluator should follow the procedures outlined below under Section 1.4: Diverging from the IL-NTG Methods.

This document will be updated over time to incorporate new programs and to reflect recommended changes to existing methodologies. All NTG data collection and analysis activities for the program types covered by this document shall conform to the NTG methods set forth herein.

## 1.3 Updating the IL-NTG Methods

This attachment is part of the IL-TRM and follows the timeline for updating of the IL-TRM, as specified in the Illinois Energy Efficiency Policy Manual. In general, the following will take place:

- Updates will generally occur annually.
- Any changes to the IL-NTG Methods document will be circulated to the full SAG, and SAG participants will have a ten business day review process.
- Updates may be discussed within the SAG throughout the year but will be completed annually.
- Annually, the ICC Staff will submit a Staff Report (with the consensus Updated IL-TRM attached) to the Commission with a request for expedited review and approval.

[29] Evaluation reports on those programs can be found at http://www.ilsag.info/evaluation-documents.html.

- Updated NTG methods go into effect upon SAG approval, which may be before the annual TRM update or before the effective date of the updated TRM.

## 1.4 Diverging from the IL-NTG Methods

The NTG methods for the programs outlined in this document are partially binding. The criteria for deviating from the IL-NTG Methods document are set forth below. In all cases, the evaluators (or any interested stakeholder) submits the proposed deviation to the full SAG for a ten business day SAG review and comment period. In the event of an objection by a SAG participant, efforts may be made to see if consensus can be reached on the proposed deviation in a subsequent monthly SAG meeting. In this case, a final opportunity for SAG review and comment to the proposed deviation will be provided following the SAG meeting.

Evaluators may modify the approaches described in this document if the following three conditions have been satisfied:

1. Evaluators must explicate within the annual evaluation research plan (or another document) how specific items in the proposed modified NTG method will diverge from what is written in this document. Evaluators must justify why the divergence is appropriate.
2. Prior to the use of the modified NTG method for a particular program, evaluation teams must be in agreement on the use and execution of the modified NTG method.
3. Any objection from SAG participants regarding the proposed modified NTG method is resolved.

Evaluators may test alternative methods of estimating NTG for a particular program in addition to the NTG methods outlined in this document, if the following three conditions have been satisfied:

1. Evaluators must explicate within the annual evaluation research plan (or other document) the proposed alternative NTG method. Evaluators must explain why the proposed alternative NTG method might be superior to the NTG methods outlined in this document for the particular program. Evaluators must discuss the foundation for expecting that the proposed alternative NTG method is likely to produce meaningful results.
2. Prior to the use of the alternative NTG method for a particular program, evaluation teams must be in agreement on the key details of the approach for implementing the alternative NTG method.
3. Any objection from SAG participants regarding the proposed alternative NTG method gets resolved.

When performing alternative NTG methods for a particular program, the choice of methods may vary across the state. For example, if ComEd's evaluator chooses to test Methods 1 and 2 for a particular program, Ameren's and Department of Commerce's evaluators do not also have to perform Methods 1 and 2 for a similar program.

Several sections of this attachment provide example questions that can be used to collect the data required in the NTG algorithms. Adjustments to refine specific question wording, e.g., to better reflect the design of the evaluated program, do not constitute divergence from the IL-NTG Methods.

## 1.5 Procedure for Non-Consensus Items

Non-consensus items that arise during the development and updating of the IL-NTG Methods document will be handled in substantially the same way as non-consensus IL-TRM Updates are addressed. The approach to be used is as follows.

- Once the Illinois NTG Working Group[30] has progressed as far as they can on the methodology, and it has been found that there is non-consensus on a specific Net-to-Gross Methods topic or procedure, the Illinois NTG Working Group shall submit to the ICC Staff and the SAG's Technical Advisory Committee

[30] The Illinois NTG Working Group consists primarily of the subset of Evaluators deliberating on NTG methodologies; however, any interested party may participate in the Illinois NTG Working Group.

(TAC) a Comparison Exhibit of Non-Consensus Net-to-Gross Methods topics/procedures within two weeks after the Illinois NTG Working Group has failed to reach consensus. The TAC will then deliberate on the issue with a goal of reaching consensus.

- If consensus does not emerge in the TAC regarding a particular Net-to-Gross Methods topic or procedure, the Comparison Exhibit of Non-Consensus NTG Methods topics/procedures is then sent to the full SAG for their deliberations and input. The SAG provides a forum where experts on all sides of the contested issue can present their expert opinions in an effort to inform parties of the contested issue and to also facilitate consensus.
- If the full SAG is unable to reach consensus, the non-consensus item will be referred to the ICC for resolution at the time of the IL-TRM Update proceeding. After receipt of the Comparison Exhibit of Non-Consensus Net-to-Gross Methods topics/procedures, the ICC Staff will submit a Staff Report to the Commission to initiate a proceeding separate from the consensus IL-TRM Update proceeding to resolve the non-consensus Net-to-Gross Methods topics/procedures.

# 2 Attribution in Energy Efficiency Programs in General

One of the most difficult aspects of evaluation, and not just within evaluation of energy efficiency programs, is attributing results to a program. Attribution provides credible evidence that there is a causal link between the program activities and the outcomes achieved by the program. Attribution research estimates the difference between the outcomes and those that would have occurred absent the program (i.e., the counterfactual). Put in research terms, evaluators must reject the null hypothesis of no causality through probabilistic statements (e.g., “strong evidence”; “high probability”). As such, it is important to realize that the concept of the counterfactual cannot be proven with certainty. So even though the NTG ratio is a single value, conceptually it is a probabilistic statement.[31] One of the main academics within evaluation stated that there is a “…total and inevitable absence of certain knowledge [arising] from the methods social scientists use” when assessing the counterfactual. (Shadish, et al., 2002) This statement is not about poor methods, but about the counterfactual itself. Because programs work with people and are usually not a laboratory experiment that can be replicated over and over[32] to find out what actions people would have taken absent an intervention, one would need a time machine to take people back in time and not provide the program. Since time machines do not exist, evaluators have developed methods that approximate the counterfactual to the best of their ability.

## 2.1 Definitions

For energy efficiency programs, evaluators differentiate between savings at a “gross” and “net” level as described below in the short set of relevant definitions. These definitions are not all encompassing or meant to restrict evaluation in any way, but to provide context before additional detail is provided in later sections. Research to determine attribution occurs to allow for a better understanding of the net level of savings.

**Table 2-1. Definitions**

| Concept | Term | Definition |
|---|---|---|
| **Consumers** | Nonparticipant | Any consumer who was eligible but did not participate in the subject efficiency program, in a given program year. |
| | Participant | A consumer who received a service offered through the subject efficiency program, in a given program year; also called program participant. The term “service” is used in this definition to suggest that the service can be a wide variety of inducements, including financial rebates, technical assistance, product installations, training, energy efficiency information, or other services, items, or conditions. Each evaluation plan should define “participant” as it applies to the specific evaluation. |
| **Gross Impacts** | Gross Impacts | The change in energy consumption and/or demand that results directly from program-related actions taken by participants in an energy efficiency program, regardless of why they participated. |
| **Attribution of Impacts** | Net Impacts | The change in energy consumption and/or demand that is attributable to a particular energy efficiency program. This change in energy use and/or demand may include, implicitly or explicitly, consideration of factors such as free ridership, participant and nonparticipant spillover, and induced market effects. These factors may be considered in how a baseline is defined (e.g., common practice) and/or in adjustments to gross savings values. |
| | Net-to-Gross Ratio | A factor representing net program savings divided by gross program savings that is applied to gross program impacts to convert them into net program impacts. The factor itself may be made up of a variety of |

[31] A probabilistic statement is not the same as the confidence and precision information calculated based on sampling theory.
[32] However, a small number of program designs do lend themselves to experimental or quasi-experimental designs that allow for regression analysis of net impacts.

| Concept | Term | Definition |
|---|---|---|
| | | factors that create differences between gross and net savings, commonly including free riders and spillover. The factor can be estimated and applied separately to either energy or demand savings. Note that the net-to-gross ratio (NTGR) = ((1-Free Ridership) + Participant Spillover + Nonparticipant Spillover). |
| | Core NTGR | 1-Free Ridership |
| | Free Rider | A program participant who would have implemented the program's measures or practices in the absence of the program. Free riders can be: (1) total, in which the participant's activity would have completely replicated the program measure; (2) partial, in which the participant's activity would have partially replicated the program measure; or (3) deferred, in which the participant's activity would have partially or completely replicated the program measure, but at a future time. |
| | Spillover | Reductions in energy consumption and/or demand caused by the presence of an energy efficiency program. There can be participant and/or nonparticipant spillover.<br>*Participant spillover* (PSO) is the additional energy savings that occur as a result of the program's influence when a program participant independently installs incremental energy efficiency measures or applies energy-saving practices after having participated in the energy efficiency program. Evaluated savings associated with Program Administrator Training programs will also be considered Participant spillover. There are several general categories of participant spillover:<br>• *Inside spillover* (ISO): Occurs when program participants implement additional program-induced energy efficiency measures at the program project site.<br>• *Outside spillover* (OSO): Occurs when program participants implement program-induced efficiency measures at other sites within the Program Administrator's service territory at which program project measures were not implemented.<br>• *Like spillover:* Occurs when program participants implement program-induced efficiency measures of the same type as those implemented through the program. Like spillover can occur at the program project sites (ISO) or at other sites within the Program Administrator's service territory (OSO).<br>• *Unlike spillover:* Occurs when program participants implement program-induced efficiency measures of a different type from those implemented through the program. Unlike spillover can occur at the program project sites (ISO) or at other sites within the Program Administrator's service territory (OSO).<br>*Nonparticipant spillover* (NPSO) refers to energy savings that occur when a program nonparticipant installs energy efficiency measures or applies energy savings practices as a result of a program's influence. |
| **Markets** | Market | The commercial activity (e.g., manufacturing, distributing, buying, and selling) associated with products and services that affect energy use. |
| | Market Effects | A change in the structure of a market or the behavior of participants in a market that is reflective of an increase (or decrease) in the |

| Concept | Term | Definition |
|---|---|---|
| | | adoption of energy efficient products, services, or practices and is causally related to market interventions (e.g., programs). Examples of market effects include increased levels of awareness of energy-efficient technologies among customers and suppliers, increased availability of energy-efficient technologies through retail channels, reduced prices for energy-efficient models, build-out of energy-efficient model lines, and—the end goal— increased market shares for energy-efficient goods, services, and design practices. |
| | Market Assessment | An analysis that provides an assessment of how and how well a specific market or market segment is functioning with respect to the definition of well-functioning markets or with respect to other specific policy objectives. A market assessment generally includes a characterization or description of the specific market or market segments, including a description of the types and number of buyers and sellers in the market, the key factors that influence the market, the type and number of transactions that occur on an annual basis, and the extent to which market participants consider energy efficiency an important part of these transactions. This analysis may also include an assessment of whether a market has been sufficiently transformed to justify a reduction or elimination of specific program interventions (or whether continued or even increased intervention is necessary). Market assessment can be blended with strategic planning analysis to produce recommended program designs or budgets. One particular kind of market assessment effort is a baseline study, or the characterization of a market before the commencement of a specific intervention in the market for the purpose of guiding the intervention and/or assessing its effectiveness later. |

Sources: State and Local Energy Efficiency Action Network. 2012. Energy Efficiency Program Impact Evaluation Guide. Prepared by Steven R. Schiller, Schiller Consulting, Inc., www.seeaction.energy.gov; Violette and Rathbun 2014. The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures, Chapter 23: Estimating Net Savings: Common Practices, http://www.nrel.gov/docs/fy14osti/62678.pdf.

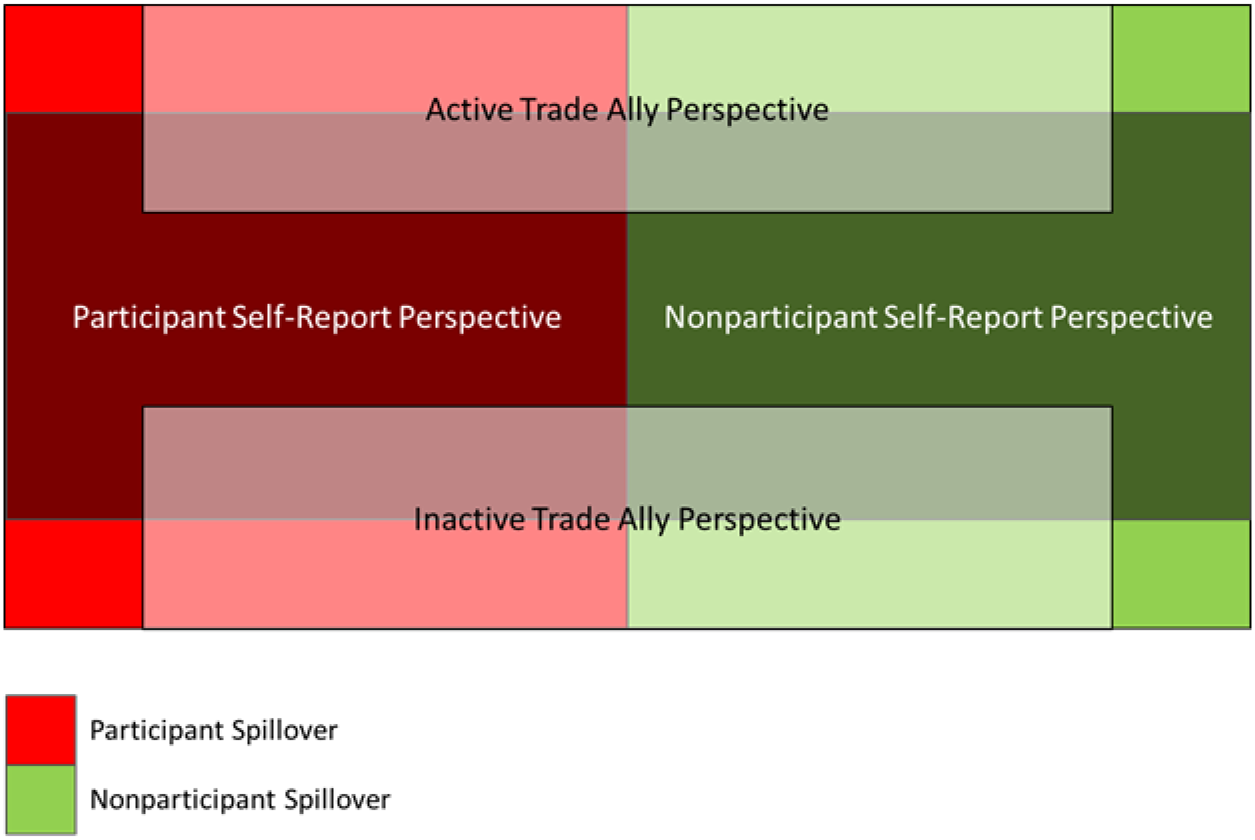
## 2.2 Spillover-Specific Issues

Some issues related to spillover are applicable for both residential and non-residential programs and are discussed in this section.

Spillover is generally categorized into two broad categories – participant spillover and nonparticipant spillover (see Table 2-1). These protocols include two general methods of assessing spillover, one through end-user (or participant/nonparticipant) research and the other through trade ally research. Estimates of participant and nonparticipant research are mutually exclusive, as long as only one of these two general methods is used for a given evaluation period. For example, there is no danger of double-counting spillover if an evaluation includes end-user research with both participants and nonparticipants. Similarly, there is no danger of double-counting spillover if an evaluation includes research with both active and inactive trade allies (see definitions in Section 5.2). However, once end-user research is combined with trade ally research, there is a potential for overlap in the resulting spillover estimates, and care must be taken to avoid double-counting.

Figure 2-1 provides a visual depiction of how the four methods (or “perspectives”) for estimating spillover included in these protocols (participant and nonparticipant self-report, Sections 3.2 and 4.1; and active and inactive trade ally spillover, Section 5.2) can be used to assess both participant (red) and nonparticipant spillover (green). This figure illustrates that (a) different spillover methods can overlap in the spillover they cover, leading to potential double-counting, and (b) some spillover may not be measured by these methods (as represented by the four corners in the diagram).

**Figure 2-1. Example - Types of Spillover and Methods for Assessment**




## 2.2.1 Measure Costs

In order to facilitate analysis of program Total Resource Cost (TRC), estimates of the total incremental measure cost (IMC) at the program level must be developed. IMC values are available for most IL-TRM measures and can be summed to the program level. However, the IMC values for spillover measures could also be estimated and added to this total. The problem is that IMC values for spillover measures can be difficult to estimate. When the magnitude of the savings justifies the effort to estimate the total IMC for spillover measures, the following approaches should be used.

- In cases where the evaluator believes the spillover measure incremental costs are not materially different from the rebated measure incremental costs, the evaluator may multiply the IMC for the rebated measure by the spillover rate to derive the IMC for the spillover measure.
- In cases where the evaluator believes the spillover measure incremental costs are materially different from the installed measure incremental costs (e.g., installation of measures that have no efficiency levels), the evaluator should use the estimated incremental project costs as the IMC for the spillover measure.

Normally, the sample-based estimates of IMCs for spillover measures should be extrapolated to the program level using sample weights. Then the total IMCs for rebated measures and the total IMCs for spillover measures should be summed and used in the TRC calculation.

For measures characterized by the IL-TRM, measure effective useful life (EUL) estimates should be based on the IL-TRM. For measures not characterized by the IL-TRM, evaluator can use either the EUL for similar measures or best professional judgment. In either case, the evaluator must provide the rationale for their choices.

# 3 Commercial, Industrial, and Public Sector Protocols

The table below lists Illinois non-residential programs and the free ridership protocol applicable to each program.[33] If the design of a given program changes significantly, then it may mean that the NTG protocol listed for that program in this document is no longer appropriate. If that happens, the evaluator should follow the procedures outlined in Section 1.4: Diverging from the IL-NTG Methods. Note that the Core Non-Residential Spillover protocol described in Section 3.2 is generally applicable to most of these programs.

**Table 3-1. Commercial, Industrial, and Public Sector Programs**

| Program Administrator | Free Ridership Protocol | Program Name |
|---|---|---|
| Ameren Illinois | 3.1 Core Non-Residential Protocol | Standard Initiative – Core Program<br>Custom Initiative<br>Streetlighting Initiative<br>Standard Initiative – Instant Incentives |
| | 3.3 Small Business Protocol | Standard Initiative – Small Business<br>Standard Initiative – Online Store |
| | 3.5 Study-Based Protocol | Retro-Commissioning Initiative |
| ComEd | 3.1 Core Non-Residential Protocol | Incentives (Standard, Custom)<br>Business Instant Discounts |
| | 3.3 Small Business Protocol | Small Business<br>Air Care Plus<br>Rural Small Business Kits |
| | 3.4 C&I New Construction Protocol | C&I New Construction |
| | 3.5 Study-Based Protocol | Incentives (Data Centers)<br>Enhanced Building Optimization Program<br>Industrial Systems<br>Retrocommissioning<br>Strategic Energy Management<br>Operational Savings |
| | 3.5 Study-Based Protocol or<br>5.3 Consumption Data Analysis Protocol | Power TakeOff |
| | 5.3 Consumption Data Analysis Protocol | Business Energy Analyzer |
| | 4.6 Multifamily Protocol | Public Housing Retrofits |
| | 3.1 Core Non-Residential Protocol | LED Streetlighting |
| Nicor Gas | 3.5 Study-Based Protocol | Strategic Energy Management |
| | 3.3 Small Business Protocol | Small Business Program |
| | 3.1 Core Non-Residential Protocol | Business Energy Efficiency Rebates |
| | 3.1 Core Non-Residential Protocol | Business Custom Rebates |
| | 3.4 C&I New Construction Protocol | Commercial and Industrial New Construction |
| | 3.1 Core Non-Residential Protocol | Combined Heat and Power |
| | 3.5 Study-Based Protocol | Retro Commissioning |
| Peoples Gas/<br>North Shore Gas | 3.1 Core Non-Residential Protocol | C&I and PS Custom |
| | 3.6 Technical Assistance Protocol | C&I and PS Direct Install and Assessment |
| | 3.1 Core Non-Residential Protocol | C&I and PS Prescriptive |
| | 3.3 Small Business Protocol | SB Custom<br>SB Direct Install & Assessment |

[33] The "Free Ridership Protocol Name" in the second column of the table refers to the numbered sections in this document, e.g., "3.3 Small Business Protocol."

| Program Administrator | Free Ridership Protocol | Program Name |
|---|---|---|
| | | SB Partner Trade Ally<br>SB Prescriptive |
| | 3.4 C&I New Construction Protocol | C&I and PS New Construction (Joint) |
| | 3.5 Study-Based Protocol | C&I and PS Gas Optimization<br>MF Gas Optimization<br>C&I and PS Retro-Commissioning (Joint) |
| All | 5.2 Code Compliance Protocol | Statewide Codes Collaborative |

## 3.1 Core Non-Residential Protocol

### 3.1.1 Core Non-Residential Free Ridership Protocol

Key considerations and guidelines for estimation of free ridership under this Core Non-Residential Free Ridership (FR) protocol are listed below:

- **Multiple Questions:** Evaluators will use program participant responses to multiple survey questions as inputs to the free ridership calculation algorithm. Evaluators will not use the response to a single question to establish a survey respondent as either a complete free rider or a complete non-free rider.
- **Program and Non-Program Factors:** Evaluators will administer survey questions to obtain respondent ratings on a numeric scale of the impact, influence, or importance on the decision to implement energy efficiency measures or take energy efficiency actions. A series of questions will focus on factors that the evaluator determines are a function of the program. Such program factors may, for instance, include the availability of the program incentive, technical assistance from program staff, program staff recommendations, Program Administrator marketing materials, and an endorsement or recommendation by a Program Administrator, account manager or program partner staff. Evaluators will also administer a series of questions to obtain respondent ratings, on a numeric scale of the impact, influence, or importance on the decision to implement energy efficiency measures, of different factors that the evaluator determines are not a function of the program. Such non-program factors may include, for example, previous experience with the measure, standard business or industry practice, and organizational policy or guidelines.
- **Vendor Recommendations:** Vendor recommendations may also be a program factor to the extent that such recommendations are a function of the program. Vendors include trade allies, contractors, distributors, suppliers, and other market actors involved in the selection and installation of program-incented equipment on behalf of the participant. The evaluator may administer survey questions to vendors to verify their involvement with participant projects and to obtain their ratings—on a numeric scale—of the impact, influence, or importance of the program on the decision to recommend the energy efficiency measures to the program participant.
- **Consistency Checks:** Evaluators should administer survey questions as checks on the consistency of responses associated with a core free ridership assessment methodology. Evaluators may also reference available quantitative and qualitative data, including consistency check data, to perform documented modifications to individual free ridership estimates resulting from the application of a core free ridership assessment methodology.
- **Quality Control Review:** For programs involving large, complex projects and decision-making, after all the survey data collection has been completed and preliminary NTGRs have been computed using the standard calculation procedures, a quality control review is completed. All quantitative and qualitative data is systematically and independently analyzed by a researcher who is familiar with the program, the individual site and the social science theory that underlies the decision maker survey instrument. They make an independent determination of whether the additional information justifies modifying the previously calculated NTGR score, and present any recommended modifications and their rationale in a

well-organized manner, along with specific references to the supporting data. Circumstances that may justify a revision of the previously calculated NTGR score include: (1) significant inconsistencies exist between one of the scores that may lead to elimination of the score that is an outlier; (2) the emerging "story" from the qualitative data is in conflict with the quantitative data, thereby requiring a callback to the customer to resolve the inconsistency and a revision to the original scoring based on the new information; or (3) the entire set of results for an interview are inconsistent, the data are too disparate and would not be helped with a callback. In such cases, a recommendation is made to remove that sample point and replace it with a back-up point.

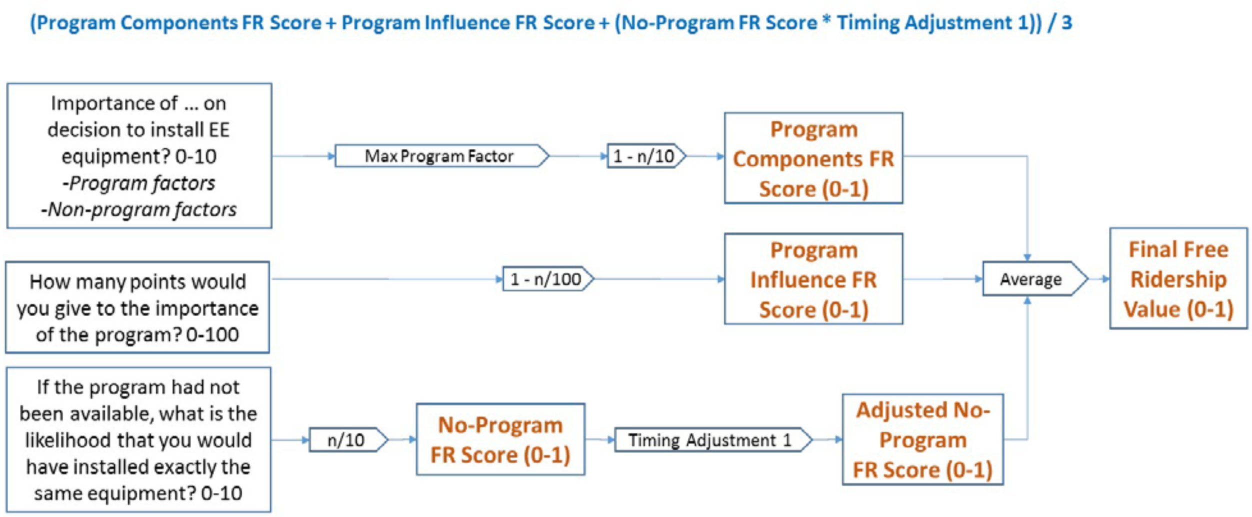
#### 3.1.1.1 Core Free Ridership Scoring Algorithm

The Core Non-Residential FR protocol combines three scores that test different ways of approaching free ridership: the Program Components FR Score, the Program Influence FR Score, and the No-Program FR Score. The three scores are combined to calculate the final free ridership value.

Two options for combining the three scores are shown graphically in Figure 3-1 and Figure 3-2. These two options use different specifications to account for the impact of the program on project timing (referred to as "deferred free ridership"; see also discussion in Section 3.1.1.1.4). Evaluators will calculate free ridership using both options and will select one option for purposes of calculating the annual incremental energy savings for comparing to the legislated goal.[34] To select the appropriate option for use, we recommend that evaluators examine the various components of the free ridership scores to understand the differences between the options and justify their choice. Evaluators may also choose to use Cronbach's alpha to examine the internal consistency of the various options (but evaluators are not *required* to select the option with the highest Cronbach's alpha if they have justification for a different choice).

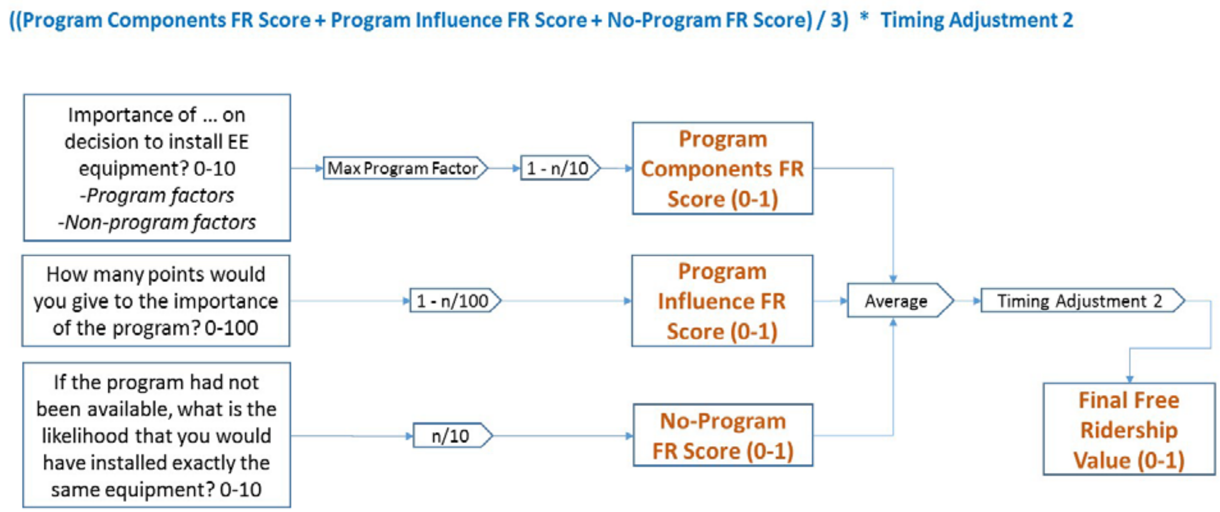
Evaluators will submit participant survey and net savings analysis data to the Illinois NTG Working Group. The group will analyze these data for the purpose of further refining the protocol and potentially reducing the number of alternative algorithm input specifications.

**Figure 3-1. Core Free Ridership Algorithm 1**




[34] As defined in 220 ILCS 5/8-103 and 220 ILCS 5/8-104.

**Figure 3-2. Core Free Ridership Algorithm 2**




#### 3.1.1.1.1 Program Components FR Score

Evaluators will administer survey questions to obtain participants' rating of the importance of various factors on the decision to implement energy efficiency measures. The numeric scales shall range from 0 to 10, where 0 means "not at all important" and 10 means "extremely important". The various factors referenced in the survey will include those that the evaluator determines are program factors and non-program factors that could potentially impact the participant decision making process. A participant rating shall be obtained for each relevant program and non-program factor.

Evaluators will calculate the "Program Components FR Score" for each survey respondent using the following equation:

Program Components FR Score = 1 - ([Maximum Program Factor Rating]/10).

These scores can range from 0 (no free ridership) to 1 (full free rider). Since the algorithm uses the numerical rating for the Program Component receiving the highest score, it is important that such scoring be accurate. To facilitate this, the scores feeding into the Program Components FR Score calculation can be enhanced by adjusting survey wording and adding consistency checks around specific program components to seek clarification on how they influenced decisionmaking. For those program components receiving scores of 8, 9 or 10, additional questions can be included to determine why that specific score was given, and further, how that Program Component specifically influenced the participant's decision to upgrade to energy efficient equipment.

Evaluation reports should list all factors considered program and non-program factors. Evaluators must document why factors were treated as program factors or non-program factors.

#### 3.1.1.1.2 Program Influence FR Score

Evaluators will administer a survey question that asks respondents to quantify the importance of the program on the decision to implement energy efficiency measures relative to the importance or impact of non-program factors. Respondents will be asked to allocate a total of 100 points to the program and to non-program factors. The points allocated to the program by the participants are the "Program Points." Evaluators will calculate the "Program Influence FR Score" as 1 - (Program Points/100). This score can range from 0 (no free ridership) to 1 (full free rider).

#### 3.1.1.1.3 No-Program FR Score

Evaluators will administer a counterfactual likelihood survey question to obtain respondent ratings on a 0 to 10-point numeric scale (where 0 means "not at all likely" and 10 means "extremely likely") of the likelihood of the respondent to implement the exact same energy efficiency measures in the absence of the program. Evaluators will calculate the "No-Program FR Score" as the numeric score of the likelihood of the respondent to implement specified energy efficiency measures in the absence of the program divided by 10. This score can range from 0 (no free ridership) to 1 (full free rider).

Note that under one of the two deferred free ridership specifications (see next subsection), a timing adjustment is applied to the "No-Program FR Score." Under this specification, the resulting score is referred to as the "Adjusted No-Program FR Score."

#### 3.1.1.1.4 Timing and Deferred Free Ridership

Evaluators will ask about the likely timing of measure installation in the absence of the program in two different ways. This is referred to as the counterfactual timing question since the evaluators are asking the respondent to speculate on what might have happened within a particular timeframe.

The first question will present a series of date ranges (e.g., within one year, between 12 months and 2 years, etc.) and ask the respondent to pick one representing their best estimate of when the measure would have been implemented in the absence of the program. The free ridership algorithm uses the midpoint of each date range, referred to as "Number of Months Expedited" below. For respondents that report accelerated adoption due to the program, this variable can take on values from 6 to 48 months.

The second question will prompt the respondent to use a 0 to 10-point numeric scale to report the likelihood, in the absence of the program, of implementing the same measure within 12 months of when it was actually implemented. This is the "Likelihood of Implementing within One Year" in the formulas below.

