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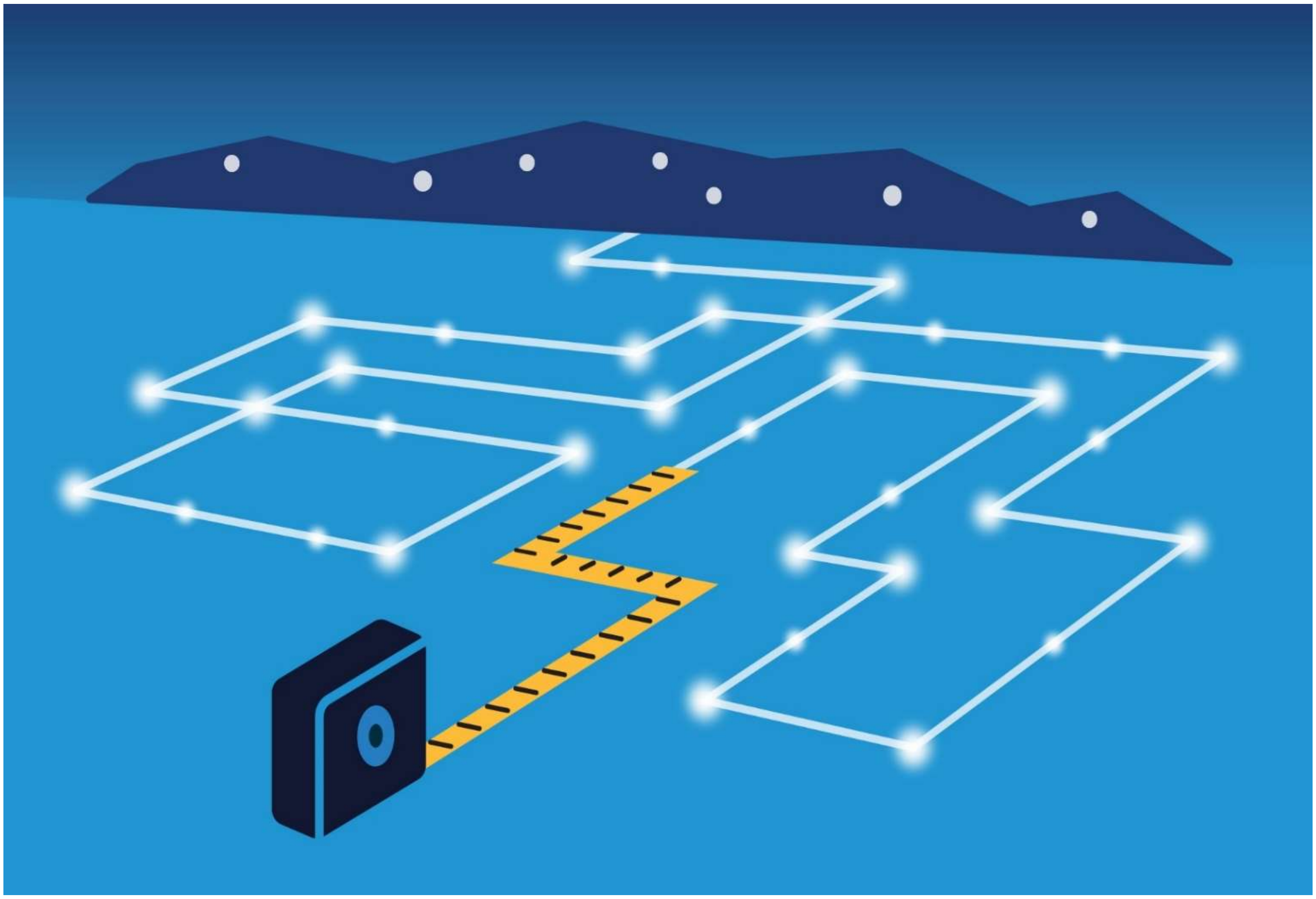

Impact and Process Evaluation of the 2016 (PY9) Ameren Illinois Company Home Efficiency Standard Program

Final

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1. Executive Summary

This report presents the results of the Program Year 9 (PY9) Ameren Illinois Company (AIC) Home Efficiency Standard Program (HES Program) evaluation. The HES Program is a home energy diagnostic and retrofit program that offers residential customers a home audit, an audit report and recommendations for retrofits, directly installed measures, and incentives for building shell retrofits. In particular, program participants may receive energy-efficient lighting, faucet aerators and shower heads, insulation, and air sealing. CLEAResult implements the HES Program with oversight from Leidos, which manages implementation of AIC's energy efficiency portfolio.