Evaluators will use the Likelihood of Implementing within One Year and/or the Number of Months Expedited variables to calculate two alternative ways of accounting for deferred free ridership:

1) Calculate *Timing Adjustment 1* as equal to:

*1 - (Number of Months Expedited - 6)/42*

Timing Adjustment 1 is multiplied by the No-Program FR Score; it can range from 0 (full deferred free ridership) to 1 (no deferred free ridership). The application of Timing Adjustment 1 is shown in Figure 3-1.

2) Calculate *Timing Adjustment 2* as equal to:

*1 - ((Number of Months Expedited - 6)/42)*((10 - Likelihood of Implementing within One Year)/10)*

Timing Adjustment 2 is multiplied by the average of the Program Components FR Score, the Program Influence FR Score, and the No-Program FR Score; it can range from 0 (full deferred free ridership) to 1 (no deferred free ridership). The application of Timing Adjustment 2 is shown in Figure 3-2.

How these timing adjustments are accounted for in the calculation of the Final FR Value is described below in the subsection "3.1.1.2 Construction of Core Free Ridership Value."

#### 3.1.1.1.5 Consistency Checks

Respondents may be asked one or more questions to facilitate understanding and potentially reconcile apparently inconsistent responses. Some questions may be asked of all respondents; others may be asked when previous answers appear inconsistent. Evaluators should report on the amount of inconsistency encountered and on the resolution to inform future protocol revisions. Three consistency checks are outlined below.

**Program Influence/Program Components Consistency Check**

A Program Influence/Program Components consistency check is triggered when the following conditions are met:

1) The number of Program Points (supporting calculation of the Program Influence FR Score) is greater than 70; and

2) No program factor is rated greater than 2.

A Program Influence/Program Components consistency check is also triggered by the following conditions being met:

1) The number of Program Points (supporting calculation of the Program Influence FR Score) is less than 30; and

2) At least one program factor is rated greater than 7. In this instance, the highest-rated program factor(s) with a rating of greater than 7 will be referenced in the consistency check question.

**Program Components/No-Program Consistency Check**

A Program Components/No-Program consistency check is triggered when the following conditions are met:

1) The likelihood of installing the exact same equipment without the program (supporting calculation of the No-Program FR Score) is greater than 7; and

2) At least one program factor is rated greater than 7.

A Program Components/No-Program consistency check is also triggered when the following conditions are met:

1) The likelihood of installing the exact same equipment without the program (supporting calculation of the No-Program FR Score) is less than 3; and

2) No program factor is rated greater than 2.

**Timing of Installation Decision/Level of Program Attribution Consistency Check**

The survey should contain a question to ask whether the respondent learned about the program after finalizing project specifications, including, where applicable, equipment efficiency level and number of units. The Timing of Installation Decision/Level of Program Attribution consistency check is triggered by the following conditions being met:

1) A respondent learned about the program after finalizing project specifications; and

2) Any of the following occur:

a) The number of Program Points (supporting calculation of the Program Influence FR Score) is greater than 70;

b) The likelihood of installing the exact same equipment without the program (supporting calculation of the No-Program FR Score) is less than 3; or

c) At least one program factor is rated greater than 7.

When the Timing of Installation Decision/Level of Program Attribution consistency check is administered, if the respondent rating of the importance of the vendor on the decision to implement the project is greater than 7, then an open-ended question will be triggered to obtain information regarding the role the vendor played in the participant decision to implement the project.

#### 3.1.1.2 Construction of Core Free Ridership Value

This protocol designates two options of constructing the core free ridership value. Evaluators will calculate free ridership using both options and will select one option for purposes of calculating the annual incremental energy savings for comparing to the legislated goal. Evaluators will present the results of both estimates of free ridership in EM&V reporting.

Evaluators will calculate free ridership values in the following two ways:

1) Core FR Algorithm 1 = AVERAGE([Program Components FR Score], [Program Influence FR Score], [No-Program FR Score*Timing Adjustment 1])

2) Core FR Algorithm 2 = AVERAGE([Program Components FR Score], [Program Influence FR Score], [No-Program FR Score]) * Timing Adjustment 2

The two Core FR Algorithms listed above are graphically presented in Figure 3-1 and Figure 3-2, respectively.

#### 3.1.1.3 Vendor Influence in the Free Ridership Calculation

##### 3.1.1.3.1 Treatment of Participant's Rating of Vendor in the Program Components FR Score of the Core FR Algorithm

The Program Components FR Score of the participant Core FR algorithm is based on participant ratings of program and non-program factors. Vendors[35] often receive a high rating for their influence on the participant's decision to install the efficient measure. To implement the Core FR algorithm, the evaluator needs to decide whether the vendor rating should be considered a program factor or a non-program factor. This section outlines three scenarios for the treatment of the participant's rating of a vendor in the Program Components FR Score of the Core FR algorithm.

**Scenario #1: Vendors are automatically considered a program factor**

The vendor is considered a program factor in the calculation of the Program Components FR Score in the FR algorithm if the program meets specific criteria, which could include the following:

1. Trade allies are an integral component of program delivery, as supported by program logic
2. The trade ally network consists of a limited number of Program Administrator-selected, pre-approved trade allies
3. Only trade allies can implement projects and submit applications on behalf of the customer
4. Trade allies complete signed agreements with the Program Administrator
5. Trade allies complete program-sponsored training

In these cases, the vendor is automatically considered a program factor, and no additional input from the vendor is needed regarding the customer's decision-making process related to the project. The participant's influence rating for the vendor goes directly into the Program Components FR Score algorithm as a program factor (if it is the highest rating given to any program factor).

**Scenario #2: Vendors are considered a program factor if the program influenced their recommendation to implement the efficient project**

For programs that have a trade ally network, but do not meet the conditions under Scenario #1 above, follow-up interviews with vendors may be used to determine if the vendor should be considered a program factor. To qualify for Scenario #2, a program's trade ally network should meet the following conditions:

1. Trade allies are registered with the program
2. Trade allies typically complete signed agreements with the Program Administrator
3. Trade allies complete program-sponsored training
4. Trade allies drive program participation, as supported by program logic

In these cases, if the size of the project warrants a greater level of effort, a follow-up interview with the vendor may be used to determine if the participant's rating of the vendor's influence should be included as a program factor. A follow-up interview is triggered under the following conditions:

1. The participant rated the influence of the vendor as 8, 9, or 10 (on a scale from 0 to 10)
2. The rating the participant gave to vendor influence is higher than any of the program factor ratings

If completed, the interview should include the following questions:

FR1a On a scale of 0 to 10 where 0 is NOT AT ALL IMPORTANT and 10 is EXTREMELY IMPORTANT, how important was the <PROGRAM>, including incentives as well as program services and information, in influencing your decision to recommend that <CUSTOMER> install the energy efficient <MEASURE> at this time?

FR1b On the same scale, how important was your firm's past participation in an incentive or study-based program sponsored by <PROGRAM ADMINISTRATOR>?

FR2 And using a 0 to 10 likelihood scale where 0 is NOT AT ALL LIKELY and 10 is EXTREMELY LIKELY, if the <PROGRAM>, including incentives as well as program services and information, had not been available, what is the likelihood that you would have recommended this specific <MEASURE> to <CUSTOMER>?

FR3a Approximately, in what percent of projects did you recommend <MEASURE> BEFORE you learned about

[35] Vendors include trade allies, contractors, distributors, suppliers, and other market actors involved in the selection and installation of program-incented equipment on behalf of the participant.

the <PROGRAM>?

FR3b And approximately, in what percent of projects do you recommend <MEASURE> now that you have worked with the <PROGRAM>?

The interview will also include consistency checks, if the vendor provides inconsistent responses to these questions.

The vendor is viewed as a program factor and the rating the participant provided for the vendor goes into the Program Components FR Score algorithm as a program factor if, after consideration of any consistency checks:

1. The response to Q. FR1a or FR1b is 8, 9, or 10

OR

2. The response to Q. FR2 is 0, 1, or 2

OR

3. The difference between the responses to FR3b and FR3a is 80% or greater

If none of these conditions are met, the rating the participant provided for the vendor does not go into the Program Components FR Score algorithm as a program factor.

In the event that an interview is not completed (e.g., the size of the project did not warrant a vendor interview or the vendor could not be reached), the evaluation reports should explain how the rating the participant provided for the vendor was treated. Guidelines for these situations may be added to this document in the future.

**Scenario #3: Vendors are considered a non-program factor**

For programs that do NOT have a trade ally network that meets the conditions under Scenario #2, vendors are considered a non-program factor. In these cases, the participant's rating of the vendor does not go directly into the Program Components FR Score algorithm as a program factor.

## 3.2 Core Non-Residential Spillover Protocol

Spillover refers to energy savings associated with energy-efficient equipment installed by consumers who were influenced by an energy efficiency program, but without direct intervention (e.g., financial or technical assistance) from the program.

To place the spillover protocols in context, we begin by defining the NTGR as:

NTGR = (1 – Free Ridership Value + PSO Rate + NPSO Rate)

Where:

PSO Rate = Participant spillover rate

NPSO Rate = Nonparticipant spillover rate

The term (1-Free Ridership) is referred to as the Core NTGR for an efficiency program.

### 3.2.1 Core Participant Spillover Protocol

The Core Participant Spillover protocol is generally applicable to most commercial, industrial, and public sector programs.

#### 3.2.1.1 Research Methods

**Data collection approach.** An initial determination of participant spillover may be made based on self-reported findings from surveys of program participants. At a minimum, surveys collecting data pertaining to participant spillover will obtain general information on the specific measures installed and information substantiating their attribution to an energy efficiency program. Research on the specific characteristics of the energy efficient equipment installed and the baseline and operating conditions needed to estimate savings may be done in one of two ways: 1) a detailed battery of measure specific questions may be administered as part of the initial survey; or 2) a separate in-depth follow-up interview may be conducted by the engineer or analyst responsible for the energy savings calculation. In either case, an engineer or analyst will use the collected data to develop an estimate of spillover savings for each project.

**Sample Frame.** One target for participant spillover research may be the most recent year's program participants who have been sampled for free ridership or process surveys. In the case where a stand-alone spillover study is being conducted, the sample frame may be broader and include those whose participation occurred during the time period of two prior program years.

Because evaluated spillover energy impacts associated with the sample are being extrapolated to the program population, it is important that the sample frame be limited to participating customers for which spillover may potentially be claimed.

Sample frames should be constructed in accordance with the following guidelines:

- Self-directing customers as defined by 220 ILCS 5/8-104(m) should be excluded from the sample frame for natural gas spillover.
- Customers of municipal electric utilities should be excluded from the sample frame for electric spillover.

**Timing of Data Collection.** Evaluators may either administer the participant spillover module as part of a comprehensive net-to-gross survey, or they may elect to implement it separately. A follow-up in-depth interview may also be conducted by an engineer or analyst to obtain additional details needed to quantify savings. Optimally, the spillover inquiry should be timed in order to allow sufficient time for spillover to occur; at a minimum, three months after the program-incented measure is installed. Projects installed up to two years after program participation occurred may be counted as spillover, provided it can be substantiated.

#### 3.2.1.2 Approach for Identifying and Quantifying Spillover

**Attribution Criteria.** Program attribution is determined by the responses to the following two survey questions:

1. How important was your experience in the <PROGRAM> in your decision to implement this measure, using a scale of 0 to 10, where 0 is not at all important and 10 is extremely important?
2. If you had not participated in the <PROGRAM>, how likely is it that your organization would still have implemented this measure, using a 0 to 10 scale, where 0 means you definitely WOULD NOT have implemented this measure and 10 means you definitely WOULD have implemented this measure?

The response to the first question cited above is "Measure Attribution Score 1," and the response to the second question cited above is "Measure Attribution Score 2."

There are two methods by which the attribution may be calculated:

1. Program attribution is established if the average of Measure Attribution Score 1 and (10 – Measure Attribution Score 2) exceeds 5.0[36]; either the Measure Attribution Score 1 or (10 – Measure Attribution Score 2) could be below 5.0—as long as the average is greater than 5.0, the threshold is met. If the average is greater than 5.0, 100% of the measure energy savings referenced in the question are considered to be attributable to the program. If the average is not greater than 5.0, none of the measure energy savings are considered to be attributable to the program.

[36] Note that the threshold value for counting spillover has been lowered from 7.0 to 5.0. The rationale for this lower threshold is: (1) the value of >5 is a strong indicator of program influence on the decision to install non-rebated equipment and is currently being used in other states (e.g., California); (2) the previous value of >7 set an unreasonably high standard for demonstrating program influence on the decision to install non-rebated equipment; and (3) past IL evaluation data show that a threshold of >5 will improve spillover estimates as it provides a better approximation of partial spillover (i.e., where a portion of the savings for each measure installed outside the program gets credited as spillover based upon the program influence rating).

2. An attribution rate may be calculated as equal to the sum of Measure Attribution Score 1 and (10 – Measure Attribution Score 2), divided by 20. For instance, if the attribution rate is 0.3, then 30% of the measure energy savings referenced in the question are considered to be attributable to the program.

Program attribution option 2 must be used in cases in which evaluators have performed the data collection and analysis required to attribute energy savings using option 2 identified above.

**Calculation of Spillover Measure Energy Savings.** Energy savings of spillover measures shall be calculated in one of two ways.

1. Those addressed in the IL-TRM shall be calculated in accordance with the methods and algorithms specified in the IL-TRM, and shall reference the IL-TRM-defined time-of-sale or new construction baseline.
2. For measures not addressed in the IL-TRM, evaluators shall quantify savings using accepted industry-wide savings methods that conform to IPMVP or other industry protocols and documents.

Evaluators will make every effort to ensure that there is no double-counting of participant spillover energy savings across multiple sources of participant and nonparticipant spillover (such as participating customer and trade ally surveys) and will document that effort.

Measure implementation must have occurred within one year of the participant spillover study data collection effort in order to be countable as participant spillover.

For the purposes of accounting for spillover savings attributable to a program, spillover will only be quantified for measures implemented within the Program Administrator's service territory.

#### 3.2.1.3 Key Participant Spillover Survey Questions

The Participant Spillover question module is designed to be a general inquiry that seeks to: (1) assess whether additional energy efficiency improvements were implemented since the rebated project was completed; (2) confirm that these measures either had not received program incentives, or that there were no plans to submit them for program incentives in the future; (3) gather basic information about the additional energy efficiency measures (e.g., their type, size, quantities, and energy efficiency rating); and (4) establish program attribution.

The basic question structure is shown below. The measure-specific questions can be repeated in order to capture multiple measures. Note that there is considerable flexibility to tailor the questions to specific types of applications and programs.

1. Since your participation in the <PROGRAM>, did you implement any ADDITIONAL energy efficiency improvements at this facility or at your other facilities within <PROGRAM ADMINISTRATOR>'s service territory that did NOT receive incentives through <PROGRAM>?
2. What measures did you implement without an incentive?

MEASURE-SPECIFIC QUESTIONS [repeated for each spillover measure][37]

1. How important was your experience in the <PROGRAM> in your decision to implement this <MEASUREX>? Please use a scale of 0 to 10, where 0 is not at all important and 10 is extremely important.
2. Can you explain how your experience with the <PROGRAM> influenced your decision to install this additional high-efficiency measure?
3. If you had not participated in the <PROGRAM>, how likely is it that your organization would still have implemented <MEASURE>? Please use a 0 to 10, scale where 0 means you definitely WOULD NOT have implemented this measure and 10 means you definitely WOULD have implemented this measure.
4. How many of <MEASURE> did you install?3
5. Questions to further define the measure (as applicable):
    a. Type

[37] Example questions to gather engineering information to support the calculation of spillover savings may be accessed here: http://www.ilsag.info/il_ntg_methods.html

   b. Efficiency
   c. Size
   d. Other attributes
6. Can you briefly explain why you decided to install this energy efficiency measure on your own, rather than going through the <PROGRAM>?

#### 3.2.1.4 Reporting of Results

Evaluators will report the following information relating to participant spillover data collection and analysis in annual EM&V reporting: 1) the number of participants surveyed; 2) the number of survey respondents reporting spillover; 3) the number of survey respondents who meet the spillover attribution threshold; 4) the number of respondents for which spillover savings were actually quantified; 5) the spillover savings for each project and overall; and 6) the spillover rate. The term (1-Free Ridership) is referred to as the Core NTGR.

The annual EM&V report should also describe the means by which the participant spillover rate is calculated. Two possible approaches are:

(1) Add the participant spillover rate to each project's Core NTGR. The project-level NTGRs are then weighted by each project's ex ante or ex post (if available) gross savings as a share of the total. This savings-weighted NTGR can then be applied to the ex post gross savings of the participant population. If the sample is stratified, sampling weights must be applied before applying the NTGR to the ex post gross savings of the participant population.

(2) Estimate program spillover effects by summing overall project-level spillover estimates for the sample and dividing this sum by the total ex ante or ex post (if available) gross savings for the sample to produce the participant spillover rate. This participant spillover rate can be added to the Core NTGR for the sample to yield the NTGR. If the sample is stratified, sampling weights must be applied before applying the NTGR to the ex post gross savings of the participant population.

In both cases, the participant spillover rate must be calculated at the project level for Option 1 or at the program level for Option 2, using the following formula.

$$Participant\ Spillover\ Rate = \frac{ISO + OSO\ in\ sample}{Ex\ Post\ Gross\ Impacts\ in\ sample}$$

Where:

ISO = Inside participant spillover

OSO = Outside participant spillover

### 3.2.2 Core Nonparticipant Spillover Protocol

The evaluation may perform research to measure nonparticipant spillover (NPSO). Evaluators will make efforts to ensure that there is no double-counting of energy savings across multiple sources and will document those efforts.

#### 3.2.2.1 Core Nonparticipant Spillover Protocol – Measured from End Users

NPSO for end users is defined as the energy savings that are achieved when a nonparticipant end user—as a result of the influence of a Program Administrator's programs—implements energy efficiency measures *outside* of the Program Administrator's programs.

One option for the evaluator would be to survey nonparticipating customers and estimate spillover savings for any efficient measures installed that respondents are able to attribute to specific Program Administrator programs. However, in many cases, nonparticipants might find it difficult, if not impossible, to reliably attribute any of their installations to the influence of a specific Program Administrator program. If an evaluator suspects that nonresidential nonparticipants will not be able to reliably attribute spillover savings to any particular Program Administrator program, a second option would be to survey nonparticipants and estimate spillover savings from the installation of efficient measures that respondents are able to attribute to their general knowledge of the Program Administrator incentives and information, regardless of the particular program source. These protocols are written assuming that the NPSO for end users will be estimated using this second option.

Note that this protocol does not address estimating spillover for upstream and midstream programs where the end user is assumed to be completely ignorant of any Program Administrator influence. Of course, when considered feasible, evaluators are free to estimate spillover and spillover rates at the program-specific level with the suggested questions presented in Section 3.2.2.1.2 modified appropriately.

#### 3.2.2.1.1 Research Methods

**Data Collection Approach.** An initial determination of spillover may be made based on self-reported findings from surveys of nonparticipants. At a minimum, surveys collecting data pertaining to nonparticipant spillover will obtain general information on the specific measures installed and information substantiating the influence of the Program Administrator on the installation decision. Research on the specific characteristics of the energy efficient equipment installed and the baseline and operating conditions needed to estimate savings may be done in one of two ways: (1) a detailed battery of measure specific questions may be administered as part of the initial survey, or (2) a separate in-depth follow-up interview may be conducted by the engineer or analyst responsible for the energy savings calculation.[38] Projects installed within the last two years of the nonparticipant spillover study data collection effort may be counted as spillover, provided program attribution and energy savings can be substantiated. In either case, an engineer or analyst will use the collected data to develop an estimate of spillover savings for each project.

**Sample Frame.** The sample frame for nonparticipant end user spillover research is composed of customers who have not participated in any programs within the last three years. Because evaluated spillover savings associated with the sample are being extrapolated to the nonparticipant population, it is important that the sample frame be limited to nonparticipants for whom spillover may potentially be claimed.

Sample frames should be constructed in accordance with the following guidelines:

- Self-directing customers as defined by 220 ILCS 5/8-104(m) should be excluded from the sample frame for natural gas spillover.
- Customers of municipal electric utilities should be excluded from the sample frame for electric spillover.
- Entities eligible to participate in the Illinois Department of Commerce and Economic Opportunity programs will not be included in sample frames for the study of nonparticipant spillover attributable to utility-administered programs.
- Entities eligible to participate in the utilities' programs will not be included in sample frames for the study of nonparticipant spillover attributable to programs administered by the Department of Commerce and Economic Opportunity.

**Timing of Data Collection.** Evaluators might administer the nonparticipant end user spillover study in parallel with the program impact evaluation, potential study or saturation study research, or at a different time.

#### 3.2.2.1.2 Approach for Identifying and Quantifying Spillover

**Key Nonparticipant Spillover Survey Questions.** The nonparticipant end user spillover question module is designed to be a general inquiry that seeks to: (1) assess whether additional energy efficiency improvements were implemented during the study period; (2) confirm that these measures had not received program incentives and that there were no plans to submit them for program incentives in the future; (3) gather basic information about the additional energy efficiency measure(s), e.g., the type, size, quantities, and energy efficiency rating; and (4) establish the Program Administrator importance ratings. Note that while the example questions can be customized to assess the influence of a specific program in the Program Administrator portfolio, they are currently worded to capture influence of the Program Administrator, regardless of program source.

Below are example questions that might be used in a nonparticipant spillover survey. They are grouped by the following topics:

---

[38] See http://www.ilsag.info/il_ntg_methods.html for detailed example questions designed to collect information required to estimate spillover savings for a variety of measures.

- **Threshold conditions:** Is there some credible evidence that it was at least possible for the Program Administrator to have influenced the decision to install additional energy efficient measures?
- **Measure description:** Enough information needs to be collected for the measure and its operation to support a credible estimate of savings
- **Attribution:** Is there credible evidence that the Program Administrator had substantial influence on the end user's decision to install the efficient measure outside of any of the programs in the Program Administrator portfolio?

**Threshold Conditions.** Spillover cases are identified using a threshold approach in which certain minimal conditions must be met for a customer's installation to be considered for spillover. The following are example questions that evaluators may use (individually or in combination) to determine that program administrator influence on the installation is possible:

1. Before installing these measures, did you know that <PROGRAM ADMINISTRATOR> offers energy efficiency programs, incentives, and information to help their business customers make energy efficiency improvements at their facilities?
2. <PROGRAM ADMINISTRATOR> offers incentives for energy efficient equipment upgrades and improvements through its <PORTFOLIO NAME> programs. Before installing these measures, had you heard about the <PORTFOLIO NAME> programs?

If the answer to either question is "yes", then the threshold condition is met.

**Measure Description.** The interview (either the initial interview or a separate in-depth follow-up interview) can be used to determine the following basic attributes (as applicable) required to support a credible estimate of savings:

1. Type
2. Efficiency
3. Size
4. Other attributes

The named measure(s) must represent equipment that is more energy efficient than either: (1) equipment required by codes or standards; (2) industry-standard practice for certain types of equipment; or (3) for Custom measures, the minimum efficiency equipment available to meet the customer's requirements. For detailed example questions designed to collect engineering information required to estimate spillover savings for a variety of measures, see http://www.ilsag.info/il_ntg_methods.html.

**Attribution.** The following questions are suggested to assess attribution. These questions should be asked separately for each potential spillover measure:

1. Earlier you mentioned that you knew that <PROGRAM ADMINISTRATOR> offers incentives to customers for installing energy efficient equipment, and also provides information to customers to help them reduce their energy usage. Thinking about all of the reasons you chose to install the energy efficient <MEASURE>, did your knowledge of these incentives and information available through <PROGRAM ADMINISTRATOR> have ANY INFLUENCE on your decision to install <MEASURE>?

<u>ASK IF Q1=YES</u>

2. Using a scale of 0 to 10, where 0 is not at all influential and 10 is extremely influential, how much influence did your knowledge of the incentives and information <PROGRAM ADMINISTRATOR> offers have on your decision to install your energy efficient <MEASURE>?
3. Just to make sure that we understand you correctly, please answer the following hypothetical question. If you had you NOT known about the incentives and information <PROGRAM ADMINISTRATOR> offers, would you still have installed your energy efficient <MEASURE>? Please use a scale of 0 to 10, where 0 means you definitely WOULD NOT have installed your energy efficient <MEASURE> and 10 means you definitely WOULD have done so.

**Consistency Checks**

Respondents may be asked one or more questions to facilitate understanding and potentially reconcile apparently inconsistent responses. Evaluators should report on the amount of inconsistency encountered and on the resolution to inform future protocol revisions.

ASK IF Q2>7 AND Q3>7 OR Q2<3 AND Q3<3

4. In your own words, can you explain HOW your knowledge of the incentives and information <PROGRAM ADMINISTRATOR> offers influenced your decision to purchase or install your energy efficient <MEASURE>?

The evaluation analyst will assess the response to this open ended question and its consistency with the other questions, and, if warranted based on clear additional information, they will adjust the score based on expert judgment. If an inconsistency exists and the open-ended response does not resolve the inconsistency, the respondent will be removed from the calculation. All instances of this occurring should be documented in the final report. Additional consistency checks, triggered and resolved within the survey with additional questions to participants, remain optional.

**Nonparticipant End User Spillover Algorithm.** The response to question #2 cited above is "Measure Attribution Score 1," and the response to question #3 cited above is "Measure Attribution Score 2."

There are two methods by which the attribution may be calculated:

1. Provided that the open-ended responses do not contradict influence of the Program Administrator, spillover is considered to be attributable to the Program Administrator if the average of the Measure Attribution Score 1 and (10 – Measure Attribution Score 2) exceeds 5.0[39]; either the Measure Attribution Score 1 or (10 – Measure Attribution Score 2) could be below 5.0—as long as the average is greater than 5.0, the threshold is met. If the average is greater than 5.0, 100% of the measure energy savings referenced in the question are considered to be attributable to the Program Administrator. If the average is not greater than 5.0, none of the measure energy savings are considered to be attributable to the Program Administrator.
2. Provided that the open-ended responses do not contradict influence of the Program Administrator, the attribution rate is calculated as equal to the sum of Measure Attribution Score 1 and (10 – Measure Attribution Score 2), divided by 20. For instance, if the attribution rate is 0.3, then 30% of the measure energy savings referenced in the question are considered to be attributable to the Program Administrator.

**Calculation of Spillover Measure Energy Savings.** Energy savings of spillover measures shall be calculated in one of two ways.

1. Those addressed in the IL-TRM shall be calculated in accordance with the methods and algorithms specified in the IL-TRM, and shall reference the IL-TRM-defined time-of-sale or new construction baseline.
2. For measures not addressed in the IL-TRM, evaluators shall quantify savings using accepted industry-wide savings methods that conform to IPMVP and other industry protocols and documents.

Evaluators will make every effort to ensure that there is no double-counting of nonparticipant spillover energy savings across multiple sources of nonparticipant spillover reporting (such as nonparticipating customer and trade ally surveys) and will document that effort.

Measure implementation must have occurred within the last two years of the nonparticipant spillover study data collection effort in order to be countable as nonparticipant spillover.

For the purposes of accounting for spillover savings attributable to the Program Administrator, spillover will only be quantified for measures implemented within the Program Administrator's service territory.

#### 3.2.2.1.3 Reporting of Results

Evaluators will report the following information relating to nonparticipant spillover data collection and analysis in annual EM&V reporting: 1) how the sample frame was defined, 2) the number of customers surveyed; 3) the number of survey respondents reporting spillover; 4) the number of survey respondents who meet the spillover attribution

[39] Note that the same 5.0 threshold value is being used for both Participant and Nonparticipant Spillover.

threshold; 5) the number of respondents for which spillover savings were actually quantified; 6) the spillover savings for each project and overall; 7) the nonparticipant spillover rate, and 8) the calculation of the weights used to extrapolate the spillover to the population of nonparticipants from which the sample was drawn.

The EM&V report should also describe the means by which the nonparticipant spillover (NPSO) rate is calculated. For each sampled site, the verified spillover savings should be summed across measures to derive the total end user NPSO for the sampled sites.[40] The estimate of site-level end user NPSO for the entire sample is then extrapolated to the entire nonparticipant population using sampling weights.

There are two options for using the estimated NPSO.

1. Allocate the portfolio-level spillover savings to individual programs in the portfolio based on each program's share of the ex post gross savings. For each program, the spillover rate could then be calculated for each program using the equation below in which the spillover allocated to each program would be the numerator and the ex post program-specific gross savings would be the denominator.

   $$Program - Specific\ NPSO\ Rate = \frac{NPSO_{Program-Specific}}{Ex\ Post\ Gross\ Impacts_{Program-Specific}}$$

   The spillover-adjusted NTGR for each program could then be used to adjust the Core NTGR for each program before calculating the TRC. In calculating the Program-Specific NPSO Rate, the numerator and denominator must be consistent in terms of the time period of measure implementation/potential implementation. While this time period must be within the last two years, it may be for a period of less than two years.
2. The NPSO Rate is calculated at the Sector level. The estimated energy savings associated with program-attributable spillover measures implemented during the study period by the entire nonparticipant population is divided by the ex post gross impacts for all the nonresidential programs in the portfolio occurring during the study period. The C&I Sector NPSO Rate is calculated using the following equation

   $$Portfolio\ NPSO\ Rate = \frac{NPSO_{Portfolio}}{Ex\ Post\ Gross\ Impacts_{Portfolio}}$$

The NPSO rate could then be used to adjust the portfolio core NTGR before calculating the portfolio TRC. Again, in calculating the Portfolio NPSO Rate, the numerator and denominator must be consistent in terms of the time period of measure implementation/potential implementation. While this time period must be within the last two years, it may be for a period of less than two years.

## 3.3 Small Business Protocol

### 3.3.1 Free Ridership

The FR algorithm for non-residential small business programs will follow the Core Non-Residential FR Protocol, with the following exceptions:

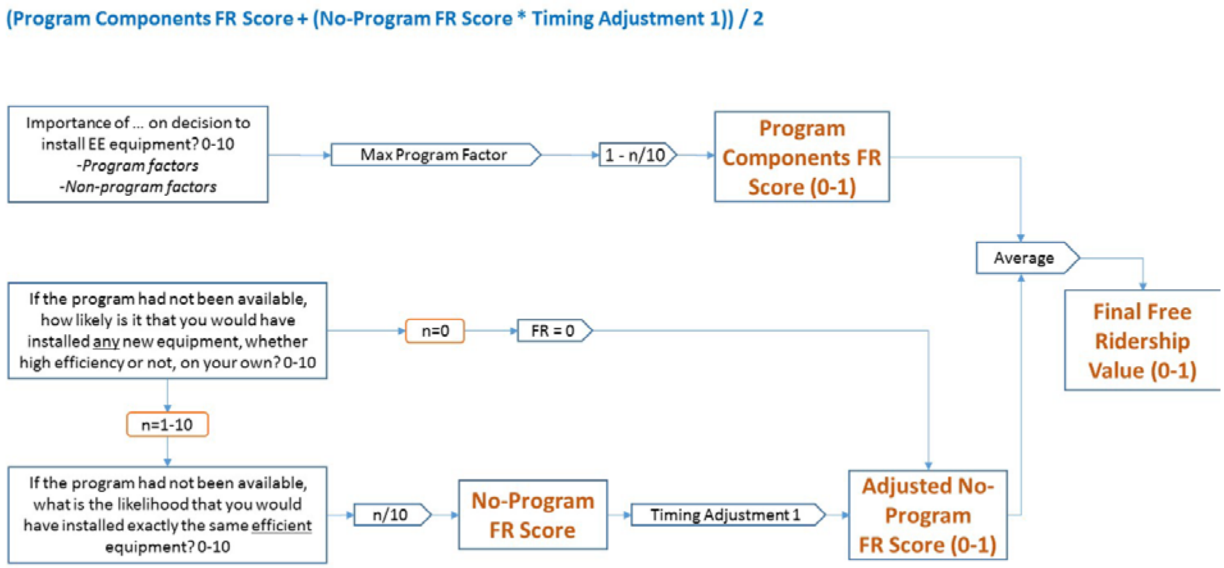
1. To reduce respondent burden, the Program Influence FR Score may be dropped from the Small Business FR algorithm. The influence of nonprogram factors will still be captured in the Program Components FR Score.
2. The counterfactual likelihood question (likelihood the participant would have installed the exact same energy efficiency equipment absent the program) may be preceded with a 0-10 scale question about the likelihood the participant would have installed any new equipment—either standard efficiency or high efficiency—on their own.
   a. If the participant provides a likelihood response of 0, then the No-Program FR Score for that participant is set to 0.
   b. If the participant provides a likelihood response of 1-10, then the participant is asked the same counterfactual questions (including the first timing question) as in the Core Non-Residential FR protocol.

[40] This includes all samples sites including those that reported no spillover savings.

3. To reduce respondent burden, the second question about timing (likelihood the participant would have installed the exact same energy efficiency equipment within 12 months) may be dropped. In this case, the only Deferred Free Ridership specification would be the one applying Timing Adjustment 1.

The diagram below, Figure 3-3, depicts the Small Business FR approach with the above exceptions implemented.

**Figure 3-3. Small Business Free Ridership**




Evaluators will calculate free ridership values for small business projects as follows:

(1) If Program Influence FR Score is dropped:

FR = AVERAGE ([Program Components FR Score], [No-Program FR Score * Timing Adjustment 1])

(2) If Program Influence FR Score is included:

FR = AVERAGE ([Program Components FR Score], [Program Influence FR Score], [No-Program FR Score * Timing Adjustment 1])

## 3.4 C&I New Construction Protocol

### 3.4.1 Free Ridership

The FR algorithm for non-residential new construction programs will follow the Core Non-Residential FR protocol, with the following exception:

- The concept of project timing and deferred free ridership is not applicable to new construction projects.[41] As a result, the various deferred free ridership specifications outlined in Figure 3-1 and Figure 3-2 will not be included in the free ridership estimation for new construction projects.

[41] New Construction programs intervene in the early phases of ongoing construction projects (i.e., after the decision to build has been made). As a result, participation in a New Construction program would not be expected to accelerate the construction of the new building.

Evaluators will calculate free ridership values for new construction projects as follows:

FR = AVERAGE ([Program Components FR Score], [Program Influence FR Score], [No-Program FR Score])

## 3.5 Study-Based Protocol

### 3.5.1 Free Ridership

The FR algorithm for non-residential study-based programs (See Figure 3-4) will follow the Core Non-Residential FR protocol, with the following exceptions:

- The counterfactual likelihood question (Q.4 in Figure 3-5 and Figure 3-6, below) will be preceded by five questions.[42]
- Q.1 A 0-10 scale question about the likelihood that the participant would have conducted the study absent the program will be included.

**At the measure-group level, the following should be included:**

- Q.2a A yes/no question to determine if the participant performs regular maintenance on the equipment treated through the program
- Q.2b If the response to Q.2a is "yes," a yes/no question to determine if the maintenance always includes the treatment provided through the program
- Q.3a A yes/no question to determine if the participant had prior awareness of the performance issues identified through the study
- Q.3b A 0-10 scale question about the participant's level of familiarity with the recommended actions to rectify the performance issue.

The counterfactual likelihood question (Q.4 – likelihood the participant would have taken action absent the program) and the first counterfactual timing question (used to develop Timing Adjustment 1) will be asked at the measure-group level. Measure-group level responses will be aggregated to the project level, using savings-based weights.

There will be two options for developing the No-Program FR Score:

1. The measure-group level Adjusted No-Program FR Score will be developed following Algorithm 1 of the Core Non-Residential FR approach, using responses to the counterfactual likelihood question (Q.4) and Timing Adjustment 1.
2. The measure-group level No-Program FR Scores will be assigned, based on responses to Q.1, Q.2b, Q.3a, and Q.3b, as follows:
   a. If Q.2b = Yes, then No-Program FR Score = 1. This assumes that if the participant performs regular maintenance on the treated equipment and that maintenance always includes the issue addressed through the program, then the participant is a full free rider for that measure group for purposes of calculating the No-Program FR Score.
   b. If Q.3a = No and Q1 = 0 and Q.2b ≠ Yes, then No-Program FR Score = 0. This assumes that if the participant was not aware of the performance issue and had a zero likelihood of performing the study absent the program and their maintenance practices do not always include the issue addressed through the program, then the participant is not a free rider for that measure group for purposes of calculating the No-Program FR Score since they would not have found out about the issue absent the program.
   c. If Q.3b = 0 and Q1 = 0 and Q.2b ≠ Yes, then No-Program FR Score = 0. This assumes that if the participant had no familiarity with how to rectify the performance issue, had a zero likelihood of performing the study absent the program, and their maintenance practices do not always include

[42] It should be noted that the question numbering in Figure 3-5 and Figure 3-6 is for reference purposes only; the additional questions do not have to immediately precede the counterfactual likelihood question.

the issue addressed through the program, then the participant is not a free rider for that measure group for purposes of calculating the No-Program FR Score since they would not have known how to address the issue absent the program.

d. For all other combinations of responses to Q.1, Q.2b, Q.3a, and Q.3b, the measure-group level Adjusted No-Program FR Scores will be developed following Algorithm 1 of the Core FR approach, using responses to the counterfactual likelihood question (Q.4) and Timing Adjustment 1.

**Figure 3-4. Study-Based Free Ridership—Overview**

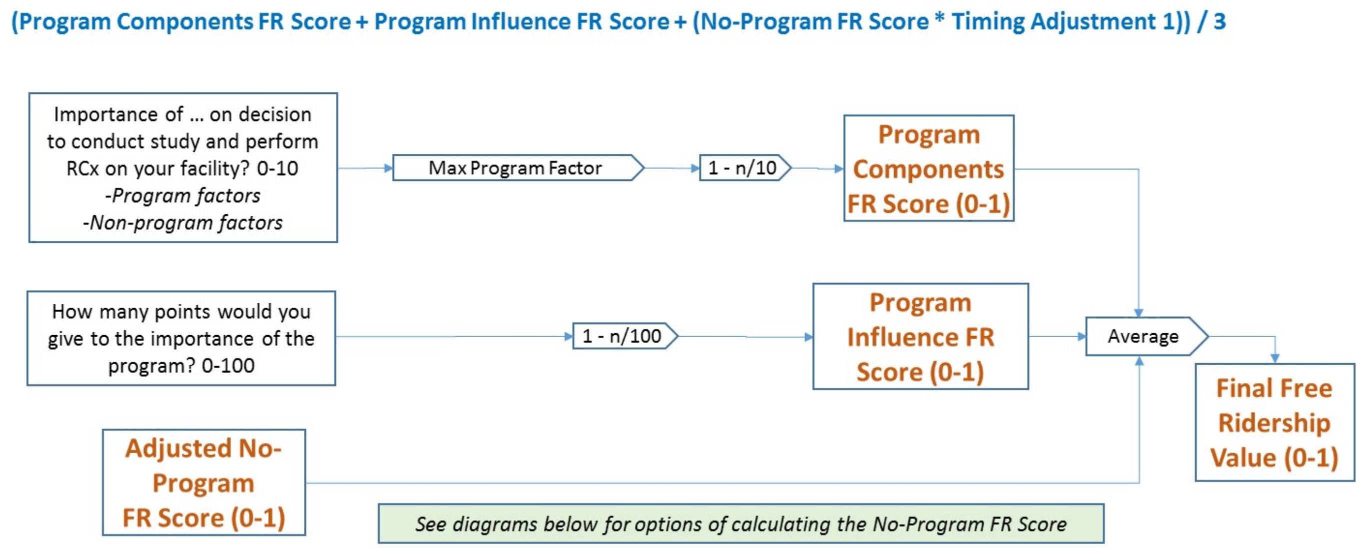



**Figure 3-5. Study-Based Free Ridership—No-Program FR Score Option #1**

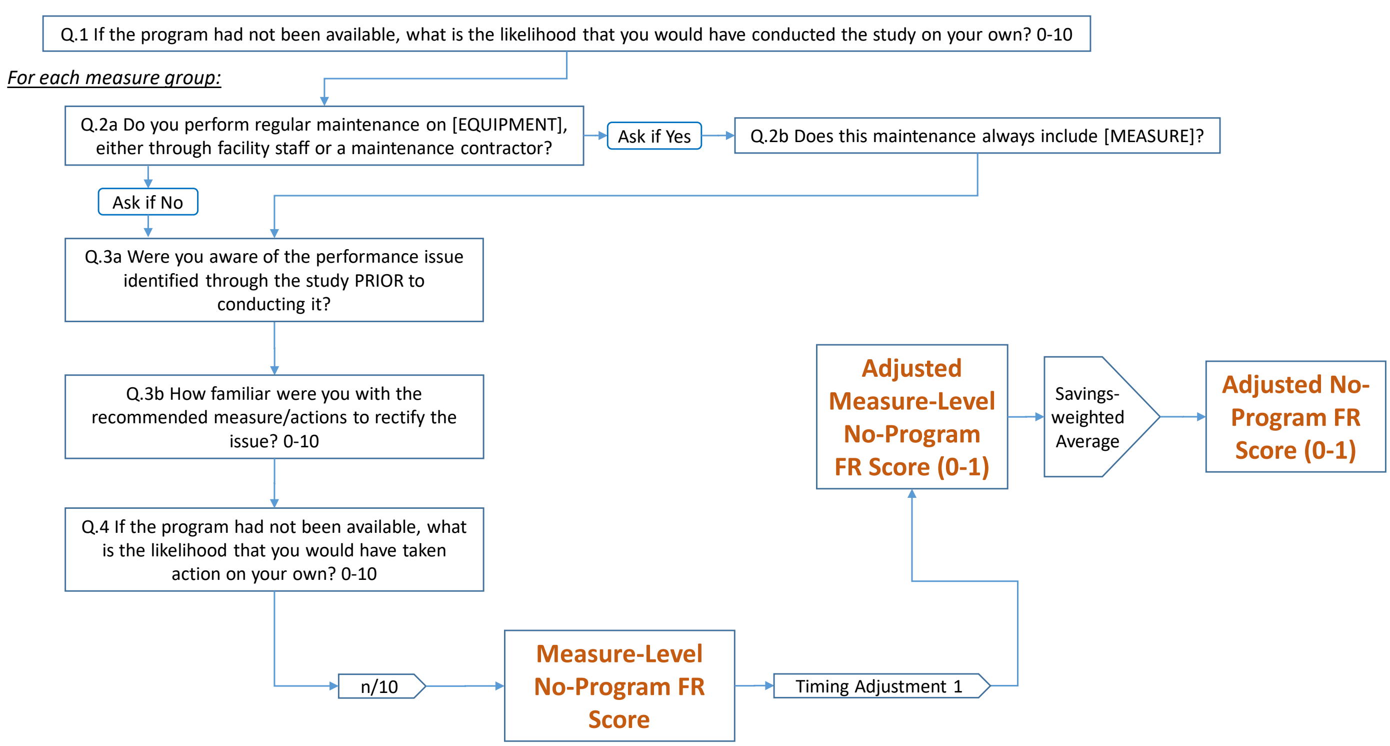
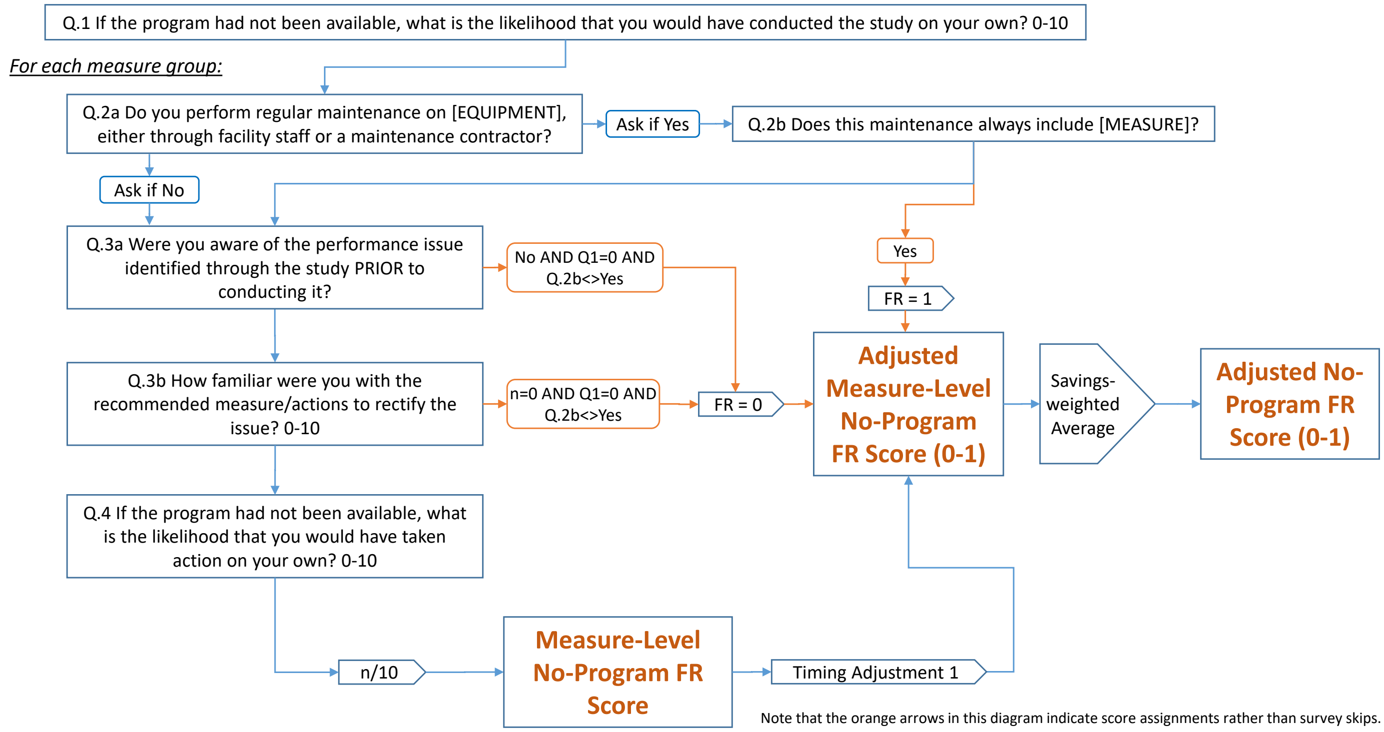


**Figure 3-6. Study-Based Free Ridership—No-Program FR Score Option #2**




Evaluators will calculate free ridership values for study-based programs as follows:

FR = AVERAGE ([Program Components FR Score], [Program Influence FR Score], [No-Program FR Score * Timing Adjustment 1])

Evaluators will develop estimates of free ridership based on the two No-Program FR Score options outlined above. Evaluators will select one of these for purposes of calculating the annual incremental energy savings for comparing to the legislated goal. Evaluators will present the results of both estimates of free ridership in EM&V reporting.

## 3.6 Technical Assistance Protocol

This protocol is applicable to programs that provide technical assistance to encourage the adoption of energy efficiency measures in non-residential facilities, but do not provide financial incentives.

Program-attributable savings from Technical assistance programs are achieved when a program participant—as a result of the program's influence via the training or technical assistance provided—undertakes energy efficiency improvements on their own, without any direct financial assistance from any other Illinois energy efficiency program.

An initial determination of program-attributable savings is made based on self-reported findings from surveys of program participants. At a minimum, surveys collecting data pertaining to participant measure implementation will obtain general information on the specific measures installed and information substantiating their attribution to the program. Research on the specific characteristics of the energy-efficient equipment installed and the baseline and operating conditions needed to estimate savings may be done in one of two ways: 1) a detailed battery of measure specific questions may be administered as part of the initial survey; or 2) a separate in-depth follow-up interview may be conducted by the engineer or analyst responsible for the energy savings calculation. These collected data may be augmented by detailed facility and measure characteristics if provided by program staff.

### 3.6.1 Free Ridership

- The FR algorithm for Technical Assistance programs is identical to the Core Non-Residential FR protocol, with the following exception:

  - For the Program Components score, the list of program and non-program components differs extensively from conventional programs and therefore, is described in some detail here. As under the Core Protocol, evaluators administer survey questions to obtain participants' rating of the importance of a comprehensive list of program and non-program factors on the decision to implement energy efficiency measures. Examples of Technical Assistance program factors that may be included are: Documentation in a program-provided technical report of the energy saving opportunities from installing the measure.

- Verbal information or guidance provided by a program representative or energy auditor during a training course or an on-site visit.
- A follow-up communication from the utility regarding implementing the recommendations provided through the audit, training or technical assistance.

Examples of Technical Assistance non-program factors that may be included are:

- Information from trade shows, conferences, or other professional gatherings
- Recommendation from an equipment vendor that sold you the measure and/or installed it
- Previous experience with the measure
- A recommendation from a design or consulting engineer
- Standard practice in your business/industry
- Corporate policy or guidelines
- Payback on the investment

# 4 Residential and Low Income Sector Protocols

The table below lists Illinois residential programs and the NTG protocol applicable to each program.[43] If the design of a given program changes significantly, then it may mean that the NTG protocol listed for that program in this document is no longer appropriate. If that happens, the evaluator should follow the procedures outlined in Section 1.4: Diverging from the IL-NTG Methods.

**Table 4-1. Residential and Low Income Programs**

| Program Administrator | Free Ridership Protocol | Program Name |
|---|---|---|
| Ameren Illinois | 4.2 Appliance Recycling Protocol | Appliance Recycling Initiative |
| | 4.3 Residential Upstream Lighting Protocol | Retail Products Initiative – Lighting Products |
| | 4.4 Prescriptive Rebate (With No Audit) Protocol | HVAC Initiative<br>Retail Products Initiative – Non-Lighting Products |
| | 4.6 Multifamily Protocol | Multifamily Initiative |
| | 4.7 Energy Saving Kits and Elementary Education Protocol | Direct Distribution of Efficient Products Initiative |
| | 5.3 Consumption Data Analysis Protocol | Behavior Modification |
| | † | Income Qualified Initiative<br>Public Housing Initiative<br>Affordable Housing New Construction (any remaining DCEO commitments) |
| ComEd | 4.2 Appliance Recycling Protocol | Fridge and Freezer Recycling |
| | 4.3 Residential Upstream Lighting Protocol | Lighting Discounts |
| | 4.4 Prescriptive Rebate (With No Audit) Protocol | Appliance Rebates<br>Heating and Cooling Rebates<br>Weatherization Rebates |
| | 4.5 Single-Family Home Energy Audit Protocol | Home Energy Assessments |
| | 4.6 Multifamily Protocol | Multifamily Assessments |
| | 4.7 Energy Saving Kits and Elementary Education Protocol | NTC Middle School Take Home Kits<br>Elementary Energy Education Kits |
| | 4.8 Residential New Construction Protocol | Residential New Construction |
| | 5.3 Consumption Data Analysis Protocol | Residential Behavior |
| | † | Income Eligible Lighting Discounts<br>Income Eligible Single Family Retrofit<br>Income Eligible Multi-Family Retrofit<br>Affordable Housing New Construction<br>Food Bank LED Distribution Program<br>Income Eligible Kits Program |
| Nicor Gas | 4.4 Prescriptive Rebate (With No Audit) Protocol | Home Energy Efficiency Rebates (Single Family) |
| | 4.5 Single-Family Home Energy Audit Protocol | Home Energy Savings (Single Family Assessment/ Direct Install) |
| | | Weatherization (Wx) Prescriptive (Air/Duct Sealing and Insulation) |
| | 4.6 Multifamily Protocol | Multi-Family (Assessment/ Direct Install)<br>Multi-Family Prescriptive Rebates |

[43] The "Free Ridership Protocol Name" in the second column of the table refers to the numbered sections in this document, e.g., "4.6 Multifamily Protocol."

| Program Administrator | Free Ridership Protocol | Program Name |
|---|---|---|
| | 4.7 Energy Saving Kits and Elementary Education Protocol | Elementary Education Kits<br>Energy Saving Kits |
| | 4.8 Residential New Construction Protocol | Residential New Construction |
| | 5.3 Consumption Data Analysis Protocol | Behavioral Energy Savings |
| | 5.2 Code Compliance Protocol | Code Compliance |
| Peoples Gas/<br>North Shore Gas | 4.4 Prescriptive Rebate (With No Audit) Protocol | Home Energy Rebates |
| | 4.5 Single-Family Home Energy Audit Protocol | Home Energy Jumpstart |
| | 4.6 Multifamily Protocol | MF Custom<br>MF Partner Trade Ally<br>MF Prescriptive<br>Multifamily (Direct Install) |
| | 4.7 Energy Saving Kits and Elementary Education Protocol | Elementary Energy Education |
| | 5.3 Consumption Data Analysis Protocol | Home Energy Reports |
| All | 5.4 Code Compliance Protocol | Statewide Codes Collaborative |

† There has been general consensus among Illinois stakeholders that the NTG value for Income Eligible programs is not likely to be significantly different from 1.0, particularly where the person making the participation decision is the Income Eligible resident. Until SAG establishes a different policy, the NTG value will be deemed at 1.0. Discussions will be held with SAG members on the value in and methods for performing such research and the timing of the application of such research.

## 4.1 Residential Cross-Cutting Approaches

The approaches in this section can apply to more than one program type but do not supersede program-specific approaches presented in later sections.

### 4.1.1 Survey Design Issues

Free ridership questions should be asked near the beginning of a participant survey, before asking satisfaction questions. This should prevent participants from confusing free ridership questions with the satisfaction questions, which could influence free ridership scores.

### 4.1.2 Participant Spillover

Effective program marketing and outreach generates program participation and increases general energy efficiency awareness among customers. Spillover can be calculated using participant survey questions, which ask participants about energy-savings actions they have taken on their own since participating in the program. Questions should be sufficiently specific to ensure energy savings associated with spillover can be reasonably well-quantified. These may include questions about measure types or measures installed, quantities, and efficiency levels. When program implementers provide recommendations to participants and can provide data on the types of recommendations made to specific participants, evaluations should attempt to determine whether participants took the recommended actions outside of the program at sites within the program administrator's service territory; if so, savings from those recommended actions should be attributed to the program.

To reduce the respondent's burden, the survey should first ask participants about the influence the program had on their taking additional energy-saving actions on their own. In particular, the evaluation team should ask two close-ended questions to determine program influence on spillover actions. The two required questions, preceded by an optional open-ended warm-up question, are:

- OPTIONAL: Did the program influence you in any way to make these additional improvements?

1. How important was your participation in the <PROGRAM ADMINISTRATOR'S> program on your making additional energy efficiency improvements on your own? [Scale from 0-10 where 0 is "not at all important" and 10 is "extremely important"]
2. If you had not participated in the <PROGRAM ADMINISTRATOR'S> program, how likely is it that you would still have implemented this measure, using a 0 to 10, scale where 0 means you definitely WOULD NOT have implemented this measure and 10 means you definitely WOULD have implemented this measure?

The response to the first required question cited above is "Measure Attribution Score 1," and the response to the second required question cited above is "Measure Attribution Score 2." The specific measures referenced in the question are considered to be attributable to the program if the "Spillover Score" is greater than 5.0:

*Spillover Score = (Measure Attribution Score 1 + (10 – Measure Attribution Score 2))/2 > 5.0*

If these conditions are met, the evaluator determines that the specific measures referenced in the question are attributable to the program; otherwise, the evaluator determines that the specific measures referenced in the question are not attributable to the program. The attribution criterion represents a threshold approach, in which energy impacts associated with measures implemented by program participants outside the program are either 100% program-attributable or 0% program-attributable.

For each measure mentioned, customers will be asked how they know the measure is more efficient than other models. If the respondent can identify the measure as ENERGY STAR or name an efficiency level that the evaluator confirms as being above the minimum federal standard, or if they identify a technology that the evaluator can confirm is above the minimum federal standard, it will count towards Participant Spillover.

Finally, depending on the measure type cited by the customer, follow-up questions should ask customers to provide reasonable information to allow the evaluator to estimate the amount of savings using IL-TRM protocols, such as quantity of appliances or the location and amount of insulation.

To calculate the spillover energy and demand savings for these actions, the appropriate version of the IL-TRM should be used. To develop the spillover rate, the total energy and demand impacts from the sampled participants who installed additional measures due to participation in the program are summed, and then this sum is divided by the total ex post sample energy and demand impacts:

$$Participant\ Spillover\ Rate\ (PSO) = \frac{Sum\ of\ Energy\ or\ Demand\ from\ Additional\ Measures\ Installed}{Sample\ Ex\ Post\ Gross\ Energy\ or\ Demand\ Impacts}$$

The equation used to adjust the Core NTGR based on participant spillover is as follows:

$$NTGR = (1 - FR + PSO)$$

#### 4.1.2.1 Data Collection

Respondents should be drawn from a random sample of current or up to one year of previous program participants. Regardless of the participation year, spillover should be measured within the last 12 months (from the survey date), but after previous participation; the tracking database should supply this information.

#### 4.1.2.2 Data Analysis

The following four steps calculate spillover:

1. Calculate total spillover savings for each participant installing an efficient measure not rebated through the program where the Spillover Score is greater than 5.0:

$$\text{Measure Spillover} = \text{Measure Savings} * \text{Number of Units}$$

2. Total savings associated with each program participant to calculate overall participant spillover savings.
3. $\text{Spillover Percentage Estimate} = \frac{\sum \text{Sample Spillover kWh Savings}}{\text{Sample Evaluated Program kWh Savings}}$

### 4.1.3 Nonparticipant Spillover Measured from Customers

The evaluation may perform research to measure nonparticipant spillover (NPSO). If so, care should be taken to ensure spillover is not double-counted with a trade-ally approach. The basic method uses a two-step process: (1) conduct a nonparticipant survey to identify potential spillover measures and (2) if needed, conduct a follow-up call or on-site visit by technical staff to confirm attribution and obtain information needed to estimate energy savings.

#### 4.1.3.1 Basic Method

##### 4.1.3.1.1 Sampling

As spillover may be rare in the nonparticipating population, determining spillover will likely require a large sample of customers who have not participated in any energy efficiency programs, including a behavioral program, within the past three years. Customers will be removed from the sample frame if their account numbers can be cross-referenced against a list of program participants from the previous three years. The survey should target household members responsible for paying utility bills. Survey respondents will be asked a screening question (whether they have participated in a program in the past three years) to confirm their household qualifies as a true nonparticipant.

##### 4.1.3.1.2 Measure-Specific Questions

Depending on the spillover measure type reported by the customer, follow-up questions should be included to gather sufficient information to reasonably assess the saving amount by applying the IL-TRM, understanding that assumptions must be made if IL-TRM inputs cannot be easily supplied by the participant. Such assumptions should be conservative, or, if not conservative, reasons for deviating from the conservative application should be documented. Measures that cannot be reasonably quantified within available evaluation budgets should be excluded from spillover calculations.

For measures included in the IL-TRM, savings will be assessed using the IL-TRM algorithms. Baselines for measures not in the IL-TRM will be assessed based on appliance standards and building codes, if applicable, and, if not, through engineering judgements of existing or market conditions. Engineering assumptions and analysis by the evaluator will be applied for measures not included in the IL-TRM. Key assumptions should be documented in the report.

#### 4.1.3.2 Attribution Approach

To receive credit for energy savings, the nonparticipant must fit the following criteria: (1) be familiar with the Program Administrators energy efficiency campaign (e.g., ActOnEnergy for Ameren); and (2) indicate that some aspect of the Program Administrator's energy efficiency programs motivated their purchases. Influence will be measured on a scale of 0 to 10, where 10 is extremely influential and 0 is not at all influential. Savings attribution requires a Spillover Score of greater than 5.0.

Survey respondents will be asked a series of questions following the logic shown in Figure 4-1. First, the customer will indicate whether they know about their Program Administrator's energy efficiency programs and/or marketing messages. If customer is aware, the survey will ask if they or anyone in their household made an energy efficiency improvement within the last year, and if so, what improvements they made. Responses to these questions will generate a list of potential spillover measures (shown at point "[A]" in Figure 4-1). Customers will be asked how they know the measure is more efficient than other models. If the respondent can identify the measure as ENERGY STAR or name an efficiency level that the evaluator confirms as being above the minimum federal standard, or if they identify a technology that the evaluator can confirm is above the minimum federal standard, it will count towards NPSO. At this point in the NPSO process, the customer could be referred for a follow-up call with a technical interviewer.[44]

To assess attribution for each spillover measure mentioned, the customer will be asked questions to be scored in two areas. Spillover may be program-attributable for those measures for which self-report data meet the following threshold condition:

---

[44] Customers who installed efficient lighting (CFL/LED) will not be eligible for NPSO if those savings are already claimed by an upstream lighting program. A separate NPSO protocol is provided specifically for upstream lighting programs.

*Spillover Score = (Attribution Score 1 + (10 – Attribution Score 2))/2 > 5.0*

#### 4.1.3.2.1 Attribution Score 1

The first score, "Attribution Score 1," measures the influence level (on a scale of 0 to 10, where 10 is extremely influential and 0 is not at all influential) their Program Administrator had on the purchase of the measure.

Influence can derive from the following:

1. General information about energy efficiency provided by the Program Administrator (e.g. through a bill insert)
2. Information from a contractor or retailer related to the Program Administrator's programs.
3. Word-of-mouth from people installing energy-efficient equipment and receiving a rebate from the Program Administrator.

Attribution Score 1 is the maximum score (or Yes response) assigned to any source of influence from the Program Administrator.

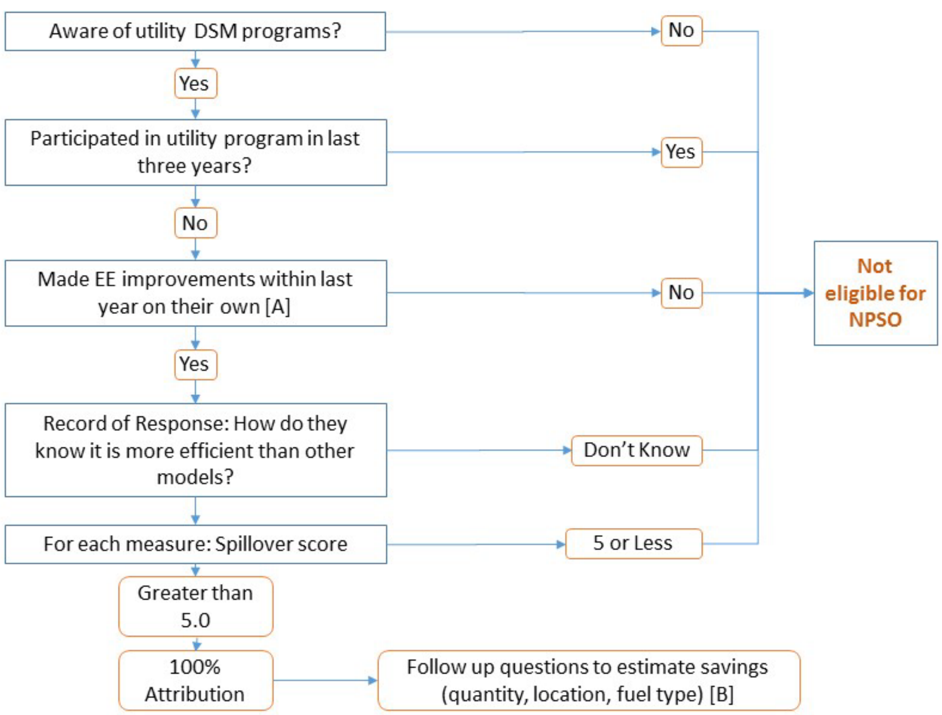
#### 4.1.3.2.2 Attribution Score 2

The second score, "Attribution Score 2," comes from the customer's response to a single question to assess the counterfactual, asking about the likelihood (on a scale of 0 to 10, where 10 is extremely likely and 0 is not at all likely) that the customer would have installed the measure had they not been influenced by the program.

The Spillover Score is then the average of the Attribution Score 1 and (10 – Attribution Score 2). If that Spillover Score is greater than 5.0, 100% of the savings are attributed to the Program Administrator for that measure.

Finally, depending on the measure type cited by the customer, follow-up questions will gather information to enable an estimate of savings (shown in the figure as [B]), such as quantity of appliances or the location of insulation.

**Figure 4-1. NPSO Question Logic**



#### 4.1.3.3 Scoring

Survey respondents' answers to the NPSO questions will determine total energy and demand savings attributed to the program. Table 4-2 lists NPSO measures under column A, the Spillover Score under column B, the estimated measure savings under column C, the percentage of allocated savings under column D, and the total allocated savings under column E. Column F shows the calculated average energy savings per spillover measure, determined by dividing the total allocated savings (the sum of column E) by the number of surveyed nonparticipating customers. The table shows how kWh NPSO savings would be calculated; calculations of therm or demand savings would be accomplished in the same manner.