Given that AIC decided to discontinue the HES Program after PY8 due to an estimated Total Resource Cost (TRC) less than 1.0, PY9 program implementation activities were limited to closing-out any remaining projects begun in the prior program year. Ultimately, the HES Program was implemented for only two months in early PY9, from May 20, 2016 to July 31, 2016. The evaluation team completed an impact evaluation of the projects completed during this time and conducted only a few process-related evaluation tasks to confirm that the close-out process went as planned.

Program Impacts

AIC expected the HES Program to achieve 81 MWh and 17,923 therms, which represents 0.1% of the overall PY9 filed planned electric savings and 0.3% of overall residential filed planned therm savings, respectively. Per the PY9 implementation plan, AIC estimated completing 123 retrofits in PY9.

The program fell short of its participation estimate, reaching 70 customers in PY9. This represents 36 audits and 34 home retrofit projects, which is 57% of the estimated program retrofits for PY9. AIC program staff noted that some of the outstanding projects were not completed since they only had the first two months of the program year to complete projects.

Overall, the program provided ex post net savings of 30.25 MWh, 0.01 MW, and 8,371 therms in PY9. The program achieved gross realization rates of 92% for MWh savings, 91% for MW savings, and 92% for therms savings. Table 1 summarizes the impacts for the HES Program in PY9.

Table 1. PY9 HES Program Net Impacts

	Ex Ante Gross	Realization Rate	Ex Post Gross	NTGR[a]	Ex Post Net
Energy Savings (MWh)	42.50	92%	39.11	0.77	30.25
Demand Savings (MW)	0.02	91%	0.02	0.75	0.01
Therms Savings	11,920	92%	10,997	0.76	8,371

[a] To obtain net program savings, we applied the SAG-approved PY6 NTGRs to ex post gross savings by measure and summed the results. We divided the ex post net program impacts by ex post gross program impacts to arrive at the program-level NTGRs.

Key Findings

The key goal for the program was to work closely with trade allies to complete any outstanding projects. According to program staff, the close-out process went smoothly, within budget, and without any lingering issues.

2. Evaluation Approach

The PY9 evaluation of AIC's HES Program involved both process and impact assessments. The following sections outline the research objectives and methods employed.

2.1 Research Objectives

The evaluation team structured the assessment of the HES Program based on the following research questions:

- Impact Questions
  - What were the estimated gross energy and demand impacts from this program?
  - What were the estimated net energy and demand impacts from this program?
- Process Questions
  - Program Design and Implementation Effectiveness
    - Did the program close-out process occur as planned?
  - Program Participation
    - How many homes received audits? How many homes received shell measures? Did participation meet expectations? If not, why?

2.2 Evaluation Tasks

Table 2 summarizes the PY9 evaluation activities conducted for the HES Program. We describe each activity in detail following the table.

Table 2. PY9 HES Program Evaluation Activities

Task	PY9 Process	PY9 Impact	Forward Looking	Details
Review of Program Materials and Data	✓			Reviewed program materials to assess program implementation and participation.
Interviews with Program Staff and Implementers	✓			Interviewed AIC, CLEAResult, and Leidos staff to understand the program's design, implementation processes, and marketing. We also confirmed evaluation priorities.
Gross Impact Analysis		✓		Conducted an engineering analysis for all PY9 participants to estimate gross impacts.
Net Impact Analysis		✓		Applied the SAG-approved PY6 NTGR to ex post gross savings by measure to estimate net impacts.

2.2.1 Review of Program Materials and Data

To understand program implementation and marketing efforts, the evaluation team reviewed the PY9 implementation plan. To assess participation, we reviewed the program-tracking database.

2.2.2 Interviews with Program Staff and Implementers

We conducted in-depth interviews with one AIC program staff person, one member of the CLEAResult implementation team, and one member of the Leidos team. The purpose of these interviews was to gain insight into whether the program close-out process was implemented according to plan.

2.2.3 Impact Analysis

To determine the gross impacts associated with the HES Program, we applied the savings algorithms and variable assumptions from the IL-TRM V5.0 to information provided in the program-tracking database. We outline the algorithms used to calculate all evaluated gross program savings in Appendix A along with all input variables.

The evaluation team calculated PY9 ex post net impacts by applying SAG-approved PY6 NTGRs to ex post gross savings by measure. Table 3 summarizes the measure-level NTGRs used to calculate PY9 HES Program net savings.