**Table 4-2. Estimation of Respondents' NPSO Savings**

| A | B | C | D | E | F |
|---|---|---|---|---|---|
| Spillover Measure | Spillover Score | Measure Savings (kWh) | Allocated Savings | Total kWh Savings | Average kWh Per Surveyed Customer |
| Measure1 | Scale of 0 to 10 | Savings1 | 100% if [B] > 5.0<br><br>0% if [B] ≤ 5.0 | [C] x [D] | N/A |
| Measure2 | Scale of 0 to 10 | Savings2 | | [C] x [D] | |
| MeasureN | Scale of 0 to 10 | SavingsN | | [C] x [D] | |
| | | | | Sum of column E = Total kWh Savings | Total kWh Savings ÷ Number of Completed Surveys |

Table 4-3 shows the process for estimating total NPSO generated by the Program Administrator during the program year (for electric savings). The savings attributed from the survey population will be extrapolated to the nonparticipating residential customer population to determine the overall NPSO savings. Then NPSO energy savings will be converted into a percentage using the total evaluated electric savings for the program year. A similar process would apply for calculating therm or demand NPSO.

**Table 4-3. Calculation of Total NPSO Generated**

| Variable | Description | Source/Calculation |
|---|---|---|
| F | Average kWh Energy Savings per Surveyed Customer | Survey data and Savings Calculation |
| J | Total Nonparticipating Residential Population | Customer database |
| K | NPSO MWh Energy Savings Extrapolated to Nonparticipating Population | [F × J] ÷ 1,000 kWh/MWh |
| S | Total Evaluated MWh Savings | Residential Portfolio Savings |
| G | NPSO Spillover Rate | K ÷ S |

## 4.2 Appliance Recycling Protocol

Appliance recycling programs (ARPs) typically offer some mix of incentives and free pickups for the removal of old but operable refrigerators, freezers, or room air conditioners. These programs encourage consumers to undertake the following:

- Discontinue use of secondary or inefficient appliances;
- Relinquish appliances previously used as primary units upon their replacement (rather than keeping the old appliance as a secondary unit); and
- Prevent the continued use of old appliances in other households through direct transfers (i.e., giving it away or selling it) or indirect transfers (resale in the used appliance market).

As the program theory and logic for appliance recycling differ significantly from standard "downstream" incentive programs (which typically offer rebates for purchases of efficient products), the free ridership estimation approach also significantly differs.

The basic and enhanced methods are described next.

## 4.2.1 Basic Method

### 4.2.1.1 Free Ridership

Free ridership is based on participants' anticipated plans had the program not been available, thus classifying a free rider as a participant who would have removed the unit from service regardless of the program.

Estimating net savings for ARPs should adopt a multistep process to segment participants into different groups, each with specific attributable savings.

In general, independent of program intervention, participating appliances would have been subject to one of the following options:

1. The appliance would have been kept by the participating household.
2. The appliance would have been discarded in a way that transfers the unit to another customer for continued use.
3. The appliance would have been discarded in a way that would have permanently removed the unit from service.

Only Option 3 constitutes free ridership (the proportion of units that would have been taken off the grid absent the program). Options 1 and 2 both indicate non-free riders. However, these respondents need to be further classified to account for secondary market impacts, described below.

#### 4.2.1.1.1 Data Collection

A participant survey—drawn from a random sample of participants—will serve as the primary source of data collected for estimating NTG for the ARP. To determine the percentage of participants in each of the three options, evaluators will begin by asking surveyed participants about the likely fate of their recycled appliance had it not been decommissioned through the program. Responses provided by participants generally can be categorized as follows:

1. Kept the appliance.
2. Sold the appliance to a private party (either an acquaintance or through a posted advertisement).
3. Sold or gave the appliance to a used-appliance dealer.
4. Gave the appliance to a private party, such as a friend or neighbor.
5. Gave the appliance to a charity organization, such as Goodwill Industries or a church.
6. Had the appliance removed by the dealer from whom the new or replacement appliance was obtained.
7. Hauled the appliance to a landfill or recycling center.
8. Hired someone else to haul the appliance away for junking, dumping, or recycling.

Additional, follow-up questions will be included to validate the viability of all responses.

Next, evaluators will assess whether each participant's final response indicates free ridership:

- Some final responses clearly indicate free ridership, such as: "I would have taken it to the landfill or recycling center myself."
- Other responses clearly indicate no free ridership, as when the appliance would have remained active within the participating home ("I would have kept it and continued to use it") or used elsewhere within the Program Administrator's service territory ("I would have given it to a family member, neighbor, or friend to use").

If the respondent planned to have the unit picked up by the retailer and the retailer would likely resell the unit in the secondary market, they are not a free rider. Absent retailer survey primary research described in the Enhanced Options below, the evaluators will utilize data from the most recent research conducted of the ComEd program to determine the proportion of free riders unless another metric is mutually agreed upon by the evaluators.[45]

Secondary Market Impacts

In the event that the unit would have been transferred to another household (Option 2 above), the question then becomes what purchasing decisions are made by the would-be acquirers of participating units now that these units are unavailable. Such would-be acquirers could:

1. Not purchase/acquire another unit.
2. Purchase/acquire another used unit.

Adjustments to savings based on these factors are referred to as the program's secondary market impacts.

If it is determined that the participant would have directly or indirectly (through a market actor) transferred the unit to another customer on the grid, the next question addresses what that potential acquirer did because that unit was unavailable. There are three possibilities:

A. **None of the would-be acquirers would find another unit.** That is, program participation would result in a one-for-one reduction in the total number of appliances operating on the grid. In this case, the total energy consumption of avoided transfers (participating appliances that otherwise would have been used by another customer) should be credited as savings to the program. This position is consistent with the theory that participating appliances are essentially convenience goods for would-be acquirers. (That is, the potential acquirer would have accepted the appliance had it been readily available, but because the appliance was not a necessity, the potential acquirer would not seek out an alternate unit.)
B. **All of the would-be acquirers would find another unit.** Thus, program participation has no effect on the total number of appliances operating on the grid. This position is consistent with the notion that participating appliances are necessities and that customers will always seek alternative units when participating appliances are unavailable.
C. **Some of the would-be acquirers would find another unit, while others would not.** This possibility reflects the awareness that some acquirers were in the market for an appliance and would acquire another unit, while others were not (and would only have taken the unit opportunistically).

The evaluators will assume Possibility C unless primary research within a Program Administrator's service territory to assess the secondary appliance market is undertaken as described in the Enhanced Options below. Specifically, evaluators will assume that half (0.5, the midpoint of Possibilities A and B) of the would-be acquirers of avoided transfers found an alternate unit.

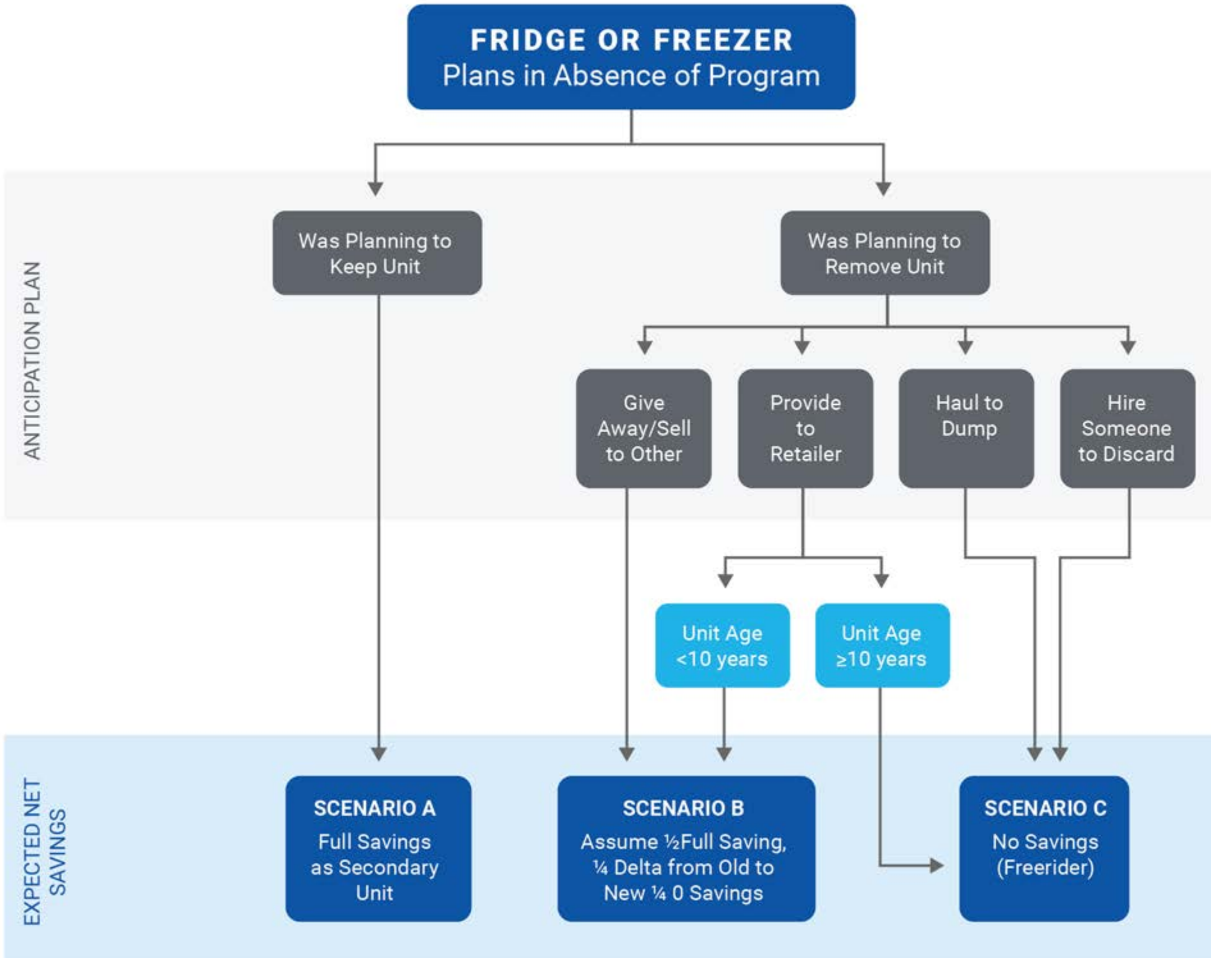
Once the proportion of would-be acquirers who are assumed to find alternate units is determined, the next question is whether the alternate unit was likely to be another used appliance (similar to those recycled through the program) or, with fewer used appliances presumably available in the market due to program activity, would the customer acquire a new standard-efficiency unit instead.

#### 4.2.1.2 Integrating Free Ridership and Secondary Market Impacts

The flow chart shown in Figure 4-2 illustrates how net savings will be derived for an ARP. As shown, below, expected savings fall into three different scenarios.

[45] Note that such retailer interviews are being conducted annually for the ComEd ARP evaluation, and answers are used directly in the calculation of the NTG ratio in cases where: (1) the respondent planned to have the unit picked up by the retailer; and (2) the retailer was interviewed.

**Figure 4-2. Appliance Retirement Scenarios**




Source: Adapted from the Pennsylvania Statewide Evaluator Common Approach for Measuring Net Savings for Appliance Retirement Programs, Guidance Memo-026, March 14, 2014.

#### 4.2.1.3 Scoring Algorithm

Net savings will be assigned individually to each respondent, based on responses provided to the questions discussed above. Net savings will be averaged across all respondents to calculate program-level net savings. The following equation will be used:

$$FR = (free\ ridership\ and\ secondary\ market\ impacts\ \% - induced\ replacement\ \%)$$

Table 4-4 demonstrates the proportion of a sample population classified into each of the eight potential (Tertiary Classification) categories and the resulting weighted net savings.

**Table 4-2. Net Savings Example for a Sample Population***

| Primary Classification | Secondary Classification | Tertiary Classification | Population (%) | UEC (kWh) w/out Program | UEC (kWh) w/ Program | kWh Savings |
|---|---|---|---|---|---|---|
| **Would have kept unit** | Scenario A: Kept No Induced Replacement | N/A | 25% | 1,026 | 0 | 1,026 |
| **Would have removed unit** | Scenario B: Transferred No | N/A | 30% | 1,026 | 520 | 506 |

| Primary Classification | Secondary Classification | Tertiary Classification | Population (%) | UEC (kWh) w/out Program | UEC (kWh) w/ Program | kWh Savings |
|---|---|---|---|---|---|---|
| | Induced Replacement | | | | | |
| | Scenario C: Removed from Service | Recycled/ Destroyed | 20% | 0 | 0 | 0 |
| | | Retailer would Recycle | 13% | 0 | 0 | 0 |
| **Net Savings (kWh)** | | | | | | 475 |

*The percent values presented in this table serve only as examples; actual research should be conducted to determine the percentage of units falling into each of these categories. Note that UEC (Unit Energy Consumption) values presented in the table represent example values, factoring in part-use.

### 4.2.2 Enhanced Method

Results can be enhanced by including three additional research efforts. The basic method has defaults where primary research on enhanced approaches cannot be performed:

1. A retailer survey, to determine the quantity and/or proportion of units returned to a retailer and that the retailer would deconstruct or recycle. Through this survey, one would determine a retailer's criteria for reselling used units vs. deconstructing them, based on unit age and condition. Results from the survey and analysis would be used to determine the proportion of those who would have returned an old appliance to the retailer that should be included in Scenario D (free riders). This research was conducted for ComEd in EPY6 evaluation and those results were applied to Ameren.
2. An appliance market assessment study to determine the size of the secondary appliance market and whether removal of participating units from the market would cause an otherwise would-be receiver to purchase an alternative used or new unit. Savings attributable to these participants are the most difficult to estimate, as the scenario attempts to estimate what the prospective buyer of a used appliance would do in the absence of finding a program-recycled unit in the marketplace (i.e., the program took the unit off the grid, so the prospective purchaser faced, in theory, a smaller supply of used appliances). It is difficult to answer this question with certainty, absent Program Administrator-specific information regarding the change in the total number of appliances (overall and used appliances specifically) that were active before and after program implementation. In some cases outside of Illinois, evaluators have conducted in-depth market research to estimate both the program's impact on the secondary market and the appropriate attribution of savings for this scenario. Although these studies are imperfect, they can provide Program Administrator-specific information related to the program's net energy impact. Where feasible, evaluators and utilities should design and implement such an approach. Unfortunately, this type of research tends to be cost-prohibitive, or the necessary data may simply be unavailable.
3. However, it is possible to estimate through nonparticipant surveys which of the disposal responses given by nonparticipants were most likely to have been to an opportunistic would-be-acquirer. Transfers that would most likely have been opportunistic are determined primarily based on the cost to the recipient. If the appliance was sold or transferred to a retailer, there would have been a cost to the recipient of that appliance. If the recipient was willing to pay for the appliance or was willing to exert the effort to visit a retail location, this suggests the recipient was actively seeking an appliance. However, if the unit were given away for free, there was little cost to the recipient and it is a reasonable proxy for the proportion of opportunistic acquirers. This proportion would replace the 50% default assumption (scenario C in Figure 4-2) of would-be-acquirers that would or would not find an alternate unit.
4. A nonparticipant survey can be used to assess how nonparticipants acquire and dispose of used units. As nonparticipants do not have the same perceived response bias as participants, they can help offset some of this potential bias in estimating the true proportion of the population that would have recycled their units in program's absence. The evaluators will average the results of the nonparticipant survey with the participant survey if the nonparticipant survey is of sufficient sample size. Otherwise, results may be used

for a qualitative characterization of potential bias. Though recommended, use of a nonparticipant survey need not be required, given budget and time considerations. A nonparticipant survey was completed as part of ComEd's EPY6 evaluation and used qualitatively to validate participant results.

## 4.3 Residential Upstream Lighting Protocol

The Illinois Residential Upstream Lighting programs to date have provided discounts on efficient lighting through retailers at the point of purchase. Such programs often remain transparent to customers purchasing incentivized lighting. Program administrators also do not know the identity of most customers purchasing the program-discounted lighting; so these customers cannot easily be contacted once they leave the store for a traditional self-report NTG evaluation survey (i.e., an after-the-fact, direct solicitation of customers regarding what they would have done in the program's absence). Similar surveys can be conducted with customers within program retailers after they have made their lighting purchasing decision but before they leave the store. For programs such as this, in store customer surveys are preferable to the traditional self-report telephone surveys that ask customers to recall their past light bulb purchases. Light bulbs are a small and relatively insignificant purchase for most people, thus the recall bias could be substantial.

Further, as upstream programs work with multiple market actors and can include wide-reaching marketing campaigns promoting energy efficiency to the general public, they tend to stimulate spillover and "market effects." As a result, estimating NTG for upstream residential lighting programs can be challenging. Multiple methods exist, each with their own strengths and weaknesses.

Ameren and ComEd implement their residential lighting programs comparably, and the evaluation teams have used a consistent primary NTG evaluation method. This section details the consensus NTG methodology, which has been used multiple times for both ComEd and Ameren and is considered the most well-vetted and defensible NTG method that has been successfully used in Illinois.

For EPY5 and EPY6, Ameren and ComEd used a customer self-report methodology to estimate NTG for their upstream residential lighting programs.[46] Customer self-report data in this method are collected during surveys conducted within program retailers with customers purchasing program bulbs (i.e., in-store intercept surveys). This method separately estimates free ridership, participant spillover, and nonparticipant spillover. Details follow on the primary data collection and scoring algorithms.

### 4.3.1 Basic Method

#### 4.3.1.1 Free Ridership

Free ridership for this program is calculated as the proportion of program bulbs that would have been purchased if the program did not exist. Three alternative scenarios could occur:

1. Full Free Rider: The customer would have purchased the same quantity of efficient bulbs (CFLs or LEDs) in the program's absence.
2. Partial Free Rider: The customer would have purchased fewer efficient bulbs (CFLs or LEDs) in the program's absence.
3. Non-Free Rider: The customer would have not purchased any efficient bulbs (CFLs or LEDs) in the program's absence.

Free ridership is calculated as the average of two distinct scores: a Program Influence Score and a No-Program score. These scores are defined as follows:

1. The Program Influence Score captures the maximum level of program influence, reported by a survey respondent, of the residential lighting program on their decisions to purchase program bulbs on the day of the survey. This program influence can take a number of forms, such as: the monetary incentive provided to decrease the cost of high-efficiency bulbs; program-sponsored educational materials that explain the

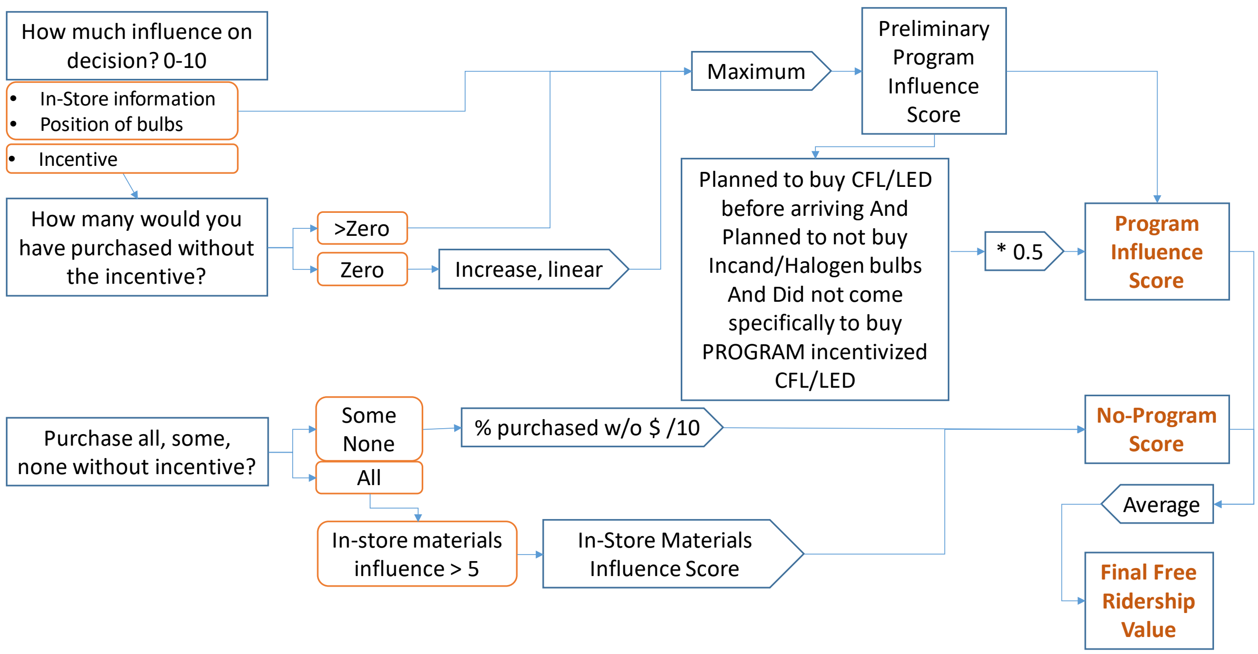
[46] ComEd has used this method since EPY2. Ameren began using it in EPY5.

benefits of efficient lighting; in-store product placement of efficient bulbs; and program bulb recommendations provided by retail store personnel.

2. The No-Program Score is used to estimate how many program bulbs a survey respondent would have purchased in the absence of the residential lighting program.

Figure 4-3 illustrates the scoring algorithm for Residential Upstream Lighting Free Ridership via In-Store Intercepts.

**Figure 4-3. Residential Upstream Lighting Free Ridership via In-Store Intercept**




#### 4.3.1.2 Data Collection

To estimate free ridership, the evaluation teams will conduct in-store intercept surveys with customers purchasing program-discounted lighting at participating retailers. Customers are asked questions that are used to estimate a Program Influence Score and a No-Program Score for each customer and efficient bulb type purchased.

**Primary Program Influence Score Questions**

1. Light bulb purchasing plans for current shopping trip (Yes/No)
2. If planning to purchase bulbs:
   a. Bulb type (CFL, LED, Incandescent, Halogen)
   b. Program administrator-incentivized bulbs (Yes/No)
3. Influence of various program factors:
   a. Program incentive
   b. In-store information (printed materials or information from Program Administrator representatives or retail personnel)
   c. Positioning of discounted bulbs within the store

**Primary No-Program Score Questions**

1. Stated preference of light bulb purchases had the Program Administrator incentive not been available (purchase all, some, or none of efficient bulbs)
2. Quantity of light bulbs purchased absent the incentive

### 4.3.1.3 Scoring Algorithms

Using the data collected from program participants during the in-store intercept surveys, Program Influence and No-Program Scores are calculated for each survey respondent and then combined to estimate a respondent-specific Free Ridership Score.

#### 4.3.1.3.1 Calculation of the Program Influence Score

Survey respondents purchasing one or more program-discounted bulbs are assigned a Preliminary Program Influence Score based on the maximum program influence level (on a 0 to 10 scale) they assigned to one or more program factors (e.g., monetary incentive/informational materials [printed or from store personnel]/product positioning). The influence level assigned to the monetary incentive should be increased for survey respondents (using a linear decreasing function)[47] who indicated that, absent the incentive, they would not have purchased any of the program bulbs they were purchasing that day.

After the Preliminary Program Influence Score is assigned, a secondary algorithm is run that adjusts the preliminary program influence based on survey data regarding the customers purchasing plans when they entered the store. Survey respondents who indicated they planned to purchase high-efficiency bulbs prior to entering the store and who had not come to the store specifically to buy Program Administrator-incentivized program bulbs, should have their Program Influence Score cut in half. This adjustment makes the final Program Influence Score reflective of their stated planned intention to purchase efficient bulbs in the program's absence.

#### 4.3.1.3.2 Calculation of the No-Program Score

The No-Program Score is based on whether a respondent states they would have purchased all, some, or none of the program-discounted bulbs in the absence of Program Administrator incentives. Respondents reporting they would have purchased all of the efficient bulbs without the incentive should be considered free riders and receive a No-Program Score of zero. Those reporting they would have purchased none of the efficient bulbs without the incentives should be classified as non-free riders and receive a No-Program Score of 10, the maximum. Respondents reporting they would have purchased some of the efficient bulbs without the incentive should be assigned a No-Program Score between 0 and 10, reflective of the percentage of efficient bulbs they would not have purchased absent the program.

Respondents reporting they would have purchased all of the program-discounted bulbs in the program's absence, but in-store materials provided by the Program Administrator had a moderate to high influence on their decision, should have their No-Program Scores adjusted to equal the level of influence they attributed to these program-sponsored informational materials.

### 4.3.1.4 Calculation of Free Ridership

The Free Ridership rate is calculated as follows:

$$\text{Free Ridership} = 1 - (\text{Program Influence Score} + \text{No-Program Score})/20$$

Using the calculated Program Influence and No-Program Scores, Free Ridership is calculated as one minus the sum of the two scores (Program Influence Score plus No-Program score), divided by 20. Dividing the sum of scores by 20 results in a ratio (between 0 and 1) that is representative of the average of the two zero to 10 scores. Subtracting this ratio from one reverses the score, thus representing the free ridership level. If either the No-Program or Program Influence Scores are missing, Free Ridership can be calculated using the single available score divided by 10. Evaluators may also reference available data to perform documented modifications to individual free ridership estimates resulting from the application of this free ridership assessment methodology.

[47] The function, adjusted monetary score = (monetary score + 10)/2, increases the monetary score using a decreasing linear function. This function results in an increase in the monetary influence score of between 0 and 5 points depending on their original monetary score (i.e., an original score of 0 would become a 5, a 5 would become a 7.5, and a 10 would remain a 10). In past Illinois evaluations, this adjustment has typically changed less than 10% of all monetary scores.

### 4.3.2 Participant Spillover

For this program, participant spillover results from purchases of non-discounted efficient bulbs by program bulb purchasers who are influenced by their participation in the residential lighting program to purchase additional non-discounted efficient bulbs.

#### 4.3.2.1 Data Collection

Data collected during in-store intercept surveys with customers purchasing program bulbs should be used to estimate participant spillover. During these surveys, customers purchasing program-discounted and non-discounted efficient bulbs (CFLs or LEDs) should be asked questions to determine whether the residential lighting program influenced their purchases of non-discounted efficient bulbs.

**Primary Program Influence Score Question**

1. Influence of the lighting program or in-store information on the customer's decision to purchase non-discounted CFLs or LEDs. (0 to 10 scale where 0 is not at all influential and 10 is extremely influential)

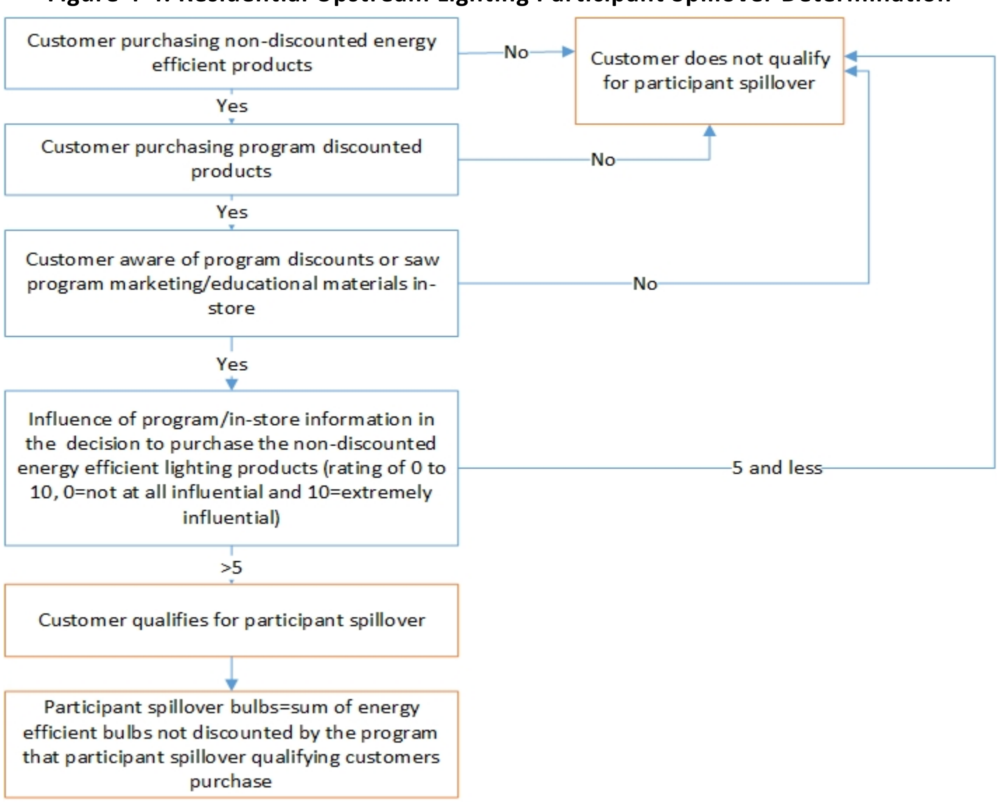
#### 4.3.2.2 Scoring Algorithm

To estimate participant spillover, the number of program-influenced, non-discounted efficient bulbs (CFLs or LEDs) purchased by program participants is divided by the total number of program bulbs purchased by these program participants. This results in the Participant Spillover Rate.

**Step 1:** Estimate the total number of non-discounted energy efficient bulbs purchased by respondents that had also purchased program-discounted bulbs and were influenced by the program. Respondents who gave a rating of greater than 5 on the program influence question are considered to be influenced by the program.

Figure 4-4 below provides a visual depiction of the process of qualifying non-discounted bulbs as participant spillover bulbs.

**Figure 4-4. Residential Upstream Lighting Participant Spillover Determination**




**Step 2:** Calculate the total number of program-discounted bulbs purchased by summing the number discounted bulbs purchased by all respondents.

**Program Bulb Purchases** = sum(Number of Discounted CFLs or LEDs purchased)

**Step 3:** Calculate the spillover rate by dividing the total number of spillover bulbs purchased by the total number of program-discounted bulbs purchased.

**Spillover Rate** = Spillover Purchases/Program Purchases

### 4.3.3 Nonparticipant Spillover

Nonparticipant spillover results from purchases of non-discounted efficient bulbs by customers who are not purchasing program-discounted bulbs, but report that the residential lighting program influenced their decision to purchase non-discounted efficient bulbs.

#### 4.3.3.1 Data Collection

Data collected during in-store intercept surveys with customers purchasing efficient bulbs not discounted by the program should be used to estimate nonparticipant spillover. During these surveys, customers purchasing non-discounted efficient bulbs (CFLs or LEDs) and not purchasing any program-discounted bulbs should be asked questions about awareness of the program discounts and point-of-purchase program marketing and educational materials. These questions are used to determine whether the residential lighting program influenced their purchases of non-discounted efficient bulbs.

**Primary Program Influence Score Question**

1. Influence of the lighting program or in-store information on the customer's decision to purchase non-discounted CFLs or LEDs. (0 to 10 scale where 0 is not at all influential and 10 is extremely influential)

#### 4.3.3.2 Scoring Algorithm

The nonparticipant spillover scoring algorithm involves estimating the total number of nonparticipants, the incidence of nonparticipants in the sample, the total number of nonparticipant spillover bulbs, and the average number of nonparticipant spillover bulbs per customer in the sample, and then extrapolating the sample estimates to the population of the utility customers. Below are the steps used to calculate the nonparticipant spillover rate.

Step 1. Determine nonparticipant spillover in the sample by following the steps outlined below.

A. Determine the total number of nonparticipating customers in the survey sample:

*Nonparticipating customers (survey) = customers who did not purchase any program-discounted energy efficient lighting products. These customers may have purchased non-discounted energy efficient lighting products, less efficient lighting products or both.*

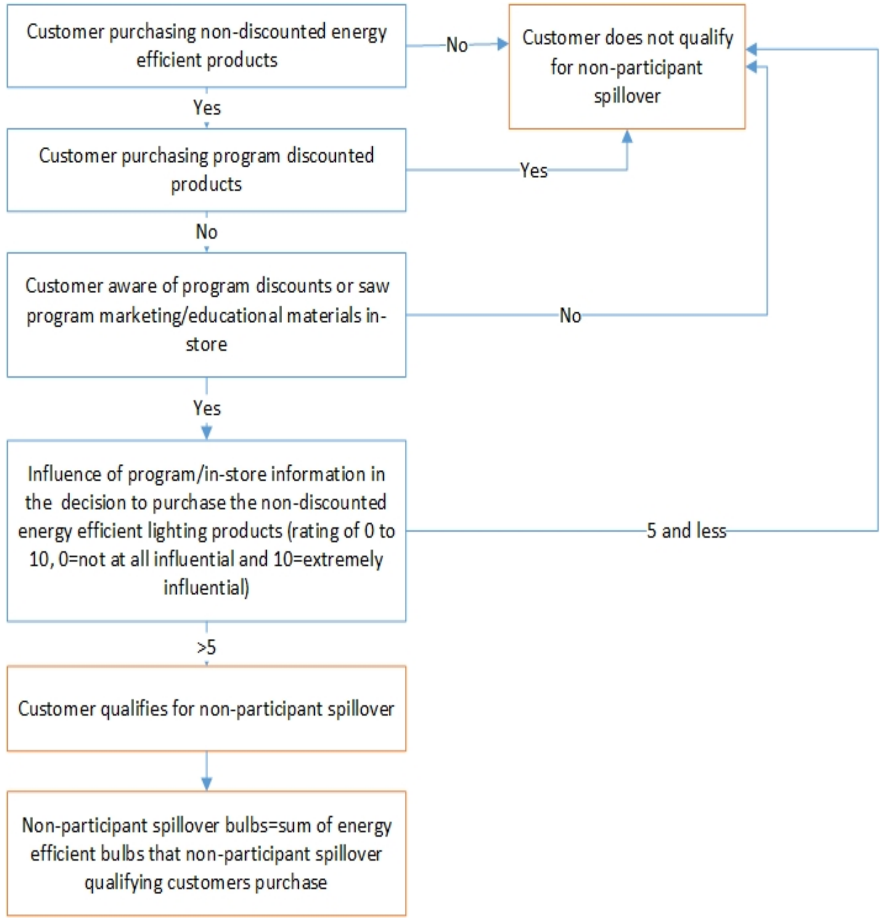
B. Determine the incidence of nonparticipating customers in the survey sample by dividing non-participating customers by total customers in the sample:

*Incidence of nonparticipating customers (survey)=Nonparticipating customers (survey)/total customers (survey)*

C. Determine total number of nonparticipant spillover bulbs by summing CFLs and LEDs not discounted by the program that were purchased by nonparticipating customers who were aware of the program discounts or marketing promoting energy efficient lighting and were influenced by it. Spillover qualifying bulbs are those purchased by customers who rate the program's influence as greater than 5. The graphic below provides a visual depiction of the process of qualifying non-discounted products as spillover products.

Figure 4-5 below provides a visual depiction of the process of qualifying non-discounted bulbs as nonparticipant spillover bulbs.

**Figure 4-5. Residential Upstream Lighting Nonparticipant Spillover Determination**




D. Determine the average number of non-participating spillover bulbs per non-participating customer by dividing the total number of non-participating spillover bulbs in the survey by the total number of non-participating customers in the survey.

*Average number of nonparticipating spillover bulbs (survey)=total number of nonparticipant spillover bulbs (survey)/nonparticipating customers (survey)*

Step 2. Extrapolate nonparticipant spillover to the population

A. Determine the total number of nonparticipating customers in the population by applying the nonparticipant incidence rate from the sample to the population

*Total number of nonparticipating customers (population)=Utility residential customer count* incidence of nonparticipating customers (survey)*

B. Determine the total number of spillover bulbs by multiplying the average number of spillover bulbs per nonparticipating customer in the survey by the total estimate of nonparticipating customers

*Total number of nonparticipant spillover bulbs=Average number of nonparticipant spillover bulbs (survey)*total number of nonparticipating customers (population)*

Step 3. Calculate nonparticipant spillover rate by dividing the total number of nonparticipant spillover bulbs in the population by the total number of program-discounted bulbs:

*Nonparticipant spillover rate=total number of nonparticipant spillover bulbs/total number of program discounted bulbs*

#### 4.3.3.3 Method Advantages and Disadvantages

The in-store intercept method described above has certain advantages and disadvantages.

Advantages: This approach catches customers at their point of purchase, before they leave the store and can no longer be contacted directly. Given the interview's timing, customers can more easily recall price factors leading to their purchase choices. Also, as customers are intercepted at the store rather than surveyed by telephone, a higher cooperation rate results.

Disadvantages: Customers may not fully connect the impact that in-store education, product placement, and advertising have on their decision making. While many consumers believe they are not influenced by advertising, retailers know advertising and product placement work. Further, store intercepts typically must be coordinated with education events, and many retailers do not allow interviews to take place in their stores. Consequently, results are not based on random samples of customers purchasing program-discounted lighting throughout the year and across all participating retailers, which could bias the results.

## 4.4 Prescriptive Rebate (With No Audit) Protocol

Prescriptive Rebate programs typically offer predetermined rebates to residential customers for purchasing measures such as high-efficiency furnaces, clothes washers, brushless/electronically commutated motors (ECMs), boilers, boiler reset controls, water heaters, air-source heat pumps (ASHPs), ground-source heat pumps (GSHPs), central air conditioners (CACs), programmable thermostats, smart thermostats, insulation, air sealing, duct sealing, and desktop power management software. The program may require installation by a registered program ally, but it does not require a home audit (although purchases may be made in response to an audit).

These programs encourage consumers to undertake the following:

- Purchase higher-efficiency equipment than they otherwise would have, had they shopped for such equipment at the same time (replace on burnout); and
- Replace operating but inefficient equipment with higher-efficiency equipment (early replacement).

The basic method for estimating free ridership and participant spillover (See Section 4.1.2) for these programs uses a participant self-report, based on a standard battery of questions. An enhanced method may utilize trade ally surveys to provide another quantitative assessment, which may be triangulated with the basic method approach. As discussed further in Section 5.2, trade ally surveys may also be used to assess nonparticipant spillover.

### 4.4.1 Basic Method

#### 4.4.1.1 Free Ridership

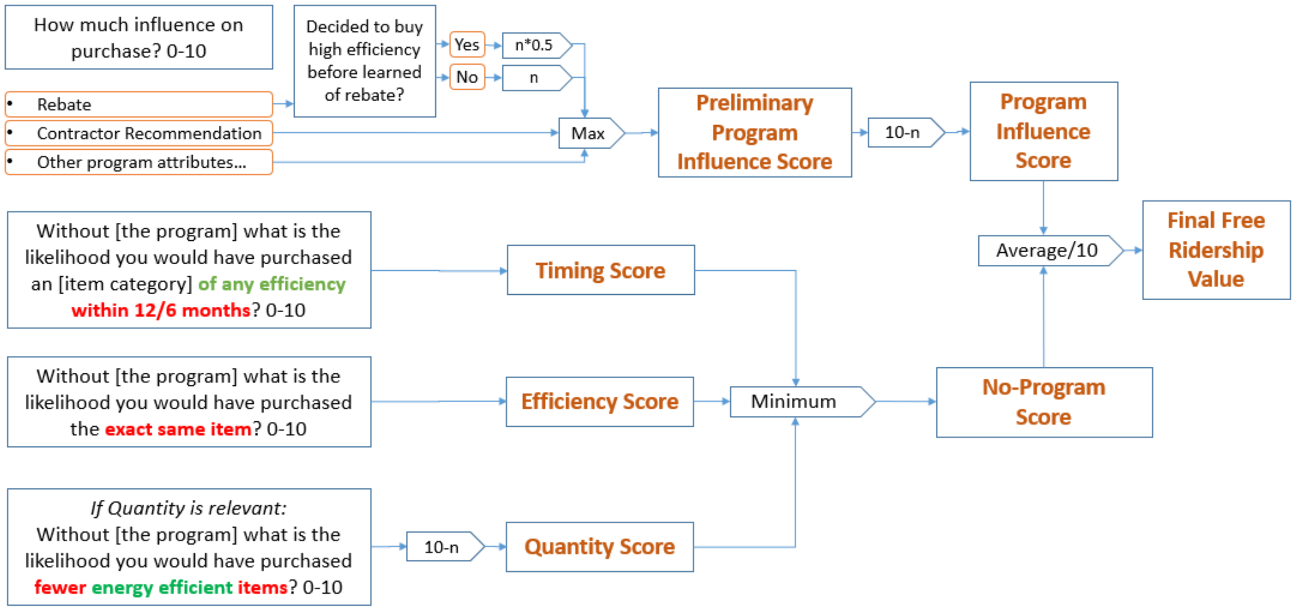
The free ridership assessment battery is brief to avoid applying an undue survey burden, yet it seeks to reduce self-report biases by including two main free ridership components:

- A Program Influence component, based on the participant's perception of the program's influence on carrying out the energy-efficient project; and
- A No-Program component, based on the participant's intention to carry out the energy-efficient project without program funds.

When scored, each component assesses the likelihood of free ridership on a scale of 0 to 10, with the two scores averaged and for a combined total free ridership score. As different and opposing biases potentially affect the two main components, the No-Program component typically indicates higher free ridership than the Program Influence component. Therefore, combining these decreases the biases.

Figure 4-6 illustrates the scoring algorithm.

**Figure 4-6. Residential Prescriptive Rebate (With No Audit) Free Ridership**




#### 4.4.1.1.1 Calculation of the Program Influence Score

Program influence is assessed by asking respondents, on a scale from 0 (not at all important) to 10 (extremely important), how important they found various program elements were on their undertaking the project the way they did. The number of elements included will vary, depending on the program's design. Logic models, program theory, and staff interviews typically inform the list of elements. Programs typically use the following elements to influence customer behavior: information; incentives or rebates; interaction with program staff (i.e., technical assistance); interaction with program proxies, such as members of a trade ally network; building audits or assessments; and financing.

In addition to asking about specific program influences, surveys ask respondents whether they planned to purchase a high-efficiency version of the product before learning of the rebate program. The respondent's rating of the rebate's influence is adjusted by 0.5 for those answering the question "yes."[48] Evaluators should conduct a sensitivity analysis around the use of this adjustment and present it in the report.

The Preliminary Program Influence Score equals the maximum influence rating for any program element rather than, for example, the mean influence rating. This is based on the rationale that if any given program element had a great influence on the respondent's action, then the program itself had a great influence, even if other elements had less influence.

An inverse relationship occurs between high program influence and free ridership: the greater the program influence, the lower the free ridership. The Program Influence (PI) Score = 10 - Preliminary Program Influence Score.

#### 4.4.1.1.2 Calculation of the No-Program Score

The No-Program (NP) Score is based on three measures of the likelihood of a participant purchasing the exact same item(s) at the same time in the absence of the program. Each of these likelihood measures are assessed on a 0-10 scale in which 0 means not at all likely and 10 means very likely.

First, the participant should be asked their likelihood of purchasing an item of *any efficiency* within 12 or 6 months

[48] The Illinois NTG Working Group discussed using this question to check for consistencies rather than adjusting the score. The NTG working group agreed that it is preferable not to directly ask about conflicting language with residential customers and to utilize an open ended question instead to assess possible reasons for conflicting statements. It is the experience of the NTG working group members that residential customers tend to be more impatient with these types of questions and can typically respond easier to an open-ended question about their motivations.

(12 months for a single or big ticket item and 6 months for less expensive items) for the Timing (T) Score. Participants who were influenced by the program to replace still-functioning equipment will likely give a low score to this question, while participants who needed to replace burned out equipment will give a high score. This measure enables the analysis to use a single algorithm for both early replacement and replace-on-burnout scenarios.

Next, the participant should be asked a key question that asks the respondent to gauge their likelihood of purchasing the *exact same item* (e.g., make, model, efficiency) had the program not existed. This measure forms the Efficiency (E) Score. A respondent stating the likelihood of purchasing the same exact item as a 5 on a scale of 0 to 10 is assigned an Efficiency Score of 5.

If multiple quantities of an item are purchased, the respondent should be asked about the likelihood of purchasing fewer energy-efficient items. The response to this question is subtracted from 10 to compute the Quantity (Q) Score.

The No-Program Score is the minimum of the Timing, Efficiency, and (if applicable) Quantity Scores. Finally, the No-Program Score is averaged with the Program Influence Score to calculate the Final Free Ridership Value.

$$No\ Program\ Score\ (NP) = Min(T, E, Q)$$

$$Free\ Ridership\ (FR) = Mean(PI, NP)$$

#### 4.4.1.1.3 Consistency Checks

To address the possibility of conflicting responses (i.e., low intention score and high influence score), the survey should include consistency checks that, at a minimum, ask participants an open-ended question to address the program's influence. For example:

- In your own words, please tell me the influence the program had on your purchase of the <insert measure name>.

In this case, the evaluation analyst will assess the response to this open ended question and its consistency with the other questions, and, if warranted based on clear additional information, they will adjust the score based on expert judgement. If an inconsistency exists and the open-ended response does not resolve the inconsistency, the respondent will be removed from the calculation. All instances of this occurring should be documented in the final report. Additional consistency checks, triggered and resolved within the survey with additional questions to participants, remain optional.

Missing responses to specific questions should be treated as "missing" for that particular question, but the observation or case will be retained in the analysis. Evaluation reports should note if this affects more than 5% of the responses.

## 4.5 Single-Family Home Energy Audit Protocol

Single-Family Home Energy Audit programs (or energy assessment programs) seek to secure energy savings for residential customers by providing audits, direct-install measures, and incentives for additional energy efficiency opportunities. The participation process generally begins with an energy audit, performed by a program-affiliated companies or individuals; this involves an auditor assessing the customer's home to identify energy-saving opportunities. At that time, the auditor may install free instant-savings measures, such as CFLs, low-flow showerheads, and faucet aerators. Auditors also may educate customers about incentives available through the audit program (e.g., air sealing, insulation) or other Program Administrator-sponsored energy efficiency programs.

For these programs, free ridership and participant spillover (See Section 4.1.2) estimates rely on participant self-reports, gathered through surveys.

### 4.5.1 Basic Method

Given the multiple components of some audit programs, net impacts should be estimated using survey batteries tailored to a customer's experience (e.g., receipt of free direct-install measures and discounted or rebated measures). The following sections outline the approach for two program components, one dealing with the direct installation of free low-cost measures and a second dealing with envelope measures, such as air sealing and insulation.

#### 4.5.1.1 No-Cost, Direct Install Measures

For free measures directly installed by program staff due to the audit, free ridership calculations should include the following components: Timing, Efficiency, and Quantity.

This approach provides several important benefits, such as deriving a partial free ridership score based on the likelihood that the participant would take similar actions in the absence of the audit. For example, partial scores can be assigned to customers who planned to install the measure, but the program influenced that installation, particularly in terms of timing (e.g., the program might have accelerated the installation) or quantity (e.g., the program might have led to installation of additional program-qualified measures).

Outlines of components and their associated survey questions follow:

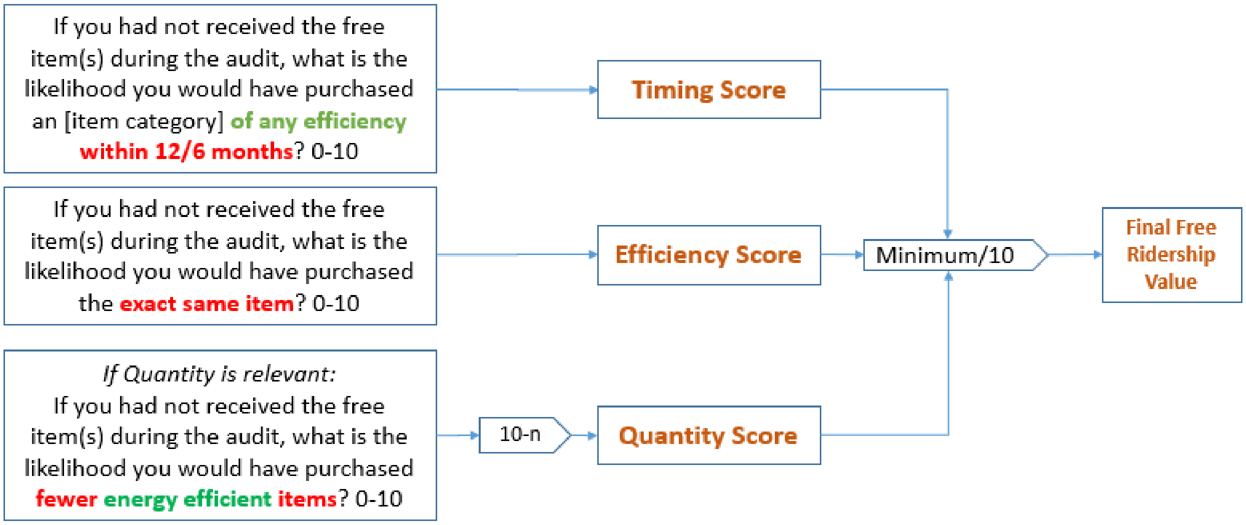
- **Timing (T).** The first question is compute the Timing (T) Score accounts for earlier installation of measures due to the program by asking respondents about their likelihood (0-10 scale) to have installed an item *of any efficiency* within 6 or 12 months, had they not received it through the program (12 months for a single or big ticket item and 6 months for less expensive items).
- **Efficiency (E).** This score reflects the likelihood that customers would have installed the exact same energy-efficient measures, had the program not existed. For free measures, this is based on a question asking respondents to rate the likelihood that they would have installed the exact same measures had they not received them for free through the audit (on a 0 to 10 scale, where 0 is not at all likely and 10 is extremely likely). A higher likelihood value means a higher level of free ridership (i.e., a lower attribution level for the program).
- **Quantity (Q).** The question to compute the Quantity (Q) Score asks respondents about the likelihood that they would have installed fewer measures or performed less weatherization without the program. The response to this question is subtracted from 10 to compute the Quantity Score, as a lower score means a greater likelihood the respondent would have installed the same or a greater number of measures.

Given the low cost of the measures provided through the direct-install component of most audit programs and the number of measures received per participant, efforts have been made to streamline the free ridership battery to reduce the respondent's burden. As such, the overall Final Free Ridership Value per measure can be calculated by taking the minimum of the Timing, Efficiency, and Quantity Scores, as shown in the following equation:

$$Free\ Ridership\ (FR) = Min(T, E, Q)$$

Figure 4-7 illustrates the algorithm for no-cost measures.

**Figure 4-7. Single-Family Home Energy Audit Free Ridership—No Cost Measures**



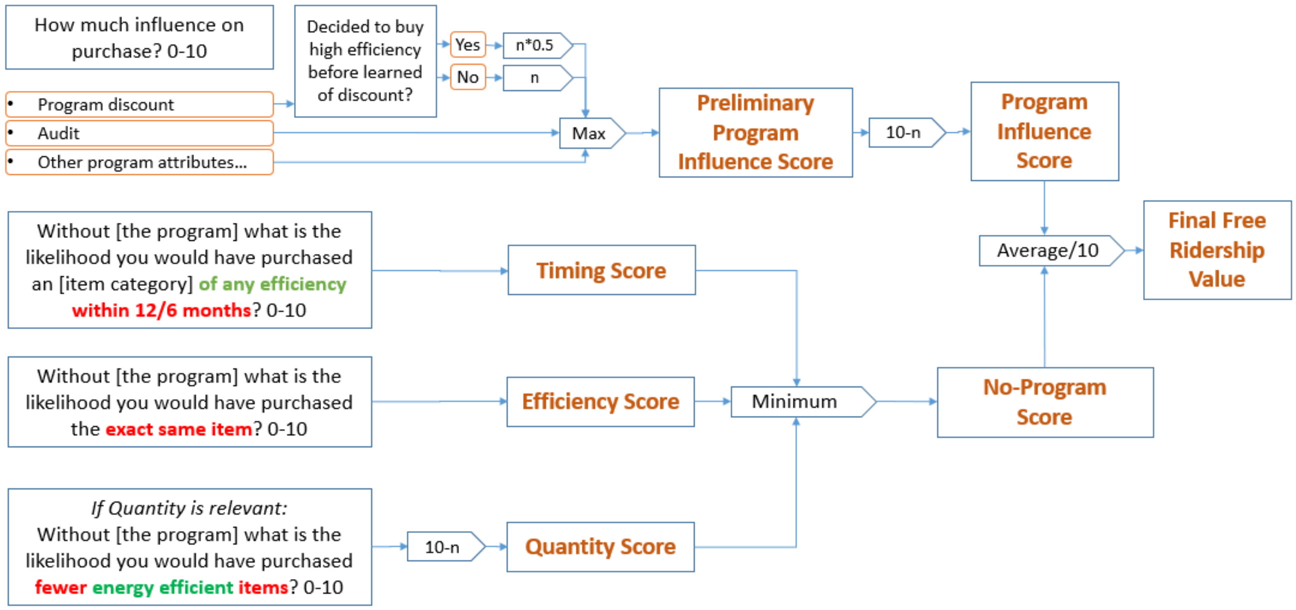

#### 4.5.1.2 Rebated/Discounted Measures

Estimating NTG for rebated measures (typically for building shells) requires a more rigorous process than estimating NTG for free direct-install measures. In particular, the approach integrates an assessment of various program components that may have influenced the participant's installation of the measures. For discounted envelope measures, the basic free ridership factor consists of the following two components:

- A Program Influence component, based on the participant's perception of the influence of various program elements—including the discount and the audit itself—on carrying out the energy-efficient project; and
- A No-Program component, based on the participant's likelihood of purchasing the exact same items at the same time in the absence of the program.

The free ridership method for discounted measures is identical to that used in the Prescriptive Rebate (With No Audit) protocol, with the one exception that the questions about program influence should be sure to include the audit itself as one of the program attributes. Evaluators should refer to Section 4.4.1.1 for details of the method. Figure 4-8 illustrates the algorithm for discounted measures.

**Figure 4-8. Single-Family Home Energy Audit Free Ridership—Discounted Measures**




#### 4.5.1.3 Consistency Checks

To address the possibility of conflicting responses (e.g., the high likelihood to install the same measure in the program's absence and the high importance of program factors), the survey should include consistency checks that, at a minimum, ask participants an open-ended question to address a program's influence, such as the following:

- In your own words, please tell me the influence the program had on your purchase of the <insert measure name>.

For low or no-cost, direct-install measures, surveys should include two questions to assess a program's influence on the respondent. The first should be asked at the beginning of the NTG battery, and the second should be asked at its conclusion. Questions include the following:

- Prior to the audit, had you purchased any <measures>? Y/N
- IF YES AND LIKELIHOOD TO INSTALL WITHOUT THE PROGRAM IS <7: Given that you had purchased <measures> before receiving the audit, why didn't you purchase additional <measures> on your own without the program? [OPEN END]
- IF NO AND LIKELIHOOD TO INSTALL WITHOUT THE PROGRAM IS >6: Given that you have not purchased <measures> before, why were you likely to purchase <measures> on your own without the program? [OPEN END]

In both cases, the evaluation analyst will assess responses to open ended questions and their consistency with the other questions; if warranted, based on clear additional information, the evaluator will adjust the original question score if required. If inconsistency occurs and the open-ended response does not resolve it, the original question response will be removed from the calculation. Final reports should document all instances of such adjustments. Optionally, additional participant questions can be included to trigger and resolve additional consistency checks.

Missing responses to specific questions (e.g., don't know or refused) should be treated as "missing" for those particular questions, but the analysis retains the observation or case. The evaluation reports should note if this affects more than 5% of responses.

## 4.6 Multifamily Protocol

Multifamily energy efficiency programs typically offer direct installation of low-cost, energy-efficient measures in multifamily dwelling units, in addition to rebates for common area lighting retrofits, air sealing, insulation, and improvements to HVAC systems and controls. These programs have various target audiences from owners, managers, or developers of market rate multifamily housing to those operating lower income or assisted living housing. Across these groups, properties must generally have a minimum of between three and five units to qualify for the programs.

Most multifamily program savings are typically achieved by encouraging customers to install higher-efficiency equipment than they would have installed on their own. However, programs may also encourage early replacement of still functioning equipment that is less efficient, thus impacting the timing of the installation, so that savings is realized earlier. The incentive may also make it more affordable for customers to install a greater number of high-efficiency measures.

The basic method for estimation of free ridership and participant spillover (See Section 4.1.2) for these types of programs is based on participant self-report gathered through surveys. For common area and building shell components of the program, participants are property managers and owners responsible for building maintenance and renovation. However, depending on the program design for the in-unit component of the program and specifically the installation of efficient lighting, participating in the program (i.e., install program measures) may be driven by either property managers/owners or tenants or, potentially, both. This distinction is due to the fact that in some market-rate apartments, the tenant is responsible for decisions related to the installation of program measures, including light bulbs, while this is not common practice in income-qualified or assisted-living settings. For other in-unit measures, such as faucet aerators and low-flow showerheads, evaluators interview property managers/owners regarding program influence, as these measures are typically direct installed by program staff, and there is a limited likelihood of tenants making changes to these features.

### 4.6.1 Basic Method

Estimating NTG for rebated measures requires a more rigorous process than estimating NTG for free direct-install measures. In particular, the approach integrates an assessment of various program components that may have influenced the participant's installation of the measures. For discounted measures, the basic free ridership factor consists of the following two components:

- A Program Influence component, based on the participant's perception of the influence of various program elements—including the discount and the audit itself—on carrying out the energy-efficient project; and
- A No-Program component, based on the participant's likelihood of purchasing the exact same items at the same time in the absence of the program.

The free ridership method for discounted measures is identical to that used in the Prescriptive Rebate (With No Audit) protocol, with the one exception that the questions about program influence should be sure to include the audit itself as one of the program attributes. Evaluators should refer to Section 4.4.1.1.1 and 4.4.1.1.2 for details of the method. Figure 4-9 and Figure 4-10 also illustrate the algorithms for CFL/LED and non-CFL/non-LED measures[49].

[49] Evaluators should word the survey questions to reflect whether measures were free or purchased with an incentive.

**Figure 4-9. Multifamily Free Ridership—Non-CFL/Non-LED Measures**

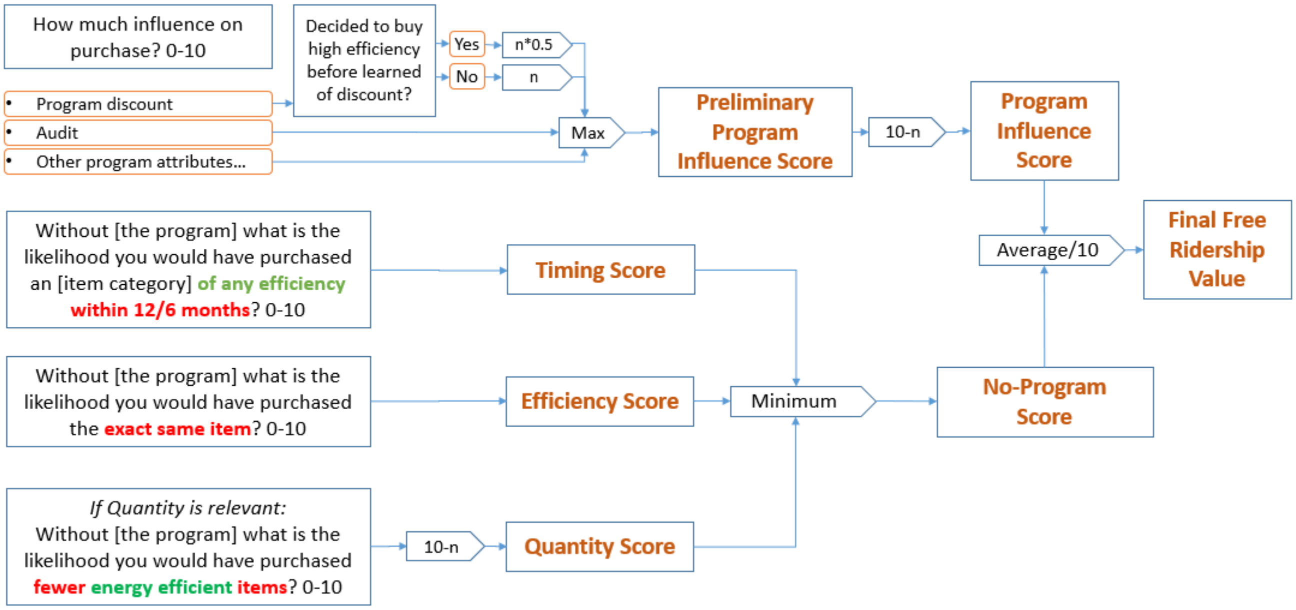
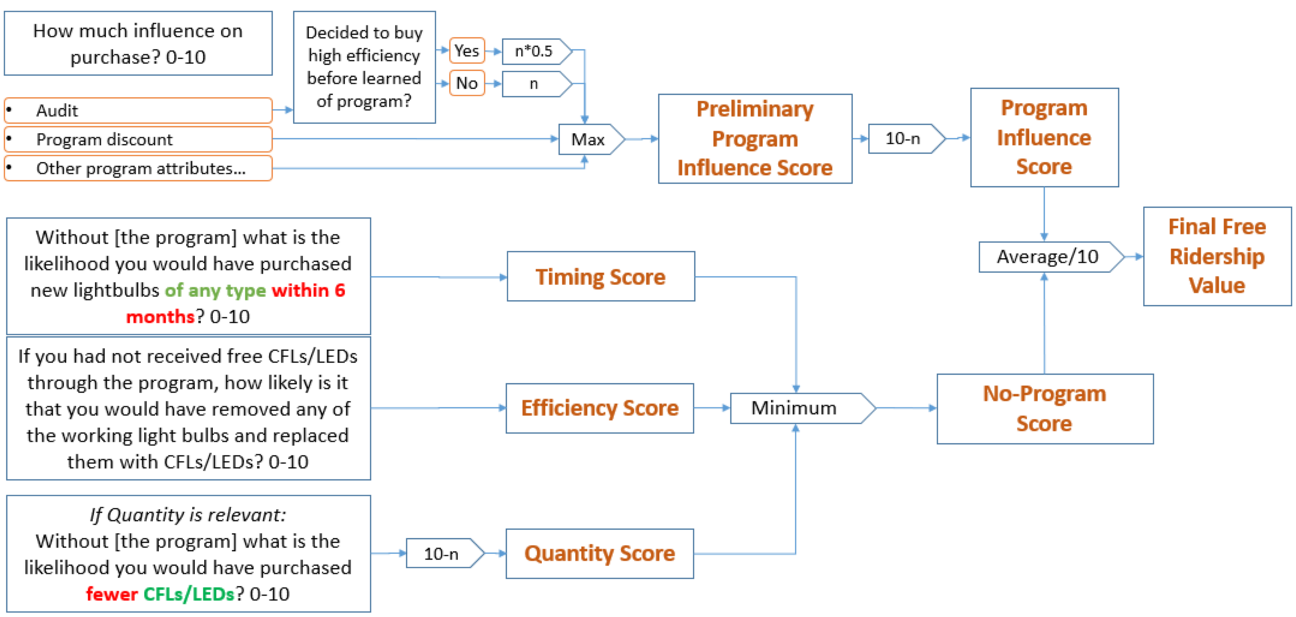



**Figure 4-10. Multifamily Free Ridership for Property Managers—CFL/LED Measures**




#### 4.6.1.1 Consistency Checks

To address the possibility of conflicting responses (e.g., high likelihood to install the same measure without the program, high importance to program factors), the survey should include consistency checks that, at a minimum, ask participants an open-ended question to address the program's influence. For example[50]:

- In your own words, please tell me the influence the program had on your purchase of the <insert measure name>.

The evaluation analyst will assess the responses to the open ended questions and their consistency with the other survey questions, and, if warranted based on clear additional information, will adjust the original question score. If

[50] Evaluators should word the consistency check questions to reflect whether measures were free or purchased with an incentive.

the open-ended response does not resolve the inconsistency, responses to the original question should be removed from the calculation. The survey may include additional consistency check triggers and resolutions through additional participant questions. The final report should document how often the consistency check rules were triggered, how often adjustments were made to scores, and how often inconsistencies could not be resolved.

Missing responses to specific questions (including don't know or refused) should be treated as missing for that particular question, but the analysis should retain that observation or case. Evaluation reports should note if this affects more than 5% of the responses.

#### 4.6.1.2 Data Collection

A participant survey should be used as the primary source of data collected for estimating free ridership in residential multifamily programs. As discussed, evaluators may field surveys with owners, property managers, or tenants, depending on a program's design and theory. Determining the appropriate audience from which to gather information for estimating free ridership depends on the program's design, and, ultimately, the party responsible for deciding to install specific program measures.