Table 3. NTGRs by Measure Category

Measure Category	NTGR	
	Electric	Gas
CFLs	0.82	--
Faucet Aerator	0.92	0.94
Shower Head	0.86	0.91
Air Sealing	0.71	0.72
Insulation	0.78	0.78

2.3 Sources and Mitigation of Error

Table 4 provides a summary of possible sources of error associated with the evaluation of the HES Program. We discuss each item in detail below.

Table 4. Potential Sources of Error

Research Task	Survey Error		Non-Survey Error
	Sampling	Non-Sampling	
Gross Impact Analysis	N/A	N/A	Analytical error
Net Impact Analysis	N/A	N/A	Analytical error

Analytical Error

It is possible that analytical error could exist within the impact analysis tasks. For instance, there could be errors in the input and analysis of data or the characterization of results. As with any evaluation, we took precautions to limit the possibility of this sort of error:

- Gross Impact Calculations: We applied the IL-TRM calculations to the participant data in the program-tracking database to calculate gross impacts. To minimize analytical errors, a separate team member reviewed all impact calculations to verify their accuracy.
- Net Impact Calculations: We applied the PY6 measure-level NTGRs to gross savings to obtain PY9 program net savings.

3. Detailed Evaluation Findings

The following sections present detailed findings from the PY9 evaluation of the HES Program.

3.1 Program Design and Implementation

The HES Program was discontinued at the end of PY8 because the program was not going to be cost effective moving forward (the program had an anticipated prospective TRC score of less than one). As a result, in PY9, AIC worked with trade allies to complete pending projects and held in-person meetings with concerned trade allies who had committed to completing projects with customers prior to the discontinuation of the program. While, as expected, some trade allies were not pleased with AIC's decision to discontinue the HES Program, all three program staff we interviewed noted that the support provided to trade allies in closing-out projects was generally well-received and that the close-out process went smoothly. However, per AIC program staff, some of the pending projects were not completed because the program only ran for the first two months of PY9.

3.2 Program Participation and Measure Installation

Participation

In PY9, the HES Program reached 70 unique participants. As shown in Table 5, over half of those participants received only an audit, which included the direct installation of program measures, while the remaining participants (49%) completed only building shell retrofits.

Table 5. Overview of Participation

Participant Type	Number of Participants	% of Participants
Audit and Retrofit	0	0%
Audit Only	36	51%
Retrofit Only	34	49%
Total	70	100%

3.3 Impact Assessment

The evaluation team applied savings algorithms from the IL-TRM V5.0 using program-tracking database inputs and applied in-service rates (ISRs) from IL-TRM V5.0 to estimate program gross savings. To assess net impacts, the evaluation team applied the Illinois SAG-approved PY6 NTGR to ex post gross impacts.

3.3.1 Measure Verification

The program offers a variety of measures to participants, including direct install measures and building shell measures. To determine the verified measure quantities, the evaluation team applied ISRs provided in the IL-TRM V5.0 to ex ante measure quantities. Table 6 summarizes the quantity of installed measures based on the team's review of the program-tracking database.

Table 6. PY9 HES Program Verified Measure Quantities

Measure Category	Measure	Unit	Ex Ante Measure Quantity [a]	In-Service Rate [b]	Verified Measure Quantity [a * b]
Lighting	CFL - Low (13W–15W)	Bulb	118	97%	114
	CFL - Medium (18W–20W)	Bulb	18	97%	17
	CFL - High (23W–25W)	Bulb	21	97%	20
	Specialty CFL - 9W Candelabra	Bulb	73	97%	71
	Specialty CFL - 14W Globe	Bulb	140	97%	136
	Specialty CFL - 15W Reflector	Bulb	41	97%	40
Domestic Hot Water (DHW)	Faucet Aerator	Aerator	25	95%	24
	Shower Head	Shower Head	18	98%	18
Envelope	Air Sealing	Cu. Ft./Min. (CFM)	55,825	100%	55,825
	Attic Insulation	Sq. Ft.	39,395	100%	39,395
	Wall Insulation	Sq. Ft.	10,792	100%	10,792
	Rim Joist Insulation	Linear Feet	4,062	100%	4,062
	Crawl Space Insulation	Sq. Ft.	2,029	100%	2,029
Total			112,557	100%	112,543

3.3.2 Ex Post Gross Impact Results

The total ex post gross impacts for the PY9 HES Program are 39,114 kWh, 18.85 kW, and 10,997 therm savings. As shown in Table 7, there is close alignment between the ex ante and ex post gross impacts with gross realization rates of 92% for electric savings, 91% for demand savings, and 92% for therm savings.