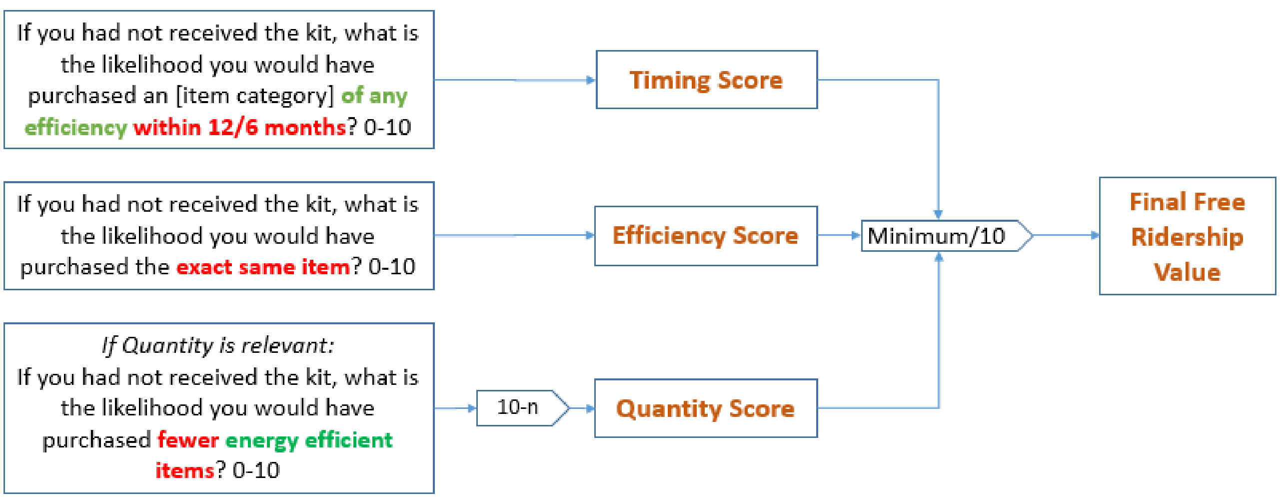
## 4.7 Energy Saving Kits and Elementary Education Protocol

Energy Saving Kits and Elementary Education Programs aim to secure energy savings through the distribution of kits containing various energy-saving measures, including (but not limited to): high-efficiency lighting (CFLs or LED lamps); bathroom and kitchen faucet aerators; and low-flow showerheads. Energy Saving Kits operate as an opt-in program; customers can request a kit by completing an Internet or phone application. Elementary Education Program participants do not request a kit as kits are distributed to all students in a classroom.

Free ridership and participant spillover (See Section 4.1.2) estimations for both programs rely upon participant self-report information gathered through surveys, despite the differences in distribution models. This methodology can be used for other energy-saving kit programs, including kits with alternative distribution methods (e.g., kits dropped off at a participant's home).

The following section contains a description of the basic NTG method used. Figure 4-11 illustrates the method.

**Figure 4-11. Energy Saving Kits and Elementary Education Free Ridership**




### 4.7.1 Basic Method

Free ridership calculations should include the following components: No-Program, Timing, and Quantity.

This approach provides several important benefits, such as the ability to derive a partial free ridership score based on the likelihood that similar actions would have taken place, even if the participant had not received a kit. For instance, partial scores can be assigned to customers with plans to install the measure, but the program at least influenced that installation, particularly in terms of timing (e.g., the program might have accelerated the installation) or quantity (e.g., the program might have led to the installation of additional measures).

Outlines of components and their associated survey questions follow:

- **Timing (T).** The first question is compute the Timing (T) Score accounts for earlier installation of measures due to the program by asking respondents about their likelihood (0-10 scale) to have installed an item *of any efficiency* within 6 or 12 months, had they not received it through the program (12 months for a single or big ticket item and 6 months for less expensive items).
- **Efficiency (E).** This score reflects the likelihood that customers would have installed the exact same energy-efficient measures, had the program not existed. This is based on a question asking respondents to rate the likelihood that they would have installed the exact same measures had they not received them for free through the kit (on a 0 to 10 scale, where 0 is not at all likely and 10 is extremely likely). A higher likelihood value means a higher level of free ridership (i.e., a lower attribution level for the program).
- **Quantity (Q).** The question to compute the Quantity (Q) Score asks respondents about the likelihood that they would have installed fewer measures without the program. The response to this question is subtracted from 10 to compute the Quantity Score, as a lower score means a greater likelihood the respondent would have installed the same or a greater number of measures.

Given the low cost of measures provided in the energy-saving kits as well as the number of measures included in each kit, efforts have been made to streamline the free ridership battery to reduce the respondent's burden. As such, the overall Final Free Ridership Value per measure can be calculated by taking the minimum of the Timing, Efficiency, and Quantity Scores, as shown in the following equation:

$$Free\ Ridership\ (FR) = Min(T, E, Q)$$

Missing responses to specific questions (e.g., don't know or refused) should be treated as "missing" for that particular question. Despite missing responses, the case will be retained in the analysis (pairwise deletion). The evaluation reports should present the percent missing for each of the three questions.

#### 4.7.1.1 Data Collection

Evaluators should use a participant survey as the primary data collection source for estimating free ridership in Energy Saving Kits and Elementary Education Programs. As a general rule, a free ridership rate should be calculated for each separate kit component, and then be weighted by savings to determine the program-level results.

## 4.8 Residential New Construction Protocol

Residential New Construction programs typically offer builder training, technical information, marketing materials, and incentives to builders for the construction of eligible homes. Eligible homes must meet specific standards, designed to achieve energy efficiency levels above local building codes. Programs may use different tiers of standards to meet correspondingly different incentives.

The basic method for estimating free ridership and participant spillover for these programs is based on builder participant self-reporting, gathered through surveys.

The following section describes the basic method used.

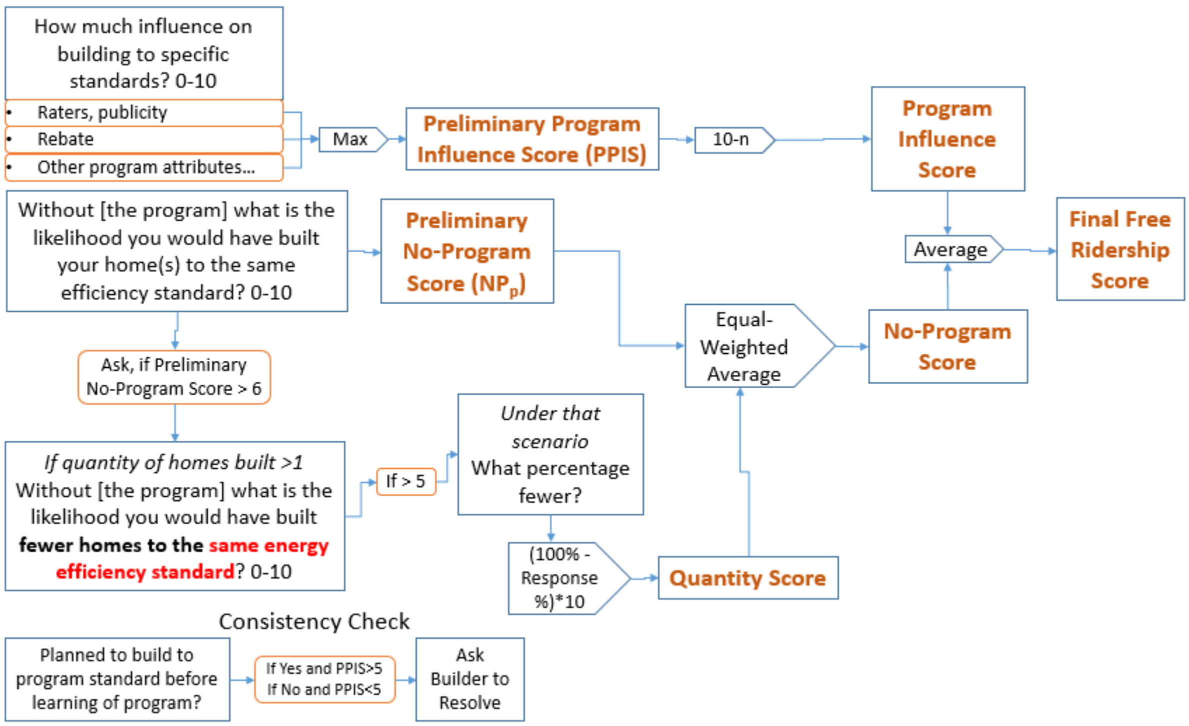
### 4.8.1 Basic Method

For this program, a free rider is a builder who would have constructed a home at the program's efficiency level in the program's absence. Given the multiple methods available to achieve desired home energy efficiency levels, survey questions consider the builder's likelihood of meeting the same energy efficiency standard, rather than whether or not the builder would have installed certain energy efficiency measures. Figure 4-12 (below) illustrates the method in more detail.

Evaluators assess Program Influence by asking respondents, on a scale from 0 (not at all important) to 10 (extremely important), how important they found various program elements in deciding to build to specific energy efficiency standards. The number of elements included vary, depending on the program's design. Logic models, program theory, and staff interviews typically inform the list of program elements included. Programs typically use the following elements to influence builder actions: marketing materials; incentives or rebates; contacts with HERS Raters; and technical assistance.

In addition to asking about specific program influences, surveys should ask builders whether they planned to build homes to the same standard before learning of the program.

**Figure 4-12. Residential New Construction Free Ridership**




#### 4.8.1.1.1 Calculation of the Program Influence Score

The Program Influence Score (PI) equals 10 minus the maximum influence rating for any program element rather than, for example, the mean influence rating. This is based on the rationale that if any given program element had a great influence on the respondent's action, the program itself had a great influence, even if other elements had less influence.

#### 4.8.1.1.2 Calculation of the No-Program Score

Evaluators calculate the No-Program score using a set of questions that ask respondents to gauge their likelihood of building homes to the same standards and in the same quantities had the program not existed. Three separate responses are considered in calculating the No-Program Score:

- The likelihood, on a scale of 0 to 10, that the builder would have built their homes to the same efficiency standard (Preliminary No-Program Score ($NP_p$))
- If that likelihood is greater than 6, the likelihood of fewer homes being built to the same efficiency standard.
- If that likelihood is greater than 6, the response to the question "for that scenario, what percentage of fewer homes would be built to the standard?" (Quantity Score = (100% - % answer) * 10, which will be a number between 0 and 10)

The resulting No-Program (NP) Score is calculated as follows:

$$NP = Mean(NP_p, Q)$$

The overall Free Ridership Value derives from the average of the PI and NP scores, as shown in the following formula:

$$FR = Mean(PI, NP)$$

#### 4.8.1.2 Consistency Checks

To address the possibility of conflicting responses (e.g., the high likelihood to build to the same efficiency standards without the program, the high importance of program factors), the survey should include, at a minimum, consistency checks that ask participants an open-ended question to address the program's influence. For example:

- In your own words, please tell me the influence the program had on your building practices.

If a high (>6) Preliminary Program Influence Score (PPIS) results, yet the builder planned to meet the same efficiency standard prior to learning of the program; or if the Preliminary Program Influence Score is lower (<7), and the builder did not plan to build to the standards prior to learning of the program, the survey should include a question to determine why this occurred, using wording that gets at the following inconsistencies:

- IF Preliminary Program Influence Score is >6 and Builder planned to meet the same efficiency standard prior to learning OF THE PROGRAM: Given that you had plans to meet the standard prior to learning about the program, why do you think the <program elements> were influential in your meeting the standard? [OPEN END]
- IF Preliminary Program Influence Score is <7 and Builder had no plans to meet the same efficiency standard prior to learning of the program: Given that you had no plans to meet the standard prior to learning about the program, why do you think the <program elements> were not more influential in your meeting the standard? [OPEN END]

The evaluation analyst will assess the responses to the open ended questions and their consistency with the other survey questions, and, if warranted based on clear additional information, will adjust the original question score. If the open-ended response does not resolve the inconsistency, responses to the original question should be removed from the calculation. The survey may include additional consistency check triggers and resolutions through additional participant questions. The final report should document how often the consistency check rules were triggered, how often adjustments were made to scores, and how often inconsistencies could not be resolved.

Missing responses to specific questions (including don't know or refused) should be treated as missing for that particular question, but the analysis should retain that observation or case. Evaluation reports should note if this affects more than 5% of the responses.

### 4.8.2 Participant Spillover

Participant spillover occurs when, due to program participation, a builder increases the energy efficiency of homes built outside the program (but inside a utility's service territory) by adopting certain building practices used in participating homes. Participant spillover can be calculated based on participant builder survey questions that ask builders about homes built within the utility service territory but outside the program. Survey questions ask whether the builder increased the energy efficiency standards of non-program homes after participating in the program, and the number of homes they applied these increased standards to, within the utility's service territory. Depending on the program characteristics, spillover should be measured as changes in specific building practices or as installation of specific measures. The text below assumes the program has been targeted at modifying building practices.

Spillover may be recorded depending on responses to the following questions:

1. How important was your experience in the <PROGRAM ADMINISTRATOR'S> program in your incorporating this building practice your other homes, using a scale of 0 to 10, where 0 is not at all important and 10 is extremely important?
2. If you had not participated in the <PROGRAM ADMINISTRATOR'S> program, how likely is it that you would still have incorporated this building practice using a 0 to 10, scale where 0 means you definitely WOULD NOT have implemented this practice and 10 means you definitely WOULD have implemented this practice?

Responses to the first question establish the Practice Attribution Score 1, and responses to the second question establish the Practice Attribution Score 2. Spillover may be program-attributable for building practices with self-report data meeting the following condition:

*Spillover Score = (Practice Attribution Score 1 + (10 – Practice Attribution Score 2))/2 > 5.0*

For responses meeting these conditions, an evaluator determines that specific building practices referenced in the question are attributable to the program; otherwise, the evaluator determines that specific building practices referenced in the question are not attributable to the program. The attribution criteria represent a threshold approach, in which energy impacts associated with building practices program participants implement outside the program are either 100% program-attributable or 0% program-attributable.

For each building practice discussed, builders will be asked how they know the building practice is more efficient than other options. If the respondent can identify the building practice as ENERGY STAR or name an efficiency level that the evaluator confirms as above the minimum federal standard, or if they identify a technology that the evaluator can confirm is above the minimum federal standard, this counts towards participant spillover.

Finally, depending on the building practice cited by the builder, follow-up questions should ask customers to provide reasonable information to allow the evaluator to estimate the amount of savings using IL-TRM protocols, such as quantity of appliances or the location and amount of insulation.

To calculate the spillover energy and demand savings for these actions, further questions should be asked to assess the gross savings of the building practice, through the appropriate version of the IL-TRM, if available, and the number of homes to which it applied. To develop the Spillover Rate, the total energy and demand impacts from the sampled participants who implemented efficient building practices in other homes due to participation in the program is summed, and then this sum is divided by the total ex post sample energy and demand impacts:

$$Participant\ Spillover\ Rate\ (PSO) = \frac{Sum\ of\ Energy\ or\ Demand\ from\ Additional\ EE\ Practices}{Sample\ Ex\ Post\ Gross\ Energy\ or\ Demand\ Impacts}$$

The equation used to adjust the Core NTGR based on participant spillover is as follows:

$$NTGR = (1 - FR + PSO)$$

#### 4.8.2.1 Sample

The sample for a spillover survey should be a random sample of current and up to one year previous program participants. Regardless of the year of participation, spillover should be measured within the set of homes that were completed within 12 months of the survey date.

### 4.8.3 Builder Nonparticipant Spillover

In addition to participant free ridership and spillover, new construction programs may create NPSO through builders exposed to the program but not actually participating. Rather, they implement some or all of the efficiency measures incorporated through the program in order to compete with builders that are participating.[51] NPSO caused by builders can be determined by surveying two groups of builders:

- “Drop out” builders, who participated in the program previously but have not participated in the past 12 months.
- True nonparticipating builders that report they were aware of the program or that other builders were taking steps to improve new home efficiency, but had never participated.

Surveys ask nonparticipating builders if their knowledge of other builders’ increased focus on energy efficiency influenced their building practices and in what manner, to quantify the program’s impact on nonparticipating homes. The survey questions will first identify specific building practices that go beyond the implemented energy code for the specific jurisdiction in which the builder is active. Table 4-6 lists the latest building energy code in place for most

[51] NPSO also can arise from nonparticipating customers as a direct result of general energy efficiency education and promotion efforts. A separate protocol addresses such NPSO. Care should be taken to ensure the different approaches do not double-count NPSO.

areas of Illinois. Evaluators should make efforts to ensure the building code under enforcement for each jurisdiction is used as the baseline when evaluating spillover savings.

**Table 4-8. IECC 2015 Building Energy Code**

| Component | IECC 2015 |
|---|---|
| Thermostat | Heating 72F; Cooling 75F Programmable Thermostat |
| Ceiling | U-0.026 |
| Walls | U-0.060 |
| Floors | U-0.033 |
| Slab | R-10, 2ft |
| Windows | U-0.32 |
| Infiltration | 5ACH50 |
| Duct Leakage | 4CFM/100CFA |
| Duct Insulation | R-8 Attic Supply,  R-6 Otherwise |
| Heat Pump | 8.2 HSPF |
| Furnace | 80 AFUE |
| **Component** | **IECC 2015** |
| Boiler | 82 AFUE |
| AC | 13 SEER |
| Lighting | 75% CFL |
| Appliances | RESNET Default |
| Gas Water Heat* | 0.58 EF |
| Electric Water Heat* | 0.92 EF |

*EF varies based on water heater storage volume and draw pattern; values in table for 40 gallon water heater with medium draw pattern.

For each component that is more efficient than code, the following additional questions are asked:

1. How many homes did you sell in <period> that incorporated this upgrade?
2. Of these homes, how many would have incorporated this upgrade, had the <program> not existed?

Evaluators should ensure that nonparticipant builders receive sufficient time to collect specific data and not rely on "guesses" to respond. Responses should also clarify whether sales counts are specific to the utility service territory in question.

The following steps calculate the program's nonparticipant builder spillover percentage:

1. Compute the difference between the total reported number of efficiency upgrades sold and the total that would have been sold in the program's absence to obtain the total number of upgrades by type of upgrade for that builder.
2. Multiply the total net number of upgrades of each type sold by each surveyed builder by the average gross unit savings for each upgrade type.
3. Sum the result for each builder from the previous step, and weight the results by the ratio of the population of non-active builders to the sample to compute the total spillover energy over the program period.
4. Divide the spillover energy savings by program gross savings.

Should a general population survey be implemented for nonparticipant spillover, care should be taken to ensure spillover is not double-counted.

# 5 Cross-Sector Protocols

The following sections include protocols that may be applicable to programs in the residential as well as in the commercial, industrial, and public sectors. Table 3-1 Commercial, Industrial, and Public Sector Programs and Table 4-1 Residential and Low Income Programs present information regarding the applicability of these protocols to specific programs.

## 5.1 Combining Participant and Trade Ally Free Ridership Scores

For a program where trade allies play a prominent role in delivering the energy efficiency measure and promoting the program, an estimate of free ridership from trade allies can be combined with one from participants to form a combined free ridership value. Elsewhere, the NTG Protocol (see Section 3.1.1.3) discusses using trade ally surveys to adjust **project-level** free ridership scores. This section discusses combining a **program-level** free ridership score from trade allies with a program-level free ridership score from participants.

If an evaluation uses this approach, the evaluator's NTG report should present the conditions that support the argument that the combined value is more likely to be reflective of reality. That argument should consider the following topics:

1. **Trade Ally Role.** What role do the trade allies play in the program? How were participating trade allies chosen? How might they differ from nonparticipating trade allies? Why does that support the proposition that their view on free ridership is accurate and reasonably unbiased?
2. **Participant Role**. What role do the participants play in deciding which measures are installed and why does that support the proposition that their view on free ridership is accurate and reasonably unbiased?
    a. For example, the participant's role in the decision **may** be significantly less in some types of programs like new construction or multifamily direct install programs. (The participant free ridership data collection method may already account for this by, for example, treating the building owner as the participant rather than the tenants.)
3. **Market Conditions**. What conditions exist in the market that support the proposition that either the trade allies' view or the participants' view on market behavior may be more accurate?
    a. For example, if the market was in its infancy before the program began and as a result participants' ability to take the energy efficiency action was limited, the trade allies may have a more accurate view on the counterfactual than the participants.
4. **Bias.** What are the hypothesized biases of the participants and trade allies? Where do they stem from? What evidence is there that they exist? How well has the data collection approach sought to mitigate that bias?
5. **Offsetting Bias.** Do the hypothesized biases of participants and trade allies offset each other or do they move the free ridership value in the same direction?

### 5.1.1 Trade Ally Free Ridership Calculation

The NTG protocols do not yet contain a standardized approach for measuring free ridership from trade allies. That approach should be developed for future versions of the TRM. In the meantime, if an evaluation team decides to estimate trade ally free ridership, they should collaborate with other Illinois evaluators on the survey design and calculation algorithm.

### 5.1.2 Triangulation

Where appropriate, evaluators should combine participant and trade ally free ridership values by weighting each value in the final result. The weighting of each value should be based on considerations of the likely bias, accuracy, and representativeness of the results. The following presents one approach for determining weights. This is an example only. The evaluator should create an approach appropriate for the program.

**Example.** Combined participant and trade ally free ridership results by rating the analysis methodology and data collected using responses (rated on a scale of 0 to 10) to the following three questions:

1. All things being equal, on a scale of 0 to 10, with 0 being not at all likely and 10 being extremely likely, how likely is the approach to provide a more accurate estimate of free ridership?
2. Similarly, on a scale of 0 to 10, with 0 being not at all valid and 10 being extremely valid, how valid and reliable is the data collected and the analysis performed (i.e., consider non-response bias, missing data (e.g., whether data collected was based on recollection or record keeping?)
3. On a scale of 0 to 10, with 0 being not at all representative and 10 being extremely representative, how representative is the sample (accounting for sampling error {confidence and precision}, and non-response bias, and any sample frame bias)?

The weight for each free ridership estimate is the average score for that estimate divided by the sum of the average scores for both estimates.

Table 4-5 provides an example scoring illustrating the calculated weights.

**Table 5-1. Example Triangulation Weighting Approach**

| **NTG Triangulation Data and Analysis** | **Participants** | **Trade Allies** |
|---|---|---|
| 1. How likely is this approach to provide an accurate estimate of free ridership? | 6 | 8 |
| 2. How valid is the data collected/analysis? | 3 | 5 |
| 3. How representative is the sample? | 8 | 10 |
| Average Score | 5.7 | 9 |
| Sum of Averages | 14.7 | 14.7 |
| Weight | 39% | 61% |

## 5.2 Spillover Measured Through Trade Allies

Many energy efficiency programs rely on trade allies to help spread program awareness and promote energy efficiency among their customers. Some programs establish lists of participating trade allies and provide trade allies with training, education, and/or marketing materials. Spillover might occur when a trade ally's business practices are influenced by a program but at least some of their energy efficient installations do not receive a program incentive.

For the purposes of measuring trade ally spillover, we define trade allies as (1) retailers, contractors or other market actors who work with end-user customers on the selection and installation of energy-using equipment; and (2) distributors who supply equipment to stores and other market actors, rather than to end-user customers. For the purposes of this section, manufacturers are not included in the definition of trade allies.[52] In addition, we differentiate between the following types of trade allies:

1. Active Trade Allies
    a. Trade allies who were active in the program during the evaluation period and appear in program tracking databases. The tracking data contains information on the quantity of incented measures associated with these trade allies and their savings;
2. Inactive Trade Allies
    a. Trade allies who are on the utility's trade ally list (and have received at least some utility training or education) but who were not active during the evaluation period and do not appear in program savings tracking databases for the evaluation period;
    b. Trade allies who were previously active in the program (and may have been on the utility's trade ally list) but have dropped out; and/or

[52] The exclusion of manufacturers from the definition of trade ally does *not* suggest that manufacturers cannot create spillover. Rather, manufacturers are excluded because the methodologies outlined in this section do not apply to them.

c. Trade allies who have never been active in the program and were never on the utility's trade ally list.

When deciding whether to conduct trade ally spillover research, the evaluator should consider the following:

- **Likelihood of trade ally spillover:** When limited evaluation resources are available, the evaluator should weigh the likelihood of trade ally spillover against the cost of the analysis when prioritizing evaluation efforts. E.g., programs that provide incentives but no training or education are less likely to generate spillover than programs that do provide training or education. Similarly, spillover from active trade allies is generally more likely than spillover from inactive trade allies, and spillover from inactive trade allies who have previously been active in the program is generally more likely than spillover from inactive trade allies who have never been active in the program.
- **Potential double-counting of spillover reported by end-use customers and trade allies:** Spillover from active trade allies and spillover from inactive trade allies are mutually exclusive, i.e., as long as the populations and samples are correctly defined, there is no danger of double-counting spillover from these two groups (see also discussion in Section 2.2). However, if the evaluator measures spillover through trade allies and end-use customers for the same evaluation period, care needs to be taken to avoid double-counting. Evaluators should clearly document potential double-counting of spillover and the steps taken to avoid it.

The following subsections provide suggested approaches for measuring spillover from active and inactive trade allies. Different approaches are outlined for these two groups because of the different types of data available for each of them. For active trade allies, program tracking data contains information on their program activity (the quantity of incented measures associated with each active trade ally and their savings). This data allows for a more rigorous spillover methodology than can be used for inactive trade allies, for whom this information does not exist.

### 5.2.1 Spillover from Active Trade Allies

Trade allies that are active in an energy efficiency program are more likely to create spillover than inactive trade allies, as their exposure to any program messaging and training/education is likely to be current and therefore more influential on their business practices. Active trade allies may create spillover if their program participation changes their business practices and leads to the completion of non-incented energy efficient projects that would otherwise not have happened. For example, as a result of program training, a trade ally might feel more comfortable talking about the benefits of energy efficiency and recommend energy efficient solutions more often. If these recommendations result in energy efficient projects, but no incentive is claimed, spillover from inactive trade allies may be present.

For active trade allies, the spillover methodology varies slightly for downstream programs and midstream programs. Approaches for both types of program are discussed below.

#### 5.2.1.1 Downstream Programs

Surveys can be used to ask active trade allies if the program influenced their sales of high-efficiency equipment to participating or nonparticipating customers and to quantify the program's impact on their high-efficiency sales. To assess if a sampled trade ally created spillover, the following screening criteria are recommended (the order of these may be adjusted by the evaluator):

1. The percentage of the trade ally's installations/sales that are high efficiency and/or the total volume of high efficiency installations/sales increased since the trade ally became exposed to the program.
2. The trade ally rated the program as important to at least one of these (as described above) high efficiency installation increases.
3. The trade ally installed/sold at least some high efficiency equipment or products during the evaluation period that did not receive an incentive.
4. The trade ally's recommendation was influential in the customers' choice of high efficiency equipment/product over standard efficiency equipment/product in instances where the equipment did not receive a program incentive.

5. The open-ended response about why customers with eligible projects do not receive an incentive supported that the non-incented high efficiency installations can be considered spillover.

Sampled trade allies who do not pass one of the above screening criteria do not qualify for spillover and may be skipped out of the rest of the spillover module.

To quantify spillover for each sampled trade ally, the survey collects information on the percentage of the trade ally's total equipment installations/sales (in terms of projects or measures) that was (1) standard efficiency, (2) high efficiency that DID receive a program incentive, and (3) high efficiency that DID NOT receive a program incentive. Based on these responses, the share of a trade ally's high efficiency installations/sales that received an incentive can be calculated as follows:

$$\textit{\% of TA's High Efficiency Equipment that Received Incentive} = \frac{\textit{\% High efficiency that DID receive a program incentive}}{\textit{\% High efficiency that DID receive a program incentive} + \textit{\% High efficiency that did NOT receive a program incentive}}$$

With this data, and the trade ally's savings from the program tracking database, the following equation is used to calculate the savings of high efficiency equipment that did not receive an incentive:

$$\textit{Savings of Non-Incented High Efficiency Equipment} = \left(\frac{\textit{Savings from Program Database}}{\textit{\% of TA's High Efficiency Equipment that Received Incentive}} - \textit{Savings from Program Database}\right) * \textit{Size Adjustment}$$

The last term in the above equation is a size adjustment that accounts for the possibility that savings from non-incented projects/measures might be different from incented ones. Information on the relative size of incented versus non-incented projects/measures is also collected in the survey.

Using this approach, spillover savings are considered to be equal to the savings of non-incented, high efficiency equipment/products, as calculated in the equation above. To compute the program spillover percentage for active trade allies, the following steps are used:

1. **Develop the spillover ratio for sampled trade allies** by summing their spillover savings and dividing this total by the program-tracked savings associated with the sampled trade allies.
2. **Develop spillover savings for the population of active trade allies** by applying the spillover ratio from Step 1 to all program savings associated with a trade ally (whether a survey respondent or not).
3. **Develop the overall spillover ratio for active trade allies** by dividing the trade ally spillover estimate from Step 2 by total program savings (whether associated with a trade ally or not).

#### 5.2.1.2 Midstream Programs

Similar to downstream programs, surveys can be used to ask active trade allies in midstream programs if the program influenced their sales of high-efficiency equipment to participating or nonparticipating customers and to quantify the program's impact on their high-efficiency sales. To assess if a sampled midstream trade ally created spillover, the following screening criteria are recommended (the order of these may be adjusted by the evaluator):

1. The percentage of the trade ally's sales that are high efficiency and/or the total volume of high efficiency sales increased since the trade ally became exposed to the program.
2. The trade ally sold at least some high efficiency equipment or products during the evaluation period that did not receive an incentive.
3. The trade ally's recommendation, marketing, or equipment/product stocking or placement was influential in the customers' choice of high efficiency equipment/product over standard efficiency equipment/product in instances where the equipment did not receive a program incentive.

Sampled trade allies who do not pass one of the above screening criteria do not qualify for spillover and may be skipped out of the rest of the spillover module.

To quantify spillover for each sampled midstream trade ally, the survey collects information on the percentage of the trade ally's total equipment sales (in terms of projects or measures) that was (1) standard efficiency, (2) high efficiency that DID receive a program incentive, and (3) high efficiency that DID NOT receive a program incentive. Based on these responses, the share of a trade ally's high efficiency sales that received an incentive can be calculated as follows:

$$\textit{\% of TA's High Efficiency Sales that Received Incentive} = \frac{\textit{\% High efficiency that DID receive a program incentive}}{\textit{\% High efficiency that DID receive a program incentive} + \textit{\% High efficiency that did NOT receive a program incentive}}$$

Through additional survey questions,[53] the evaluator should develop an attribution percentage, i.e., the proportion of non-incented high efficiency projects or measures that are attributable to the program. With this data, and the trade ally's savings from the program tracking database, the following equation is used to calculate the trade ally's spillover savings:

$$\textit{Spillover Savings} = \frac{\textit{Savings from Program Database}}{\textit{\% of TA's High Efficiency Sales that Received Incentive}} * \textit{Savings from Program Database} * \textit{Attribution \%} * \textit{Size Adjustment (if applicable)}$$

The last term in the above equation is a size adjustment that accounts for the possibility that savings from non-incented projects/measures might be different from incented ones. Information on the relative size of average energy savings of incented versus non-incented projects/measures is also collected in the survey if the evaluator expects a potential difference in relative size.

To compute the program spillover percentage for active midstream trade allies, the following steps are used:

1. **Develop the spillover ratio for sampled trade allies** by summing their spillover savings and dividing this total by the program-tracked savings associated with the sampled trade allies.
2. **Develop spillover savings for the population of active trade allies** by applying the spillover ratio from Step 1 to all program savings associated with a trade ally (whether a survey respondent or not).
3. **Develop the overall spillover ratio for active trade allies** by dividing the trade ally spillover estimate from Step 2 by total program savings (whether associated with a trade ally or not).

### 5.2.2 Spillover from Inactive Trade Allies

Inactive trade allies may create spillover if they are exposed to the program but do not directly facilitate program participation, i.e., they did not complete any projects through the program during the evaluation period. Rather, they promote and stock higher-efficiency equipment due to the influence of the program on the market.

Surveys can be used to ask inactive trade allies if the program influenced their sales of high-efficiency equipment to participating or nonparticipating customers and to quantify the program's impact on their high-efficiency sales. The general questions take the following form:

- Q.1: How many <measures> did you sell in <utility>'s service territory in <period>?
- Q.2: How many of them were <efficiency level> or higher?
- Q.3: Had the <program> not existed, how many <measures> of <efficiency level> or higher do you think you would have sold in <utility>'s service territory?

Evaluators should attempt to allow trade allies sufficient time to collect specific data (e.g., by sending information ahead of the interview or conducting additional follow-up; this might require providing incentives as inactive trade

---

[53] As some trade allies may find it difficult to directly quantify the program's attribution effect on non-program sales, the evaluator may need to use a series of questions to guide the trade ally to provide an estimate of the overall attribution. Questions may include asking about what factors influence sales of non-program efficient equipment/products and how the program influences individual factors to provide context for an overall attribution estimate.

allies tend to be hard-to-reach) and not rely on "guesses" to respond. Additional questions should be included to document how the program influenced sales of additional energy efficient measures and why these measures did not receive an incentive.