Table 7. PY9 HES Program Gross Impacts

Program	Number of Participants	Ex Ante Gross[a]			Ex Post Gross		
		kWh	kW	Therms	kWh	kW	Therms
HES Program	70	42,495	20.81	11,920	39,114	18.85	10,997
Gross Realization Rate[b]					92%	91%	92%

[a] Source of ex ante savings: PY9 program-tracking database.
[b] Gross Realization Rate = ex post gross value/ex ante gross value.

Table 8 summarizes the ex post gross electric impacts results by measure.

Table 8. HES Program Gross Electric Impacts by Measure

Measure	Verified Measure Quantity	Units	Ex Ante Gross Impacts		Ex Post Gross Impacts		Gross Realization Rate[a]	
			kWh	kW	kWh	kW	kWh	kW
Air Sealing	55,825	CFM	11,611	8.03	11,916	8.35	103%	104%
Attic Insulation	39,395	Sq. Ft.	8,574	6.42	8,479	6.35	99%	99%
Crawl Space Insulation	2,029	Sq. Ft.	4,874	2.35	2,264	0.87	46%	37%
Specialty CFL – 14W Globe	136	Bulb	4,227	0.52	4,218	0.52	100%	100%
CFL – Low (13W – 15W)	114	Bulb	2,883	0.28	2,883	0.28	100%	100%
Specialty CFL – 9W Candelabra	71	Bulb	2,766	0.29	2,766	0.29	100%	100%
Wall Insulation	10,792	Sq. Ft.	2,058	1.38	2,034	1.36	99%	99%
Specialty CFL – 15W Reflector	40	Bulb	1,813	0.20	1,813	0.20	100%	100%
Rim Joist Insulation	4,062	Linear Feet	1,786	1.05	838	0.35	47%	33%
CFL – High (23W – 25W)	20	Bulb	838	0.08	838	0.08	100%	100%
CFL – Medium (18W – 20W)	17	Bulb	484	0.05	484	0.05	100%	100%
Shower Head	18	Shower Head	516	0.05	516	0.05	100%	100%
Faucet Aerator	24	Aerator	65	0.10	65	0.10	100%	100%
Total	112,543		42,495	20.81	39,114	18.85	92%	91%

Note: Numbers may not total due to rounding.
[a] Gross Realization Rate = ex post gross value/ex ante gross value.

Table 9 summarizes the ex post gross therm impacts results by measure.

Table 9. HES Program Gross Therm Impacts by Measure[a]

Measure	Verified Measure Quantity	Units	Ex Ante Gross Impacts	Ex Post Gross Impacts	Gross Realization Rate[b]
			Therms	Therms	Therms
Attic Insulation	39,395	Sq. Ft.	4,449	4,449	100%
Air Sealing	55,825	CFM	3,855	3,971	103%
Crawl Space Insulation	2,029	Sq. Ft.	1,801	1,030	57%
Wall Insulation	10,792	Sq. Ft.	945	945	100%
Rim Joist Insulation	4,062	Linear Feet	639	370	58%
Shower Head	18	Shower Head	177	177	100%
Faucet Aerator	24	Aerator	54	54	100%
Total	112,144		11,920	10,997	92%

Note: Numbers may not total due to rounding.
[a] This table excludes lighting measures since ex post impact analysis does not include waste heat penalties.
[b] Gross Realization Rate = ex post gross value/ex ante gross value.

Differences in ex post and ex ante gross savings stem from differences in input values for the savings algorithms for each measure. In particular, differences in the inputs for air sealing and attic insulation measures have the largest impact on program-level realization rates as these measures account for 30% and 22% of the total program energy savings, respectively. Table 10 summarizes the source of differences between ex ante and ex post gross savings for measures with realization rates that differ from 100%.

Table 10. Reasons for Realization Rates per Measure

Measure	Gross Realization Rate			Source of Discrepancy		
	kWh RR	kW RR	Therms RR	CDD/ HDD	HVAC Cooling Efficiency	Other Discrepancies
Air Sealing	102.6%	103.9%	103.0%		✓	• Air leakage conversion factors
Attic Insulation	98.9%	99.0%	100.0%		✓	
Specialty CFL – 14W Globe	99.8%	99.6%	N/A			• Waste heat factors (WHF)
Crawl Space Insulation	46.5%	37.1%	57.2%	✓	✓	
Wall Insulation	98.8%	98.5%	100%		✓	
Rim Joist Insulation	46.9%	32.8%	58.0%	✓	✓	• R-value of existing foundation wall assembly above grade (R_old) and Framing Factor (FF)

[a] Cooling Degree Days (CDD) and Heating Degree Days (HDD)

Through our discussions with the implementer, we identified the sources of the differences between ex ante and ex post savings. Note that while certain inputs may increase savings, others decrease savings. The combination of all inputs brings about the overall realization rate for a specific measure. We describe the differences in the ex ante and ex post savings calculations in detail below.

- Cooling Degree Days (CDD) and Heating Degree Days (HDD): For crawl space and rim joist insulation measures, the implementer applied IL-TRM V5.0 CDD and HDD values for conditioned spaces to calculate ex ante savings. However, based on discussions with the implementer, and our understanding of the baseline conditions, the evaluation team applied unconditioned CDD and HDD values consistent with the IL-TRM V5.0 and consistent with how we have handled these measures in previous program years. We used this same approach for rim joist insulation projects. As a result, ex post estimates are 42.1% to 62.1% smaller than ex ante analysis (see Table 11).

Table 11. Changes in Realization Rate Due to CDD and HDD

Measure	kWh	kW	Therms
Crawl Space Insulation	-57.2%	-55.7%	-42.8%
Rim Joist Insulation	-60.2%	-62.1%	-42.1%

- HVAC Cooling Efficiency: For projects with unknown cooling equipment age, the implementer applied a weighted average cooling efficiency of 11.05 SEER based on an assumed mix of cooling equipment age. In the ex post analysis, the evaluation team used the cooling equipment age provided within the program-tracking database to assign the appropriate cooling efficiency as stated in the IL-TRM V5.0. For participants without cooling equipment age, the evaluation team applied an average of 11.65 SEER, derived from participants with cooling equipment age (n=31). For several projects where the cooling equipment is a central air conditioner manufactured in 2015, the implementer applied an efficiency of 14 SEER instead of 13 SEER as prescribed by the IL-TRM V5.0. Differences in HVAC cooling efficiencies minimally impacted air sealing and insulation results.

- Air Leakage Conversion Factors: For projects with an unknown number of floors, the implementer used IL-TRM V5.0 N_cool and N_heat values for a 1.5–story home located in Springfield to calculate ex ante savings. For the ex post analysis, the evaluation team calculated an average N_cool and N_heat value using values prescribed in the IL-TRM V5.0 for each climate zone. We applied the average value for projects with unknown number of floors based on the project location. Differences in air leakage conversion factors only impacted air sealing measures. As a result, ex post estimates are 3.5% higher for energy savings and 3.0% higher for gas savings compared to ex ante analysis.

- Waste heat factors for energy and demand: The implementer applied IL-TRM V5.0 waste heat factors for cooled location (1.06 for energy and 1.11 for demand) to calculate ex ante savings for all specialty CFL – 14W globe measures. However, one of the specialty CFL measures was installed in an uncooled home. For the ex post analysis, we therefore applied waste heat factors of 1.0 for energy and 1.0 for demand as prescribed by the IL-TRM V5.0 to bulbs that are installed in uncooled locations. Differences in waste heat factors decreased ex post energy savings by less than 1%.

- R-value of existing foundation wall assembly above grade: For the ex ante analysis of rim joist insulation measures, the implementer applied an R_old value of 3 instead of 3.18 that was agreed upon between the implementer and the evaluation team. As a result, ex post demand savings are 6.9% smaller than ex ante demand savings.

- Framing Factor: Ex ante demand savings for rim joist insulation measures omitted the framing factor of 0.05. As a result, ex post demand savings are 5% smaller than ex ante demand savings.

3.3.3 Ex Post Net Impacts Results

To determine the overall net savings associated with the HES Program, the evaluation team applied the SAG-approved PY6 NTGRs to ex post gross savings. As a result, the program achieved a net realization rate of 91% for kWh, 90% for kW, and 92% for therms (see Table 12). Notably, there is a slight difference in ex ante and ex post realization rates because ex ante analysis applied unrounded NTGRs while ex post analysis applied the values in Table 3.

Table 12. PY9 HES Program Net Impacts

Program Component	Ex Ante Net[a]			Ex Post Net		
	kWh	kW	Therms	kWh	kW	Therms
Standard Program	33,066	15.82	9,122	30,245	14.20	8,371
Net Realization Rate[b]				91%	90%	92%

[a] Source of ex ante savings: PY9 program-tracking database.
[b] Net Realization Rate = ex post net value/ex ante net value.

4. Conclusions and Recommendations

The HES Program ended in PY9 and as a result, the key goal for the program during its two months of operation was to work closely with trade allies to complete any outstanding projects. According to program staff, the close-out process went smoothly, was completed within budget and without any lingering issues. The program also wrapped up with high gross and net savings realization rates.