For programs that offer a number of different measures, the evaluator should select and ask about a small number of measures or measure groups that are most likely to generate spillover, e.g., the program's highest impact measures. The selection of trade allies to include in this research will depend on the measures selected, e.g., if the highest impact measures are lighting measures, the population of trade allies from which to sample should be lighting contractors.

The following steps are used to calculate the spillover percentage for inactive trade allies:

1. **Develop the total number of spillover units for each trade ally** by computing the difference between the total reported number of high-efficiency units sold and the number that would have been sold in the program's absence, for each measure type.
2. **Develop the total spillover savings for each trade ally** by multiplying the trade ally's total number of spillover units (from Step 1) by the average gross unit savings, for each measure type.
3. **Compute the total spillover savings for the program period** by summing the spillover savings from all sampled trade allies (from Step 2) and multiplying this sum by the ratio of the population of inactive trade allies to the sample, for each end-use.
4. **Compute the program spillover percentage** by summing the spillover savings for all end-uses (from Step 3) and dividing this sum by program gross savings.

It should be noted that the methodology for inactive trade allies requires the evaluator to quantify the number of trade allies in the population. Depending on which types of inactive trade allies are targeted by the research, determining the size of the population may be challenging and may lead to uncertainty in the results. When targeting trade allies that are on the utility's trade ally list (but are not active) or those who have been active in the past but have dropped out, program records allow for accurate estimation of the population size. However, when targeting trade allies that have never been active in the program and were never on the utility's trade ally list, secondary market data is required to develop estimates of population size. The evaluator should carefully document the target population for any inactive trade ally research, data sources used to quantify the population size, and any uncertainty associated with their estimates.

## 5.3 Consumption Data Analysis Protocol

This protocol refers to impact analyses that use consumption data from customer's monthly bills (commonly referred to as billing analysis) or AMI meter reads[54] to estimate program energy savings. This protocol discusses different consumption data methods and where they fall on the NTG spectrum with respect to participant spillover, nonparticipant spillover, and free ridership; this has implications for whether a NTGR needs to be applied after the consumption data analysis estimate is obtained in order to achieve an estimate of net savings. Decisions of whether to apply a NTGR after conducting a consumption data analysis should be made by the evaluator on a case-by-case basis taking into account the guidelines of this protocol for when these methods are net, gross, or somewhere in between.[55] The remainder of this section discusses NTG for various consumption data analysis methods and then goes through some details of the various analysis methods.

In general, consumption data analysis methods split into two approaches. One approach is to use a comparison group in a randomized control treatment (RCT) design, a random encouragement design (RED) or a quasi-experimental design. These comparison group approaches can, under the right circumstances, be used to directly

---

[54] Benefits of using AMI data can include: having more observations per customer, which may improve model precision; obviating concerns over billing periods with differing numbers of days; and, for hourly models, providing the ability to observe intraday load shifting in addition to energy savings.

[55] For example, it is generally accepted that programs for income qualified customers have little to no free ridership as these customers are unlikely to install the measures without the incentive of the program. For specific guidance on income qualified programs see Section 4.

estimate net savings eliminating the need for a NTGR adjustment. A second approach is to estimate savings without a comparison group (for example, using a pre/post regression model for program participants). Approaches without a comparison group produce gross savings and must be adjusted by a NTGR to achieve net savings.

In consumption data analysis, energy consumption of the treatment and control groups can be appropriately compared through a regression analysis, using time-series observations on the usage of individual customers in the treatment and comparison groups during the pre- and post-treatment periods. Due to the combined time-series/cross-section structure of such data sets, panel regression techniques can be used.[56]

In general, consumption data analysis methods are best suited to the following situations:

1. When the expected net savings per participant (i.e., the effect size) are large or when large participant/nonparticipant sample sizes are possible.
2. When the program can be designed using a randomized controlled trial (see Section 5.3.2).
3. Programs where nonparticipant spillover is expected to be trivial within the comparison group.
4. Cases where self-selection bias can be effectively controlled for.

### 5.3.1 Consumption Data Analysis and NTG

Different consumption data analysis methods produce different savings estimates in terms of the NTG spectrum, as summarized in Table 5 – 3. These methods will always yield gross savings with respect to nonparticipant spillover and net savings with respect to participant spillover. However, the savings estimates may be net, gross, or somewhere in between with respect to free ridership, depending on the evaluation technique.

**Table 5-3. NTG Summary for Consumption Data Analysis**

| Consumption Data Analysis Method | Free Ridership | Participant Spillover* | Nonparticipant Spillover** |
|---|---|---|---|
| Randomized Controlled Trial (RCT) | ✓ | ✓ | § |
| Random Encouragement Design | | | |
| No Instrumental Variable (IV) | † | ✓ | § |
| IV | † | ✓ | § |
| IV w/ Inverse Mills Ratio (IMR) | †*** | ✓ | § |
| Quasi-Experimental Design (QED) **** | | | |
| Matching | | | |
| To Nonparticipants | †***** | ✓ | § |
| To Prior or Future Participants | § | ✓ | § |
| Regression Discontinuity (RD) | ✓ | ✓ | § |
| Variation-in-Adoption (VIA) | § | ✓ | § |
| Without a Comparison Group | § | ✓ | § |
| § Indicates not accounted for (gross)<br>✓ Indicates fully accounted for (net) | | | |

[56] "Panel" refers to the data set consisting of time-series observations on energy consumption of a cross-section of treatment and control customers. Panel estimation techniques refer to the model's inclusion of terms that control for individual customer heterogeneity (e.g., customer fixed effects or a lagged dependent variable), and cluster-robust standard errors, which can accommodate differing error variances across customers and an intracustomer correlation of errors.

† Indicates partially accounted for (between net and gross)
* Participant spillover within the analysis timeframe in the same building and fuel type is captured. Other sources of participant spillover may not be captured. See the subsection on participant spillover below for details.
** Nonparticipant spillover is not captured as a positive in consumption data analysis and may actually reduce the estimate of savings if it occurs within the comparison group. See the subsection on nonparticipant spillover below for details.
***This method has been tested in simulation but needs further use in practice.
**** Note that this is a non-exhaustive list of QED evaluation techniques.
***** As noted in first few paragraphs of Section 5.3, these comparison group approaches can, under the right circumstances, be used to produce an of estimate net savings, eliminating the need for a NTGR adjustment (see Goldberg et al., 2017).

When consumption data analysis methods are being used to update the TRM, the update should explicitly state how a NTGR should be applied to the given measure or program in the future. The language used should consider different program delivery mechanisms (which often have different NTG values) and how stable the NTG value is likely to be over time (thus allowing for consideration of how frequently it should be updated).

### 5.3.1 Nonparticipant Spillover

Nonparticipant spillover is never captured by consumption data analysis, making these savings estimates gross with respect to nonparticipant spillover (i.e., nonparticipant spillover is not accounted for by the estimate directly from the consumption data analysis without further adjustment). To the extent that nonparticipant spillover occurs in the comparison group being used for evaluation, the effect of the program may be underestimated as the difference between the participant group and the comparison group is decreased by the amount of nonparticipant spillover. If nonparticipant spillover is expected to be large (based on the best research available or given the program's logic model) and occur within the evaluation comparison group, that may be a reason to use other methods for evaluating savings. If a billing analysis is done in these cases, a traditional nonparticipant spillover analysis (using techniques like nonparticipant surveys or interviews) should be used to help quantify this effect (these analyses are discussed in various subsections of Chapter 4 of this protocol). Within the comparison group, it can also be difficult to distinguish the effects of nonparticipant spillover, free ridership, and market transformation as all of these effects increase uptake of a measure without going through the program among the nonparticipant group.

In cases where nonparticipant spillover is not expected to occur in the comparison group but may occur in the broader population (for example, if we go from a pilot evaluation where measures were restricted among the comparison group to a full program deployment), adjustments for nonparticipant spillover (or justification for why there is no nonparticipant spillover) should be made as appropriate on a program-by-program basis.

### 5.3.2 Participant Spillover

Participant spillover is captured by consumption data analysis, making these savings estimates net with respect to participant spillover (i.e., participant spillover is accounted for by the estimate directly from the consumption data analysis without further adjustment). This occurs because consumption data analysis measures all changes in participant usage (captured by the utility billing system or AMI meter reads) regardless of whether the changes are related to the program. A few caveats apply:

1. Consumption data analysis does not capture participant spillover that occurs outside the home or business being analyzed. For example, spillover at a participant's vacation home or spillover at other facilities owned by the same firm.
2. Consumption data analysis does not capture participant spillover that occurs in a different fuel type. For example, if the analysis is done on electric data but there is participant spillover into natural gas.
3. Consumption data analysis does not capture participant spillover that occurs outside the analysis period (typically a one-year period).

If these sources of participant spillover that are not captured are expected to be large (based on the best research available or given the program's logic model), adjustments or additional analysis to capture these types of participant spillover may be required.

### 5.3.3 Free Ridership

With respect to free ridership, consumption data analysis can produce savings estimates that are net, gross, or somewhere in between (i.e., free ridership can be fully, not at all, or partially accounted for by the estimate directly from the consumption data analysis without further adjustment). Where they fall depends on whether the comparison group accounts for (or nets outs) free ridership in the estimation. For a summary of where each method falls see Table 5-1, above.

Methods that yield gross savings estimates with respect to free ridership have no comparison group or have a comparison group that is made up of other (prior or future) participants. In these cases, a free ridership adjustment (or justification of why there is no free ridership) is necessary. These methods include:

- Matching to older or newer participants[57]
- Variation-in-adoption (VIA)[58]
- Any method without a comparison group

Methods that yield net savings estimates with respect to free ridership have a nonparticipant comparison group that has the same level of free ridership as the participants. In these cases, the comparison group is engaging in energy efficiency activities at the same rate as the participant group would have without the program. This nets out the free ridership and means no free ridership adjustment is necessary. These methods include:

- Randomized controlled trial (RCT)
- Regression discontinuity (RD)
- Random encouragement design (RED) under at least one of the following conditions:
    - Analysis is done using instrumental variables with an inverse mills ratio[59]
    - Designs where only the encouraged group can join the program (and as such the participants who join the program include only compliers and not always takers[60])
    - There is no relationship between how much energy a customer will save by participating and their inclination to participate

Methods where there is a nonparticipant comparison group that is expected to have a different level of naturally occurring adoption than the participant group can result in savings estimates that fall somewhere between net and gross with respect to free ridership. For example, a group of participants would be expected to be comprised of more natural adopters than a group of nonparticipants who never joined the program. These methods include:

- RED (in situations not covered by the previous list showing when RED is net)
- Matching to nonparticipants

In these cases, it is up to the evaluator to decide whether an estimate is most appropriately considered net or gross on an analysis-by-analysis basis. Some guidelines include:

- Measures where instant upstream rebates exist for a large portion of the market are likely gross as there should be very few customers who got the measure in the nonparticipant group
- Measures for income qualified customers are typically considered net as these customers are unlikely to

[57] Except in the case of income qualified programs where the use of future participants can produce an estimate of net savings. For specific guidance on income qualified programs see Section 4.

[58] See Harding and Hsiaw (2013). This is a distinct method from the UMP Chapter 8 (Agnew and Goldberg, 2017) pooled fixed effects approach which can be estimated with multiple years of participants. VIA hinges on rolling enrollment and in essence uses each participant as a control and a treatment customer through time. The Chapter 8 pooled fixed effects approach uses participants from an earlier time period as a comparison group for participants from a later time period.

[59] For details see: Goldberg, M.; Agnew, K.; Train, K.; Fowlie, M. (2017). *Mitigating Self-Selection Bias in Billing Analysis for Impact Evaluation.* Pacific Gas and Electric Company. CALMAC Study ID PGE0401.01. <http://www.calmac.org/publications/Mitigating_Self_Selection_Bias_in_Bill_Analysis_8.4.17.pdf>

[60] See Section 5.3.2.

install the measures without the incentive of the program

In some cases, evaluators may be able to implement techniques when using a nonparticipant comparison group such that the savings are sufficiently close to net and do not require further net to gross adjustment. One example of these techniques is the IV-IMR method proposed in Goldberg et. al. (2017). The UMP Chapter 21 (Violette and Rathbun, 2017) also has some discussion of getting net savings estimates using these approaches, although UMP Chapter 8 (Agnew and Goldberg 2017) should be reviewed in conjunction as it is more specific to consumption data methods. However, these techniques often require customer characteristic data that is not readily available to evaluators and some of them needed to be further tested beyond theoretical simulations.

### 5.3.4 Consumption Data Analysis Designs with a Comparison Group

This section discusses descriptions of and considerations for estimating savings via consumption data analysis designs with a comparison group. Although the ideas of net and gross savings are touched upon, the full discussion on whether each of these methods produce net or gross savings and under what circumstances is in Section 5.3.1.

### 5.3.5 Randomized Controlled Trials

In a randomized controlled trial (RCT) design, evaluators (and sometimes implementation contractors) randomly assign sampled members of a population of interest to a treatment group or a control group. Among the benefits offered by an RCT—when properly applied—is that it produces net savings estimates by netting out free ridership.[61] The evaluation of a program must be designed and implemented this way from the outset; it is not possible for an evaluation team to apply RCT evaluation techniques after the program has been implemented if random assignment to treatment and control groups was not done before program launch. While such designs are rarely possible outside of Home Energy Report programs, one should not overlook the possibility of such designs in evaluating new pilot programs.

For some programs, evaluators must take a second step to ensure savings are not being double-counted, either counting savings being claimed by other programs or savings already credited to earlier program efforts (often called "legacy uplift"). Only net increases in participation in other programs should be considered in this uplift adjustment; changes to total savings do not need to be made based on decreases in participation in other programs.

### 5.3.6 Random Encouragement Designs

In a random encouragement design (RED), eligible customers are randomly assigned between an encouraged group (who receives incremental encouragement to join the program[62]) and a non-encouraged, or control, group (who does not receive the encouragement). Members of either group can join the program, but the encouraged group is expected to do so at a higher rate.[63] If the encouragement is not effective at driving the encouraged group into the program at a higher rate than the non-encouraged group then the evaluation design breaks down and other (likely quasi-experimental) methods will be needed to estimate program savings.

In an RED, both the encouraged and non-encouraged group are made up of the following:

1. Always takers – customers who will join the program with or without the encouragement
2. Compliers – customers who only join the program if they receive the encouragement
3. Never takers – customers who will never join the program, regardless of whether they receive the

[61] RCTs eliminate free rider bias because the random assignment of customers to treatment and control groups equally distributes such participants between the two. Due to differential attrition and random chance, small differences may occur between the distributions of free riders in the two groups for any given sample. Their expected values, however, will be identical, and in any case the size of any such discrepancies shrinks as sample size increases. Thus, this is only a potential concern for programs with unusually small numbers of participants.) Upon comparing the two groups' energy consumption, free riders' energy savings in the control group cancel out those in the treatment group, eliminating free rider bias.

[62] The encouragement could take many forms including targeted marketing or direct monetary incentives.

[63] This design does not preclude mass marketing of the program to all customers but relies on the encouragement being effective at driving the encouraged customers into the program at a higher rate than the non-encouraged customers.

encouragement

In the non-encouraged group, the always takers can be distinguished from the compliers and never takers (they're the portion of the non-encouraged group who joins the program), but the compliers and never takers cannot be distinguished from one another (they're both observed not to join the program). In the encouraged group, the never takers can be distinguished from the always takers and compliers (they're the portion of the encouraged group who does not join the program), but the always takers and compliers cannot be distinguished from one another (they're both observed to join the program).

Like RCTs, REDs are a form of experimental design. An RED is known to give an unbiased estimate of net savings (with respect to free ridership) for the compliers. Applying this savings to the always takers group requires some explanation of why it is likely to be accurate. Additionally, the RED design provides the average net savings per participant for those who participate because of the encouragement but otherwise would not (compliers). This is not necessarily the same as the net savings for the original program without extra encouragement. In particular, we would expect free-ridership to be lower among those who need extra encouragement. Thus, the RED might be expected to overstate net savings for the original program if free-ridership is present but would still provide useful information.

There are several methods for evaluating REDs using panel data including methods using instrumental variables (IVs) and the inverse mills ratio (IMR).[64]

### 5.3.7 Quasi-Experimental Designs

Where randomized assignments prove infeasible, quasi-experimental design (QED) evaluation methods can be substituted (although experimental designs are typically preferable when possible). Depending on the exact QED implemented, the savings may be net, gross, or somewhere in between with respect to the different pieces of a NTG adjustment (participant spillover, nonparticipant spillover, and free ridership). The specifics of net versus gross estimation are covered in Section 5.3.1, this subsection does not rehash this issue but rather describes estimation for a subset of QED methods.

Three quasi-experimental approaches are commonly used to evaluate behavior-based energy efficiency programs that cannot be constructed as experiments:[65]

- Regression discontinuity (RD)
- Variation-in-adoption (VIA)[66]
- Matched controls (MC)

All three rely on a nonrandom comparison group.

**Regression Discontinuity.** RD requires basing a program's eligibility on a continuous variable (e.g., customers'

[64] See, for example:

Goldberg, M.; Agnew, K.; Train, K.; Fowlie, M. (2017). *Mitigating Self-Selection Bias in Billing Analysis for Impact Evaluation.* Pacific Gas and Electric Company. CALMAC Study ID PGE0401.01. <http://www.calmac.org/publications/Mitigating_Self_Selection_Bias_in_Bill_Analysis_8.4.17.pdf>

Fowlie, M.; Greenstone, M.; Wolfram, C. (2015). *Are the Non-Monetary Costs of Energy Efficiency Investments Large? Understanding Low Take-up of a Free Energy Efficiency Program*. American Economic Review: Papers and Proceedings 105(5): 201-204. < https://www.povertyactionlab.org/sites/default/files/publications/389_500%20Weatherization%20AER.pdf>

[65] There are many other types of QEDs that may be appropriate for evaluation but these are some of the most commonly used for evaluation in IL.

[66] See Harding and Hsiaw (2013). This is a distinct method from the UMP Chapter 8 (Agnew and Goldberg, 2017) pooled fixed effects approach which can be estimated with multiple years of participants. VIA hinges on rolling enrollment and in essence uses each participant as a control and a treatment customer through time. The Chapter 8 pooled fixed effects approach using participants from an earlier time period as a comparison group for participants from a later time period. The Chapter 8 pooled fixed effects method is discussed in Section 5.3.3.

adjusted gross income falling below a cutoff value for them to qualify for the program). When this is true, the RD method assumes customers just beyond the cutoff likely will be very similar, on average, to those just inside of it. The method compares changes in energy usage for a group just outside of the eligible range to that of a group of participants just on the other side of the eligibility cutoff. The RD approach, however, is susceptible to an important weakness: misspecification of the regression functional form.[67]

**Variation-in-Adoption.** The VIA model applies only to program participants.[68] For this method, customers must sign up for the program on a rolling basis. VIA takes advantage of its enrollees' differential timing to compare energy usage of customers opting in to that of customers not yet opting in (but doing so later). The method relies on an assumption that, in any given month, customers that soon opt in have similar characteristics to those who have enrolled, both in observable and unobservable characteristics. For this assumption to prove valid, customers must decide to opt into the program at different times for essentially random reasons (e.g., influenced only by marketing exposure and program awareness).[69] In particular, the decision to opt in should not relate to observable or unobservable household characteristics.[70]

**Matched Controls.** MC creates a control group by matching each treatment customer to the most similar nonparticipant customer available on the basis of exogenous covariates from the pre-enrollment period known to highly correlate with post-enrollment usage.[71] The covariate most likely to correlate with post-enrollment energy usage in a given time period is customer energy usage during the same period of the preceding year, but other observable factors may be used when available. Implementing MC requires customer usage data for the year preceding all opt-in customers' decisions to participate in the program, along with a large group of nonparticipants who can be assumed to be similar to opt-in customers, aside from their program participation status. Whenever possible, the pool of potential matches should be drawn from the same geography, customer class, and rate category as the participants.

Another option is to pull the nonparticipants from a group of prior or future participants in the program (sometimes referred to as the cohort design[72]). These groups are similar to current participants since we know that they also join the program at an earlier or future date, significantly mitigating the issue of self-selection bias (wherein, customers who join the program are different from those who do not in unobservable ways).[73] However, using this design can significantly decrease the number of participants for analysis and the size of the potential matching group. It can also require the evaluator to delay the analysis if more recent participants are being used as the comparison group.[74]

---

[67] The most common misspecifications are: mistaking a nonlinear relationship for a discontinuity; and failing to recognize potential interactions between assignments and the treatment studied. See W.R. Shadish, T.D. Cook and D.T. Campbell, *Experimental and Quasi-Experimental Designs for Generalized Causal Inference*, Wadsworth 2002, pp. 229-238.

[68] Harding, M. and Hsiaw, A. 2013. *Goal Setting and Energy Conservation* Available at: http://people.duke.edu/~mch55/resources/Harding_Goals.pdf.

[69] This differs from an RCT with a recruit-and-delay design, in which customers do not choose when to opt in, but instead are randomly assigned different times to opt in, and from an RCT with a recruit-and-deny design, where customers are randomly denied access to the program.

[70] As the validity of the VIA method depends on this assumption, it should be empirically tested to the extent possible. If program marketing is punctuated and dates of marketing exposure are known, it is possible to test whether household enrollment in any particular month is driven by marketing activity, as opposed to observed household characteristics or unobserved heterogeneity. A test of whether the energy usage of households before they opt in differs from households that opt in during any particular month as opposed to another month is built into the VIA regression model's functional form. See Harding and Hsiaw, op. cit., for details.

[71] See Daniel E. Ho, Kosuke Imai, Gary King, and Elizabeth Stuart, 2007, "Matching as Nonparametric Preprocessing for Reducing Model Dependence in Parametric Causal Inference." *Political Analysis* 15(3): 199-236.

[72] See W.R. Shadish, T.D. Cook and D.T. Campbell. (202). *Experimental and Quasi-Experimental Designs for Generalized Causal Inference*. New York: Houghton Mifflin Company, pp. 148-153

[73] Though there could still be a selection issue based on when customers choose to join the program. As with VIA, the assumption is that the timing of participation is basically random.

[74] The cohort design has also been used, under certain conditions, to control for exogenous factors when estimating gross

The MC method involves identifying a nonparticipant customer whose energy usage closely matches that of a program participant in the months preceding the participant's enrollment in the program. The logic inherent in this approach is: if the analyst finds a set of nonparticipants who, on average, are the same as participants regarding energy consumption before program enrollment, these matches will provide a good counterfactual estimate of how much energy participants would have used in the program's absence.

The MC approach does present a main weakness: it can only identify matches based on observable customer characteristics, which leaves open the exclusion of the possible influence of relevant unobservable variables. While factors other than pre-enrollment energy usage plausibly could be used (e.g., household income, demographics, geographic location) in the matching process to address relevant unobservable characteristics (e.g., attitudes toward energy conservation and environmental concerns), this assumption cannot be directly tested.[75]

There is a special case of MC called propensity-score matching. This develops a binary choice (logistic regression) model to predict the probability that a customer will opt into the program, and then, for a comparison group. The logistic regression reduces each household's set of covariates to a single propensity score. Nonparticipants are then matched to participants based on their propensity scores. This functions well if observable variables used to calculate the propensity score sufficiently correlate with relevant unobservable variables to explain differences between treatment and control customers that cannot be explained by matching on observable variables. With most evaluations of energy efficiency programs, however, little (if any) data are available on nonparticipating customers other than their energy usage. In some cases, the demographic data necessary to estimate these models can be obtained from providers such as Experian and assigned to each participant and nonparticipant.

**Self-Selection Bias and QED.** Self-selection bias due to observable and unobservable variables is always a possibility with QEDs. One can collect as much information as possible on both participants and members of the comparison group and include them as covariates in the regression model, but there may still be self-selection bias related to unobservable variables. Several techniques have been developed to help mitigate it. Efforts to address the biasing effects of *unobserved* differences using Inverse Mills Ratios began at least as early as the late 1980s. Since then, Train (1993) and Goldberg and Train (1995), using simulated datasets, demonstrated that failing to correct for self-selection can overestimate net savings, but that there are effective strategies to reduce this bias substantially.

One approach is to calculate and enter the propensity score, based on observable variables, as an additional covariate into the regression model. Of course, the most difficult issue to address is the differences between participants and nonparticipants that are unobserved and unobservable. To mitigate both overt and hidden bias, a variety of approaches that attempt to take advantage of recent developments in statistics and econometrics are available:

- Sample selection models (e.g., Heckman's two-step estimator (1978, 1979); treatment effect model (Green, 2003); instrumental variables estimator (Wooldridge, 2002)
- The propensity score matching model (Rosenbaum and Rubin, 1983, 1985; Hansen and Klopfer, 2006; Guo and Fraser, 2014)[76]
- Matching estimators and synthetic controls (Abadie and Imbens, 2002, 2006)
- Instrumental variables approach with the predicted probability of participation serving as the instrumental variable and the inclusion of an Inverse Mills Ratio (IMR) (Goldberg et al., 2017)

Another issue that should be considered is that, when using a comparison group in a QED, the composition of the

savings. See Agnew, K. and M. Goldberg. (2017). Whole Building Retrofit with Consumption Data Analysis Evaluation Protocol: Chapter 8 of the Uniform Methods Project, National Renewable Energy Laboratory.

[75] Such secondary, observable characteristics are rarely available to evaluators of energy efficiency programs, except for geographic location (e.g., postal zone of customer premise).

[76] Note that propensity scores cannot remove hidden biases except to the extent that unmeasured variables are correlated with the measured covariates used to compute the propensity score

comparison group needs to be carefully considered.[77,78] For example, simply selecting a random sample of nonparticipants from the general nonparticipant population could result in an estimate of savings that is somewhere between net and gross, thus overestimating net savings. For a single-measure residential program like an air conditioner (AC) replacement program, the eligible population is the population of customers who have purchased a new air conditioner. That is, part of the eligible population appropriate to a net effects comparison group would be those who purchased and installed some air conditioner, whether efficient or not. Simply selecting from the general residential population would include households with no air conditioner, those with older ACs of varying vintages, those with new standard efficient ACs and those with new program-qualified ACs. The results would be virtually uninterpretable. Of course, for more complex multi-measure programs, finding the appropriate comparison group is far more challenging.

### 5.3.8 Consumption Data Analysis Designs without a Comparison Group

Although less common, consumption data methods can also be used to estimate savings without the use of a comparison group. These methods typically estimate gross savings, and net savings are found by multiplying gross savings by a separately estimated NTGR. There are basically two types of pre/post models to estimate gross savings:

- the pooled participant-only linear fixed-effects approach
- site-specific regression models

In both modeling approaches, exogenous factors must be controlled for.[79]

**Pooled Approach.** The pooled approach addresses exogenous change without the inclusion of a separate comparison group. In this model, participants who received a measure installation during a certain time interval serve as a steady-state comparison for other participants in each other time interval. Almost all observation points include premises that are still in their pre-installation period and premises that are in their post-installation period, so the effect of post- versus pre- is estimated to control for exogenous trends. Note that if changes at the site that affect energy use are not or cannot be explicitly modelled the estimated gross savings will be biased. This method is typically used in analysis of residential and small (and occasionally for large) commercial programs.

**Site Specific Regression Models.** This approach involves the estimation of site-specific regression models to estimate savings. This method is often used for large commercial and industrial customers or in other situations where it is difficult to identify an adequate comparison group (for example, in evaluation of Strategic Energy Management programs). In these cases, single customer regressions are typically run as a time series without a cross-section of customers.

Note that both the pooled approach and the site-specific approach and the conditions that must be met before using them are discussed in Agnew and Goldberg (2017).

### 5.3.9 Program Implementation and Consumption Data Analysis

The approach the evaluation can use to estimate net savings is greatly dependent on the design of the program and the size of the expected savings (i.e., the signal-to-noise ratio).

**RCT and RED**: These designs must be integral to a program's implementation. Without the ability to randomly assign customers to the control and treatment groups (or at least randomly encourage customers to participate in a program), the ability of the design to yield unambiguous estimates of net impacts is compromised. Evaluators often help design how a program is implemented. However, if they not involved at the outset, they cannot carefully review choices made by the implementation team. RCT and RED designs are difficult to perform well within the commercial and industrial sectors due to a low signal-to-noise ratio. One solution for these two sectors is to increase the sample size but this is not always feasible.

---

[77] See Agnew at al., Section 8.1.3 (The Importance of Measures Applicability)

[78] Katherine Randazzo, Richard Ridge and Seth Wayland. Evaluating Whole-Building Programs: It is harder and easier than you think! Presented at the International Energy Program Evaluation Conference in August 2017.

[79] Exogenous factors include non-program-related effects due to the economy and other factors affecting energy consumption.

**QED**: A QED may be designed after a program has been implemented. It relies on determination of an equivalent comparison group, which is often chosen based on energy use and other variables, if available. QED is also difficult to perform well within the commercial and industrial sectors due to a low signal-to-noise ratio. One solution for these two sectors is to increase the sample size but this is not always feasible.[80]

**Methods without a Comparison Group**: These methods can also be implemented by the evaluator after the program has been designed. They are most appropriate in situations where it is difficult to construct an appropriate comparison group.

For any kind of evaluation design, evaluators may also analyze the data to help understand the savings within specific segments if sufficient information and data points are available.

**References**


- Abadie, Imbens, 2002, 2006
- Agnew, Goldberg, 2017
- Donaldson, 2009
- Fowlie, Greenstone, Wolfram, 2015
- Goldberg, Agnew, Train, Fowlie, 2017
- Goldberg, Train, 1995
- Green, 2003
- Guo, Fraser, 2014
- Hansen, Klopfer, 2006
- Harding, Hsiaw, 2013
- Heckman, 1978, 1979
- Ho, Imai, King, Stuart, 2007
- Mohr, 1995
- Shadish, Cook, Campbell, 2002
- Scriven, 2008
- Randazzo, Ridge, Wayland, 2017
- Rosenbaum, Rubin, 1983, 1985
- Train, 1993
- Wooldridge, 2002


## 5.4 Code Compliance Protocol

The protocol represents a basic framework for estimating the NTGR that may be refined based on impact evaluation results. The NTGR is used to convert an estimate of gross savings into an estimate of net savings. Two general methods can be used to estimate gross energy impacts: (1) utility billing data analysis; and (2) building energy modeling.[81] The specific method used depends on the availability of necessary data.

### 5.4.1 Data Collection

#### 5.4.1.1 Program Documentation

To inform the NTGR estimate, the evaluator documents program delivery. Information collected includes the

[80] A power analysis can be undertaken before the actual analysis to determine whether the sample size available is likely to be large enough to produce statistically significant savings at the desired confidence level.

[81] The modeled energy savings approach is similar to the approach described by Department of Commerce in Exhibits 6.1 and 6.2 from excerpts of Docket 13-0499 through estimation of potential energy savings.

following: the number, location, and dates of training workshops; the topics covered; materials disseminated; the number of trainees in each workshop and the type of trainee; and the hours of instruction.

#### 5.4.1.2 Stakeholder Interviews

To inform the NTGR estimate, the evaluator conducts interviews with key stakeholders involved in the program. Interviews should include training program managers, instructors, and trainees. Trainees typically include contractors, builders, consultants, code officials, and others involved in building design and construction. The interviews seek to gather information on how training affected building design, construction, new code compliance, and enforcement.

### 5.4.2 Attribution Assessment

The NTGR estimation method stays the same, regardless of the method used to estimate gross energy savings.

A Delphi panel[82] produces an NTGR estimate that reflects the share of gross energy savings resulting from increased code compliance attributable to the program. Formed by selecting four to six knowledgeable professionals not associated with the program in any way,[83] the panel receives estimates of gross energy savings, building construction data, and evidence of attribution—including the results of stakeholder interviews and program documentation. Panel members individually review the information and provide feedback regarding their NTGR estimates and rationales. Responses are compiled, with combined, anonymous responses circulated to all panel members. Panelists review this information, revise their initial estimates and rationales, as they deem appropriate, and provide new estimates and rationales. Evaluators review the second set of estimates and rationales to develop a final attribution estimate, accompanied with a summary of supporting rationales. This NTGR estimate, used in combination with the gross energy savings estimate and building construction data, produces a final estimate of net energy savings attributable to the program.