Appendix A. Engineering Analysis Algorithms

In PY9, the impact evaluation efforts estimated gross impact savings for the HES Program by applying savings algorithms from the IL-TRM V5.0 using the information provided in the program-tracking database. We present the algorithms and input variables used to calculate all evaluation program savings below.

A.1 CFL Algorithms

The evaluation team determined ex post lighting savings using the algorithms below. All variable assumptions are from the IL-TRM V5.0 unless otherwise referenced.

Equation 1. Standard and Specialty CFL Algorithms

Energy Savings: $\Delta kWh = ((WattsBase - WattsEE)/1{,}000) * ISR * Hours * WHF_e$

Demand Savings: $\Delta kW = ((WattsBase - WattsEE)/1{,}000) * ISR * WHF_d * CF$

Where:

WattsBase = Wattage of existing equipment

Table 13. Baseline Wattages for Lighting Measures

Measure	EISA Adjusted[a]	Baseline Wattage	Resource
CFL - Low (13W–15W)	Yes	43	IL-TRM V5.0
CFL - Medium (18W–20W)	Yes	53	
CFL - High (23W–25W)	Yes	72	
Specialty CFL – 9W Candelabra	No	40	
Specialty CFL – 14W Globe	No	60	
Specialty CFL – 15W Reflector	No	65	

[a] The Energy Independence and Security Act of 2007 (EISA) schedule requires baseline adjustments to measures with incandescent baseline wattages of 100W (as of June 2012), 75W (as of June 2013), and 60W (as of June 2014).

WattsEE = Wattage of installed CFL

Table 14. CFL Wattages for Lighting Measures

Measure	CFL Wattage	Resource
CFL - Low (13W–15W)	13	Actual installed CFL wattage
CFL - Medium (18W–20W)	20	
CFL - High (23W–25W)	23	
Specialty CFL – 9W Candelabra	9	
Specialty CFL – 14W Globe	14	
Specialty CFL – 15W Reflector	15	

ISR = In-service rate of installed CFLs = 96.9%

Hours = Annual operating hours

Table 15. Annual Hours of Use for Lighting Measures

Measure	Hours
Standard CFL (Spiral)	793
Specialty CFL (Globe)	639
Specialty CFL (Candelabra)	1,190
Specialty CFL (Reflector)	861

WHF_e = Waste heat factor for energy (accounts for cooling savings from efficient lighting)

Table 16. Waste Heat Factors for Energy

Bulb Location	WHF_e
Interior single family or unknown location	1.06
Exterior or uncooled location	1.00

WHF_d = Waste heat factor for demand (accounts for cooling savings from efficient lighting)

Table 17. Waste Heat Factors for Demand

Bulb Location	WHF_d
Interior single family or unknown location	1.11
Exterior or uncooled location	1.00

CF = Summer peak coincidence factor

Table 18. Coincidence Factors for Lighting Measures

Measure	CF
Standard CFL (Spiral)	0.074
Specialty CFL (Globe)	0.075
Specialty CFL (Candelabra)	0.121
Specialty CFL (Reflector)	0.091

A.2 Lighting Measures Heating Penalty

The evaluation team determined gas heating penalties for all lighting measures using the algorithm below. Based on the agreement between the Illinois Commerce Commission (ICC) and AIC, we do not include heating penalties in the ex post energy savings, but will include this in the data for the PY9 cost-effectiveness analysis.

Equation 2. Heating Penalty Algorithm

Gas Heating Penalty: $\Delta therms = -(((WattsBase - WattsEE)/1{,}000) * ISR * Hours * HF * 0.03412)/\eta Heat$

Where:

WattsBase = Wattage of existing equipment (see Table 13)

WattsEE = Wattage of installed CFLs (see Table 14)

ISR = In-service rate or the percentage of units rebated that get installed = 96.9%

Hours = Annual operating hours (see Table 15)

HF = Heating Factor = 0.49

ηHeat = Efficiency of heating equipment = 0.70 AFUE

Table 19 summarizes the heating penalties for the six lighting measures offered through the program.

Table 19. Per-Measure Heating Fuel Penalties for CFL Lighting

Heating Equipment	Measure	ΔkWh	Δtherms
Gas Heating	CFL - Low (13W–15W)	n/a	−0.55
	CFL - Medium (18W–20W)	n/a	−0.61
	CFL - High (23W–25W)	n/a	−0.90
	Specialty CFL - 9W Candelabra	n/a	−0.85
	Specialty CFL - 14W Globe	n/a	−0.68
	Specialty CFL - 15W Reflector	n/a	−1.00

A.3 Water Heating Conservation Measure Algorithms

The evaluation team determined ex post water heating conservation measure savings using the algorithms below. All variable assumptions are from the IL-TRM V5.0 unless otherwise referenced.

Equation 3. Low-Flow Shower Head Algorithms

Energy Savings: *ΔkWh = %ElectricDHW * ((GPM_base * L_base - GPM_low * L_low) * Household * SPCD * 365.25/SPH) * EPG_electric * ISR*

Demand Savings: *ΔkW = ΔkWh/Hours * CF*

Therm Savings: *ΔTherms = %FossilDHW * ((GPM_base * L_base - GPM_low * L_low) * Household * SPCD * 365.25/SPH) * EPG_gas * ISR*

Equation 4. Low-Flow Faucet Aerator Algorithms

Energy Savings: *ΔkWh = %ElectricDHW * ((GPM_base * L_base - GPM_low * L_low) * Household * 365.25 *DF/FPH) * EPG_electric * ISR*

Demand Savings: *ΔkW = ΔkWh/Hours * CF*

Therm Savings: *ΔTherms = %FossilDHW * ((GPM_base * L_base - GPM_low * L_low) * Household * 365.25 * DF/FPH) * EPG_gas * ISR*

Where:

%ElectricDHW = 100% if electric water heater, 0% if gas water heater

%GasDHW = 100% if gas water heater, 0% if electric water heater

GPM_base = Flow rate of the baseline shower head or faucet aerator in gallons per minute (GPM) (see Table 20)

GPM_low = As-used flow rate of the low-flow shower head or faucet aerator (see Table 20)

Table 20. GPM for Water Heating Measures

Measure	GPM_base	GPM_low
Faucet Aerator	1.39	0.94
Shower Head	2.67	1.75

L_base = Length (in minutes) per baseline shower head or baseline faucet (see Table 21)

L_low = Length (in minutes) per low-flow shower head or low-flow faucet (see Table 21)

Table 21. L_base for Water Heating Measures

Measure	Minutes
Faucet Aerator – Kitchen	4.5
Faucet Aerator – Bathroom	1.6
Shower Head	7.8

Household = Average number of people per household = 2.56

SPCD = Showers per capita per day = 0.60

SPH = Shower heads per household for single family homes = 1.79

DF = Drain factor (see Table 22

Table 22. Drain Factor for Faucet Aerators

Measure	DF
Faucet Aerator – Kitchen	75%
Faucet Aerator – Bathroom	90%

FPH = Faucets per household for single-family homes (see Table 23)

Table 23. Faucets Per Household

Measure	FPH
Faucet Aerator – Kitchen	1
Faucet Aerator – Bathroom	2.83

EPG_electric = Energy per gallon (EPG) of hot water supplied by electric water heater (see Table 24)

EPG_gas = Energy per gallon of hot water supplied by gas water heater (see Table 24)

Table 24. EPG for Water Heating Measures

Measure	EPG_electric	EPG_gas
Faucet Aerator – Kitchen	0.09690	0.00415
Faucet Aerator – Bathroom	0.07950	0.00341
Shower Head	0.11700	0.00501

ISR = In-Service Rate of installed low-flow shower heads or low-flow aerators

Table 25. ISR for Water Heating Measures

Measure	ISR
Faucet Aerator	95%
Shower Head	98%

Hours = Annual recovery hours for shower head or faucet use for single family homes

Table 26. Hours for Water Heating Measures

Measure	Hours
Faucet Aerator – Kitchen	94
Faucet Aerator – Bathroom	14
Shower Head	302

CF = Summer peak coincidence factor

Table 27. Coincidence Factors for Water Heating Measures

Measure	CF
Faucet Aerator	0.0220
Shower Head	0.0278

A.4 Air Sealing Algorithms

The evaluation team determined ex post air sealing savings using the algorithms below. All variable assumptions are from the IL TRM V5.0 unless otherwise referenced.