[82] The Delphi panel should be conducted according to best practices. For example, see: Day J and Bobeva M (2005) "A Generic Toolkit for the Successful Management of Delphi Studies" *The Electronic Journal of Business Research Methodology* Volume 3 Issue 2, pp. 103-116, available online at [www.ejbrm.com](http://www.ejbrm.com).

[83] Delphi panelists should have no biases that would affect their assessment of the program's effectiveness. Selected individuals should be knowledgeable about building codes and all factors that could conceivably affect code compliance.

# 6 Appendix A: Overview of NTG Methods

The evaluation teams present information in this appendix to provide a relatively quick overview of NTG methods for readers unaccustomed to the possible methods that evaluators may deploy. It is not meant to be a complete or deep discussion about each of the methods presented. However, the evaluators in Illinois considered the inclusion of this appendix to be very important in acknowledging the current suite of methods deployed by evaluators throughout the U.S. and giving a framework for work within Illinois.

Much of the information shown below is taken directly from a single source—the national Uniform Methods Project, Chapter 23: Estimating Net Savings: Common Practices. (Violette and Rathbun, 2014) This document has done a nice job of summarizing the eight most common attribution methods currently in use across the U.S. The evaluation teams recommend that readers go first to this reference for further information. Additionally, while there are slightly over 100 references within the Violette and Rathbun document, other non-duplicative references are included where reasonable as additional resources for those interested in further research into any specific method.

## 6.3 Survey-Based Approaches

Virtually all Illinois based evaluations use a survey-based approach for programs where primary data is used to determine net savings. (The main exception is for behavioral programs which use statistical analysis based on a randomized control trial program design.) Survey-based approaches obtain data from program participants and nonparticipants using a structured data collection instrument implemented via phone, in person, or online.[84] At times, evaluators create and use an unstructured depth-interview guide to collect information about attribution, and this provides both contextual data and quantitative data about a given project.

### 6.3.1 Self-Report Approach

The self-report approach relies on the abilities of customers to discuss the program influence as well as the somewhat abstract ideas of the counterfactual (i.e., what would have occurred absent the program) after making a choice to purchase an energy efficient item or take an energy efficient action unrelated to a purchase. For program participants, this could include doing nothing (i.e., leaving the existing equipment as-is), installing the same energy efficient equipment as they did through the program, or an intermediate step of installing equipment that is more efficient than what they had in place previously, but less efficient than what they installed through the program. Evaluators also use this approach when collecting information from trade allies or distributors. This self-report approach is not new, nor is it exclusively used by the energy efficiency industry. An important attribute of this approach is its reliance on well-designed and fielded survey questions; so that the data underlying subsequent analyses are accurate and complete.

The output of this approach is a NTG ratio which can be considered an index of the program's influence on the decision to install energy-efficient equipment. The NTG ratio is applied to gross savings in order to obtain an estimate of net savings. The NTG ratio may include free ridership, spillover, or market effects, depending on the survey and analytical design. NTG ratios may be calculated at the measure, suite of measures, or program level and are typically average values weighted by savings. If sufficient information is available, analysis of NTG ratios among certain customer segments may be done to further inform changes to program design.

**References**

- Sudman, 1996
- Stone, et al., 2000
- Bradburn, et al., 2004

[84] Historically, evaluators in Illinois have collected the majority of primary data via telephone surveys. As evaluations increasingly leverage online surveys to collect information relevant to attribution, careful attention should be paid to mode effects that are due to interviewer-administered versus self-administered surveys (e.g., scale direction effects). It is recommended that evaluators, where possible, assess the differences between telephone and online survey methods for the purposes of future updates to these protocols.

### 6.3.2 Econometric/Revealed Preference Approach

The econometric/revealed preference approach, while still considered a survey approach due to how data is collected, moves beyond asking people about the counterfactual and instead uses the observations of the evaluator to collect information for analysis of a NTG ratio. Within this approach, evaluators typically deploy similar sampling designs as for the self-report approach to collect data, but actively gather what a person is doing (i.e., what is being purchased in a store) to determine attribution.

## 6.4 NTG with Consumption Data Analysis

As mentioned in Section 5.3, evaluators use randomized control trials (RCTs), random encouragement designs (REDs), and quasi-experimental designs (QEDs) using consumption data (like monthly bills or AMI meter reads) to estimate savings for a variety of programs. RCTs estimate net savings by design but other consumption data analysis methods may be net, gross, or somewhere in between. In some cases, evaluators may be able to use methods that produce estimates that are acceptably close to net without further adjustment, while in other cases a NTGR may need to be developed outside the consumption data analysis and then multiplied by the estimate to produce net savings. Therefore, the NTG adjustment method will differ and needs to be justified by the evaluator on a case by case basis.

## 6.5 Deemed or Stipulated NTG Ratios

A deemed (or stipulated) NTG ratio is a value known prior to implementing a program and applied to estimate net savings for that program in a certain year.

Deemed or stipulated NTG ratios may be based on previous primary data collection, a review of secondary data, or agreed to among stakeholders. In Illinois, deemed or stipulated NTG ratios should reflect best estimates of likely future actual NTG ratios for the relevant program year, taking into consideration stakeholder input, the evaluator's expertise, and the best and most up-to-date information.

## 6.6 Common Practice Baseline Approaches

For this method, the evaluation team estimates what a typical consumer would have done at the time of the project implementation. Essentially, what is "commonly done" becomes the basis for baseline energy consumption and calculation of net savings. No gross impacts are calculated in this approach. This baseline is defined as the counterfactual "i.e., what would have occurred absent the program" and has been referred to as current practice, common practice, or industry standard practice. Evaluators determine these practices through multiple methods, but often can be from self-report or on-site audits. The difference between the energy use of measures installed in the program and the energy use associated with current practice is considered by some to be sufficiently close to the net savings.

This approach is not in use in Illinois, but it is used elsewhere in the country, such as the Pacific Northwest and Delaware.

## 6.7 Market Analyses

Market analyses can be done in several ways. Market analyses are often used in theory-driven evaluations of market transformation programs.

Other non-sales data market analyses can be postulated on changes specified in program logic such as: 1) changes in the number of energy-efficient units manufactured; 2) changes in market actor behavior around promotion or stocking of energy-efficient items; or 3) reductions in prices. The analyses involving non-sales data must make a clear link between the program intervention and the changes found in the market. Additionally, outside of Illinois, while evaluators have extrapolated the market changes to specific energy or demand reductions, this activity may be viewed as tenuous due to assumptions that evaluators must make within the analysis.

Illinois is in a position to begin to discuss market analyses and how specific research may be able to interpret changes that have occurred (or may occur in the future) because of the program interventions over the past eight years.

Market analyses can be backward looking through historical tracing, but it is best used when the logic of an intervention is described and specific market metrics are tracked over time.

## 6.8 Structured Expert Judgment Approaches

Closely tied to market analysis, this approach is a way for evaluators to gather credible evidence of changes that arise due to the intervention of a program. When deployed, it is often used as a cost-effective approach to estimate market effects or reach agreement on a NTG value when several different types of evidence are available. The key premise of this approach is the use of a select group of known experts that all stakeholders agree can provide unbiased information as well as having sufficient knowledge to judge what may have occurred absent a program intervention.

A Delphi Panel is an example of this approach where data are collected from two or more rounds of data collection (which can occur via e-mail, Internet, or in person). A round is when experts make their thoughts known about a specific subject; the evaluation team synthesizes the data and provides this collated data back to the group to discuss again. Allowing the full experts to see how their peers think about a topic helps to move the group towards consensus.

**References**

- Mosenthal, et al., 2000
- Powell, 2002

## 6.9 Program Theory-Driven Approach

This approach is not included in the Violette and Rathbun (2014) document as a high-level method, but it is discussed by the authors under the historical tracing method. The Illinois evaluators believe that it deserves at least a short discussion within this framework.

A program theory is the written narrative about why the activities of a program are expected to bring about change. Typically associated with this approach is the direct graphical explication of the linkages between activities, outputs, and outcomes through an impact logic model.[85]

A theory-driven evaluation denotes "[A]ny evaluation strategy or approach that explicitly integrates and uses stakeholder, social science, some combination of, or other types of theories in conceptualizing, designing, conducting, interpreting, and applying an evaluation." (Coryn 2011) Within this approach, the ultimate conclusions regarding the efficacy of a program are based on the preponderance of the evidence and not on the results of any single analysis. Coryn and colleagues systematically examined 45 cases of theory-driven evaluations published over a 20-year period to ascertain how closely theory-driven evaluation practices comport with the key tenants of theory-driven evaluation as described and prescribed by prominent theoretical writers. One output from this analysis was the identification of the core principles and sub-principles of theory-driven evaluation. If interested, please review the reference under Coryn 2011.

As an approach, it is best used for complex programs and/or causal mechanisms that extend far into the future. Evaluators collect evidence that supports or rejects hypotheses that are explicit in the logic model. The case for program attribution is strengthened based on the extent to which an evaluation shows that the expected changes occur. Additionally, the evaluation team may be able to collect data that will answer questions about the longer-term outcomes of a program. This type of data collection may be very similar to market tracking activities described briefly above under Market Analyses.

This approach does not specifically estimate a NTG value, but Program Administrators can choose to keep, drop, or change a program based on intermediary data. Regulators must be convinced that the logic of a program is sound and that the intermediary outcomes are causally linked to expected savings.

[85] Evaluators may use logic models to show program processes as well, but this is a program flow chart, not an impact model.

**References**

- Weiss, 1997
- Chen, 2000
- Coryn, 2011

## 6.10 Case Studies Design

Case studies are used extensively in social sciences as well as many other disciplines or practice-oriented areas, such as political science, economics, education, and public policy. Case studies help to understand the how and why of a situation and typically retain a holistic aspect of real-life events. As such, they may be a useful approach to determine attribution. As with program theory design, though, the data collected and analyzed within a case study approach will not typically yield a specific NTG value, but can provide credible evidence and insight that supports or refutes the changes brought about by program intervention.

To be used to assess attribution, evaluators must carefully design case studies to assure they account for the threats to causality (i.e., internal validity) that arise in any design. While not typically thought of in this manner, case study design can address multiple types of validity such as construct, internal, and external validity as well as assuring reliability. When establishing construct validity and reliability, evaluators must use multiple sources of evidence, create and maintain a study database, and maintain a “chain of evidence” within the analysis. Internal validity is shown through analytic tactics such as pattern matching, explanation building, addressing rival explanations, or using logic models. External validity centers on the ability to generalize the analytical findings to other similar situations. External validity may be shown through the replication of findings.

**References**

- Yin, 2003
- Stake, 2006

# 7 Appendix B: References

Abadie, A. and G. W. Imbens. (2002). Simple and bias-corrected matching estimators [Technical Report]. Department of Economics, University of California, Berkeley. Retrieved March 6, 2016, from http://ideas.repec.org/p/nbr/nberte/0283.html.

Abadie, A. and G. W. Imbens. (2006). Large sample properties of matching estimators for average treatment effects. Econometrica, 74, pp. 235-267.

Agnew, K. and M. Goldberg. (2017). Whole Building Retrofit with Consumption Data Analysis Evaluation Protocol: Chapter 8 of the Uniform Methods Project, National Renewable Energy Laboratory.

Bradburn, Norman, Sudman, Seymore, and Wansink, Brian. 2004. Asking Questions. The Definitive Guide to Questionnaire Design – For Market Research, Political Polls, and Social and Health Questionnaires. San Francisco, CA: Jossey-Bass.

Chen, Huey-Tsyh. 1990. Theory-Driven Evaluations. Sage Publications.

Coryn, Chris L.S., Norakes, Linday A., Westine, Carl D., Schröter, Daniela C. 2011. "A Systematic Review of Theory-Driven Evaluation Practice from 1990 to 2009." American Journal of Evaluation, 32(2): 199-226.

Donaldson, Steward I., Christie, Christina A., Mark, Melvin M. 2009. What Counts as Credible Evidence in Applied Research and Evaluation Practice? Los Angeles, CA: Sage Publications, Inc.

Fowlie, M.; Greenstone, M.; Wolfram, C. (2015). Are the Non-Monetary Costs of Energy Efficiency Investments Large? Understanding Low Take-up of a Free Energy Efficiency Program. American Economic Review: Papers and Proceedings 105(5): 201-204. <https://www.povertyactionlab.org/sites/default/files/publications/389_500%20Weatherization%20AER.pdf>

Greene, W. H. (2003) Econometric Analysis (5th Ed.). Upper Saddle River, N.J.: Prentice Hall.

Goldberg, M. L. And K. Train, (1995) Net Savings Estimation: An Analysis of Regression and Discrete Choice Approaches. Submitted by Xenergy Inc. To CADMAC Subcommittee on Base Efficiency.

Goldberg, M.; Agnew, K.; Train, K.; Fowlie, M. (2017). Mitigating Self-Selection Bias in Billing Analysis for Impact Evaluation. Pacific Gas and Electric Company. CALMAC Study ID PGE0401.01. <http://www.calmac.org/publications/Mitigating_Self_Selection_Bias_in_Bill_Analysis_8.4.17.pdf>

Gou, Shenyang and Mark W. Fraser, (2015). Propensity Score Analysis: Statistical Methods and Applications. Los Angeles, CA: SAGE Publications.

Hansen, B. B. and S. O. Klopfer. (2006). Optimal Full Matching and Related Designs via Network Flows. Journal of Computational and Graphical Statistics, 15, pp. 1-19.

Harding, M. and Hsiaw, A. 2013. Goal Setting and Energy Conservation Available at: http://people.duke.edu/~mch55/resources/Harding_Goals.pdf.

Heckman, J. J. (1979). Sample Selection Bias as a Specification Error. Econometrica, 47(1), pp. 153-162.

Heckman, J. J. (1978). Dummy Endogenous Variables in a Simultaneous equations system. Econometrica, 46(1), pp. 931-960.

Ho, D.E., Imai, K., King, G. and Stuart, E., 2007. "Matching as Nonparametric Preprocessing for Reducing Model Dependence in Parametric Causal Inference." Political Analysis 15(3): 199-236.

Mohr, Lawrence B. 1995. Impact Analysis for Program Evaluation, Second Edition. Thousand Oaks, CA: Sage Publications, Inc.

Mosenthal, Philip, Prahl, Ralph, Neme, Chris, and Cuomo, Robert. 2000. A Modified Delphi Approach to Predict Market Transformation Program Effects. Proceedings from the 2000 ACEEE Conference.

Powell, Catherine. 2002. "The Delphi Technique: Myths and Realities." Journal of Advanced Nursing. 41(4), 376-382.

Randazzo, K., Ridge, R. and Wayland, S. Evaluating Whole-Building Programs: It is harder and easier than you think! Presented at the International Energy Program Evaluation Conference in August, 2017.

Rosenbaum, P. R. and D. B. Rubin. (1983). The central role of the propensity score in observational studies for causal effects. Biometrika, 70, pp. 41-55. 21

Rosenbaum, P. R. and D. B. Rubin. (1985). Constructing a control group using multivariate matched sampling methods that incorporate the propensity score. American Statistician, 39, pp. 33-38.

Scriven, Michael. "A Summative Evaluation of RCT Methodology and an Alternative Approach to Causal Research." March 2008. Journal of MultiDisciplinary Evaluation, Volume 5, Number 9. ISSN 1556-8180.

Shadish, William R., Cook, Thomas D., and Campbell, Donald T. 2002. Experimental and Quasi-Experimental Designs for Generalized Causal Inference. Boston: Houghton Mifflin Company.

Stake, Robert E. 2006. Multiple Case Study Analysis. The Guilford Press.

Stone, Arthur A., Turkkan, Jaylan S., Bachrach, Christine A., Jobe, Jared B., Kurtzman, Howard S., Cain, Virginia S. editors. 2000. The Science of Self-Report. Implications for Research and Practice. Lawrence Erlbaum Associates, Inc.

Sudman, Seymour, Bradburn, Norman, Schwarz, Norbert. 1996. Thinking about Answers. The Application of Cognitive Processes to Survey Methodology. Jossey-Bass.

Train, Kenneth. (1993). Estimation of Net Impact from Energy Conservation Programs. Submitted to the Southern California Edison Company.

Violette, Daniel M.; Rathbun, Pamela. (2017). Chapter 21: Estimating Net Savings – Common Practices: Methods for Determining Energy-Efficiency Savings for Specific Measures. Golden, CO; National Renewable Energy Laboratory. NREL/SR-7A40-68578. http://www.nrel.gov/docs/fy17osti/68578.pdf

Weiss, Carol H. 1998. Evaluation Methods for Studying Programs and Policies, 2nd Edition. Upper Saddle River, New Jersey: Prentice Hall.

Wooldridge, J. M. (2002). Econometric Analysis of Cross Section and Panel Data. Cambridge: MIT Press.

Yin, Robert K. 2003. Case Study Research. Design and Methods. Thousand Oaks, CA: Sage Publications, Inc.

# Attachment B: Effective Useful Life for Custom Measure Guidelines

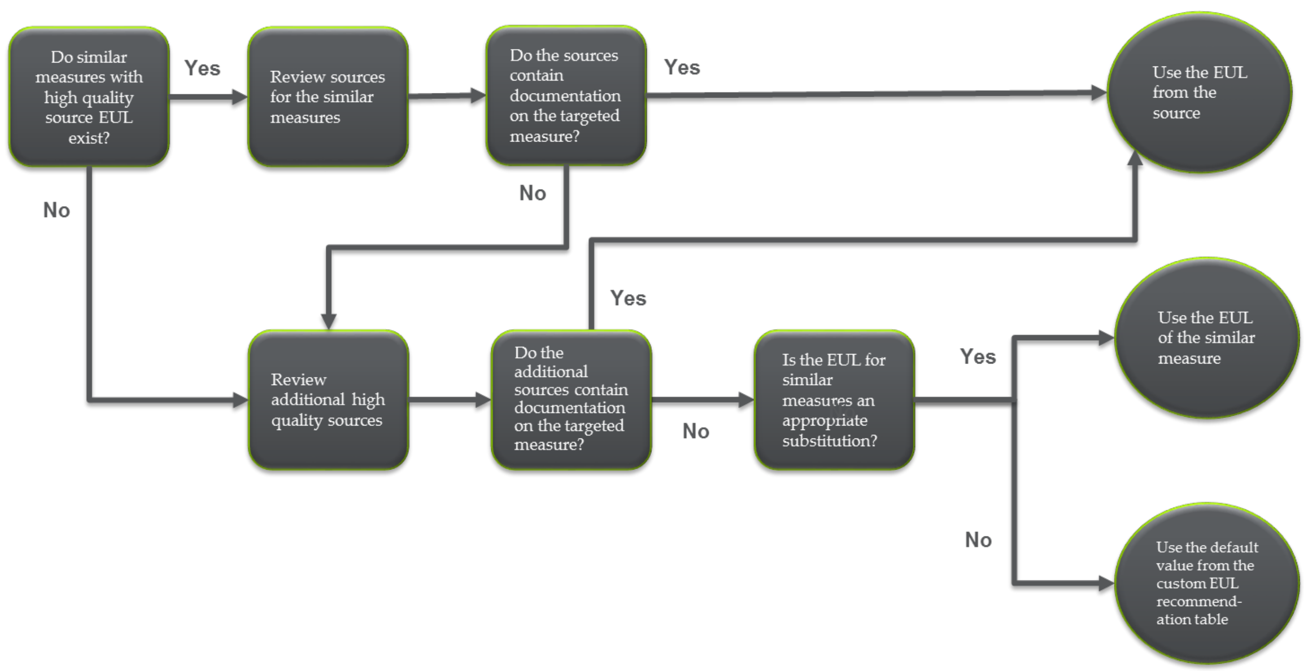
This section provides guidelines on the EUL values to use for the custom measures and programs. The approach for assigning EUL values to non-TRM measures is different from the approach used to assign EUL values to prescriptive measures because the non-TRM EUL (1) may be dependent on a mix of measures, or (2) may not be supported by previous primary and secondary research.

Similar to evaluating custom program savings on a retrospective basis, if there is a defined EUL for a measure or project[86] that does not use a TRM value or the correct TRM value, the evaluator will revise the value accordingly and apply the results in the verified lifetime savings and CPAS. As a result, the implementation team should be consistent and comprehensive in its documentation of the identified EUL.

The complexities of the various approaches for custom-like programs require a program-by-program perspective. The following process should be used to determine the EUL value for custom measures. Figure 1 provides guidance as to what the evaluation team will review and address in providing evaluated CPAS savings. Similar to first year energy savings calculations, appropriate documentation should be provided to support the EUL value which may include references, approach, and reasons.

1. Identify the non-TRM measure and consider if there are similar measures with high quality EUL values already in the TRM. This initial step provides a benchmark for the EUL value.
2. Review the sources used to determine the EUL values for those similar measures. See Table 2.
3. If the sources do not have EUL documentation for the non-TRM measure, research additional sources. The level of research effort should be commensurate with the savings potential for the non-TRM measure.
4. If EUL documentation for the non-TRM measure is insufficient (such as a low-quality source from Table 2), assess if EUL values for similar measures are appropriate substitutes.
5. If none of the above meets the source reference quality criteria, use the recommended default EUL value provided in Table 1.

**Figure 1. Proposed Approach for Determining EUL for Non-TRM Measures[87]**




[86] A measure is considered one isolated technology that can be defined for energy savings and EUL. A project is made up of a system of technologies such as an HVAC system retrofit where specific measure savings cannot be individually analyzed.
[87] Custom EUL recommendation table is Table 1.

The recommended values in Table 1 are a result of initial research into EUL values for non-TRM measures and may be considered as deemed. The recommended values can be used by program implementers when the steps presented in Figure 1 do not result in sufficient information to determine the appropriate EUL value for a non-TRM measure.

**Table 1. Recommended Custom Measure End-Use Categories, Subcategories and Effective Useful Life Values**

| Program/End-Use Category | End-Use Subcategory | Sample Mapped Measures | EUL (years) | Notes |
|---|---|---|---|---|
| Combined Heat and Power | Combined Heat and Power | CHP | Capped at 25 | Project specific |
| Compressed Air | Custom Compressed Air – Equipment | Compressed Air Pressure Reduction | 15 | Default value<br>Future research may show that EULs for compressed air measures vary significantly between equipment and controls. |
| | | Low-Pressure Blower System (replacing compressed air) | | |
| | Custom Compressed Air – Controls | Compressed Air Flow Controller | | |
| | Compressed Air Leak Repair | Compressed Air Leak Repair | 1 - 5 | A range of possible lifetime values is provided. Therefore, the implementers of this measure must justify the reason for selecting an appropriate measure life for each project and the decision will be subject to evaluation with the risk of adjustments.[88] |
| Data Centers | Custom Data Centers - Equipment | Data Center | 15 | Default values<br>Future research may show that EULs for data center measures vary significantly between equipment and controls. |
| | Custom Data Centers – Controls | | 15 | |
| Energy Management System | Energy Management System | Energy Management System | 15 | Default values |
| HVAC | Custom Electric HVAC – Equipment | Custom Electric HVAC | 13 | Default values |
| | | VAV Fume Hood | | |
| | Custom Electric HVAC - Controls | Chilled Water Reset | 15 | |
| | | Fume Hood Occupancy Controls | | |
| | | Electric HVAC Controls | | |

[88] Note during IL TRM v7.0 updates, this assumption was discussed at length with the realization that there is a lack of a strong source for defaulting the lifetime and different applications may vary significantly. It is hoped that future research will help to inform an appropriate assumption(s) to update this assumption for v8.0.

| Program/End-Use Category | End-Use Subcategory | Sample Mapped Measures | EUL (years) | Notes |
|---|---|---|---|---|
| | | Low-Flow High Performance Hood - | | |
| | | Reduce/Optimize Air Change per Hour (ACH) Rate - Chiller | | |
| | | Sash Stops | | |
| Lighting | New Construction/ Custom Lighting | Ceramic MH Lamp | 15 | Section 4.5.8 of the TRM covers 'Miscellaneous Commercial/Industrial Lighting'. It applies to "energy efficient lighting upgrades that are not captured in other measures within the TRM". The measure applies to retrofits and appears to be applicable to any non-prescriptive lighting measures, which would imply a 15-year measure life for custom lighting measures. It does not cover new construction or controls, thus the recommendation to include these subcategories. |
| | | New Construction Lighting | | |
| | Custom Lighting - Controls | Advanced Lighting Control Systems | 8 | |
| Non-Res New Construction | Non-Res New Construction | New Construction – Electric Measures | 17.4 | Based on research of measure level breakdown of typical projects in a program year. |
| | | New Construction – Gas Measures | 20.6 | |
| Refrigeration | Custom Refrigeration | Efficient Refrigeration Condenser | 15 | Default value<br>Research may show that EULs for refrigeration measures vary significantly between equipment and controls.<br>If that is not the case, the recommended end-use subcategory will continue working well.<br>If that is the case, at that time the end-use subcategories should be updated to the following:<br>Custom Refrigeration – Equipment<br>Custom Refrigeration – Controls |
| | | Floating Head Pressure Controls | | |
| | | Refrigerated Cases | | |
| | | Refrigeration Compressor | | |
| | | Refrigeration Controls | | |
| Res New Construction | Res New Construction | New Construction Electric Measures | 18 | |
| | Affordable Housing New Construction | Affordable Housing New Construction | - | Varies by project based on implemented measures |

| Program/End-Use Category | End-Use Subcategory | Sample Mapped Measures | EUL (years) | Notes |
|---|---|---|---|---|
| Retro commissioning | Retro commissioning | Electric RCx Measures | 7.5 | Research may show that EULs for RCx measures vary significantly between RCx categories or RCx delivery methods.<br>If that is not the case, the recommended program level value will continue working well. |
| Strategic Energy Management | Strategic Energy Management | SEM | 5 | Only applicable to behavior or operational measures. |
| Custom – Other | Custom Other | Barrel Wraps for Injection Molders and Extruders<br>Blowers<br>Building Envelope<br>Controls<br>Cooling Tower/Heat Exchanger<br>Filter<br>Injection Molding Machine<br>Low Pressure Drop High Efficiency (Non-HEPA) Air Filters<br>Piping/Duct Modification<br>Pump/Fan Replacement<br>Vacuum System | Custom | This category is intended to capture unique, one-off projects/measures that do not fall under the other recommended end-use categories. Each project/measure should have a custom EUL. To achieve this, the implementer will provide an ex ante EUL for the project/measure and the evaluator will assess it for reasonableness and revise as necessary.<br>As a last resort where there is no basis for a custom EUL a default of 13 years is provided and is deemed appropriate for electric measures. |

Source quality will be determined using hierarchy to describe the strength of the identified source as shown in Table 2 below. In cases where a range of values are provided by a source versus an absolute EUL, the median value should be used. In other cases, if more than one high quality source is available with conflicting values, the one with primary research data with strong confidence in the findings should prevail, otherwise, the average EUL should be calculated.

**Table 2. Source Strength Type and Examples**

| | Source Name | Description |
|---|---|---|
| **TYPE 1: Sources identified as highest strength:** Primary research conducted or vetted by third-party entities such as trade organizations, national labs, or government organizations | | |
| 1.1 | U.S. Department of Energy Federal Energy Conservation Standards | The U.S. Department of Energy (DOE) produces Technical Support Documents (TSD) detailing the analysis behind the federal conservation standards established for each product it regulates. Each TSD contains a chapter, often titled "Life Cycle Cost and Payback Period Analysis", that offers DOE's EUL estimate for the product and explains how this value was derived. Although the method depends on the data available for a given product, DOE's analysis generally relies on some combination of primary research, secondary research, modeling, and/or input from industry experts. The TSDs are linked from DOE's rulemaking page for each product, https://energy.gov/eere/buildings/standards-and-test-procedures.<br><br>The TSD measure life values are based on shipment data, secondary literature research and primary research which include discussions with industry experts. Navigant considers as high quality because of the stakeholder review process and due diligence required to create these documents. Only the best available sources are used to support the EUL values used in life-cycle cost analysis for DOE federal equipment standards. |
| 1.2 | LED lighting reports prepared by Navigant | Navigant has performed extensive market research on the state of LED lighting for the US. DOE Solid State Lighting Program most recently published in 2016. It includes typical lifetime operating hours for each lamp type by sector.<br><br>https://energy.gov/sites/prod/files/2016/09/f33/energysavingsforecast16_2.pdf |
| 1.3 | Appliance Magazine | Appliance Magazine publishes an annual report on the market value, life expectancy, and expected unit replacements for a range of consumer appliances. The appliances listed in this report change from year to year, so older versions of the report may be referenced for products no longer listed. As noted in the report, these EUL estimates represent the expert judgment of magazine staff based on input obtained from many sources. Portrait of the U.S. Appliance Industry (2001-2009). U.S. Appliance Industry: Market Share, Life Expectancy and & Replacement Market, and Saturation Levels (2010). U.S. Appliance Industry: Market Value, Life Expectancy and Replacement Picture (2011-2014). |
| 1.4 | C&I Measure Life and Persistence<br><br>Project | In 2011, Northeast Energy Efficiency Partnership sponsored this study of EUL of commercial and industrial lighting. The primary objective of this study was to conduct primary and secondary research and analysis for estimates of measure lifetimes that included on-site verification of CFL bulbs and fixtures, LED exit signs, HID fixtures, and T8 fixtures. Installations occurred from 1999-2009. http://www.neep.org/sites/default/files/resources/NEEP_CI_Persistence_Report-FINAL.pdf |
| **TYPE 2: Sources identified as medium-high strength:** Meta-analyses conducted by third-party organizations, that show some level of evaluating the studies that comprise the dataset | | |
| 2.1 | California DEER | The most recent and comprehensive DEER documentation of EUL sources was from 2008 and 2014. The 2008 version identifies all the sources reviewed and justification for selected measure life. The 2014 measure list identifies the source used for the measure life. Many of the original references are from 2005, http://deeresources.com/files/deer2005/downloads/DEER2005UpdateFinalReport_ItronVersion.pdf, p. 11-1. |

| | Source Name | Description |
|---|---|---|
| 2.2 | Regional Technical Forum (RTF) reference workbook | Ongoing revisions as measures undergo review. Similar to the 2008 DEER, the RTF identifies all the sources reviewed and justification for selected measure life. |
| 2.3 | GDS Reports | GDS Measure Life Report Residential and Commercial/Industrial Lighting and HVAC Measures – 2007. This study used various data sources such as DEER, state TRMs, and evaluation studies with a working group to review and decide on each value. |
| 2.4 | Focus on Energy Report | Focus on Energy Evaluation Business Programs: Measure Life Study Final Report: August 25, 2009 – this is a critical review of studies, workpapers and technical guides including a review of the underlying sources or supporting research. |
| 2.5 | ASHRAE | Original source is from Akalin, M.T. 1978. Equipment life and maintenance cost survey (RP-186). ASHRAE Transactions 84(2):94-106;<br><br>Recent work is ASHRAE system life database (research project 1237-TRP) - which is a crowd-sourced approach to collecting actual system data. https://xp20.ashrae.org/publicdatabase/system_service_life.asp?selected_system_type=7 |
| **TYPE 3: Sources identified as medium strength:**<br><br>Compilations conducted by third-party organizations. Original sources should be cited, and locatable where applicable | | |
| 3.1 | State TRMs | Many state TRMs reference each other and other sources of varying strength. Due diligence on reference documentation is not always present for the measure life. Many TRMs are reviewed via a stakeholder process. |
| 3.2 | ENERGY STAR calculators prepared by U.S. EPA and DOE (depending on the references used) | EPA's Energy Star offers calculators to help consumers and businesses estimate the energy and cost savings that could be realized by choosing to buy Energy Star certified products. Within these calculators, Energy Star offers a typical EUL and cites the source. Energy Star generally cites a single high-quality source (e.g., DOE, Appliance Magazine) for each EUL value and offers no analysis or discussion of the selected value. Energy Star's calculators can be accessed at www.energystar.gov. For example, their appliance calculator is available at www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx. |
| **TYPE 4: Sources identified as medium-low strength:**<br><br>Primary research conducted by interested parties such as manufacturers, distributors, retailers or installers | | |
| 4.1 | Interview with interested parties (with no statistical rigor or analysis) | Manufacturer, distributor, installer, etc. have a vested interest and may overstate the benefit. |
| **TYPE 5: Sources identified as low strength:**<br><br>Source where the basis of measure life is anecdotal, based on design specs, warranty period, etc. | | |
| 5.1 | Industry blogs, Implementer or Navigant experience | Typically based on professional judgment and not rooted in any data. |