Equation 5. Air Sealing Algorithms

Energy Savings: *ΔkWh = ΔkWh_cooling + ΔkWh_heating*

*ΔkWh_cooling = [(((CFM50_existing - CFM50_new)/N_cool) * 60 * 24 * CDD * DUA * 0.018)/(1,000 * ηCool)] * LM*

*ΔkWh_heating (electric heat) = (((CFM50_existing - CFM50_new)/N_heat) * 60 * 24 * HDD * 0.018)/(ηHeat * 3,412)*

Demand Savings: *ΔkW = (ΔkWh_cooling/FLH_cooling) * CF*

Gas Savings (gas heat): *ΔTherms = (((CFM50_existing - CFM50_new)/N_heat) * 60 * 24 * HDD * 0.018)/(ηHeat * 100,000)*

*ΔkWh_heating (gas heat furnace fan run time reduction) = ΔTherms * F_e * 29.3*

Where:

CFM_existing = Infiltration at 50 Pascals as measured by blower door before air sealing

CFM_new = Infiltration at 50 Pascals as measured by blower door after air sealing

N_cool = Conversion factor from leakage at 50 Pascal to leakage at natural conditions (applied per participant based on project location and height of home)[1]

Table 28. N_cool by Climate Zone and Number of Stories

Climate Zone	N_cool (by # of stories)				
	1	1.5	2	3	Unknown[a]
1 (Rockford)	39.5	35.0	32.1	28.4	33.8
2 (Chicago)	38.9	34.4	31.6	28.0	33.2
3 (Springfield)	41.2	36.5	33.4	29.6	35.2
4 (St. Louis, MO)	40.4	35.8	32.9	29.1	34.6
5 (Paducah, KY)	43.6	38.6	35.4	31.3	37.2

[a] An average of N_cool values for 1, 1.5, 2, and 3 stories

CDD = Cooling Degree Days (applied per participant based on location)

Table 29. Cooling Degree Days by Climate Zone

Climate Zone	Conditioned CDD
1 (Rockford)	820
2 (Chicago)	842
3 (Springfield)	1,108
4 (Belleville)	1,570
5 (Marion)	1,370

DUA = Discretionary Use Adjustment = 0.75

ηCool = Seasonal Energy Efficiency Ratio (SEER) of cooling system (applied per participant based on existing equipment age provided in database)

Table 30. ηCool for Air Sealing Measures

Cooling Equipment Age	SEER
Before 2006	10.0
2006–2014	13.0
Central Air Conditioning (AC) After 1/1/2015	13.0
Heap Pump After 1/1/2015	14.0
Unknown[a]	11.6

[a] For measures where the cooling equipment age is not provided in the database (n=2), we calculated an average cooling efficiency based on SEER values derived from measures with cooling equipment age information (n=31).

LM = Latent Multiplier to account for latent cooling demand (applied per participant based on project location)

[1] For projects where the height of the home (number of stories) was not provided in the tracking database, the evaluation team applied the N_cool value for an unknown number of stories.

Table 31. Latent Multiplier by Climate Zone

Climate Zone	Latent Multiplier
1 (Rockford)	3.3
2 (Chicago)	3.2
3 (Springfield)	3.7
4 (Belleville)	3.6
5 (Marion)	3.7

N_heat = Conversion factor from leakage at 50 Pascal to leakage at natural conditions (applied per participant based on project location and height of home)[2]

Table 32. N_heat by Climate Zone and Number of Stories

Climate Zone	N_heat (by # of stories)				
	1	1.5	2	3	Unknown[a]
1 (Rockford)	23.8	21.1	19.3	17.1	20.3
2 (Chicago)	23.9	21.1	19.4	17.2	20.4
3 (Springfield)	24.2	21.5	19.7	17.4	20.7
4 (St. Louis, MO)	25.4	22.5	20.7	18.3	21.7
5 (Paducah, KY)	27.8	24.6	22.6	20.0	23.8

[a] An average of N_heat values for 1, 1.5, 2, and 3 stories

HDD = Heating Degree Days (applied per participant based on project location)

Table 33. Heating Degree Days by Climate Zone

Climate Zone	Conditioned HDD
1 (Rockford)	5,352
2 (Chicago)	5,113
3 (Springfield)	4,379
4 (Belleville)	3,378
5 (Marion)	3,438

ηHeat = Efficiency of space heating equipment (applied per participant based on existing equipment age provided in database)

Table 34. ηHeat for Air Sealing Measures

Existing Heating Equipment	Equipment Age	COP
Heat Pump	Before 2006	1.70
	2006–2014	1.92
	2015 and beyond	2.40
Electric Resistance	N/A	1.00
Gas Furnace	N/A	0.72

[2] For projects where the height of the home (number of stories) was not provided in the tracking database, the evaluation team applied the N_heat value for an unknown number of stories.

FLH_cooling = Full Load Cooling Hours (applied per participant based on project location)

Table 35. Full Load Cooling Hours by Climate Zone

Climate Zone	FLH_cooling
1 (Rockford)	512
2 (Chicago)	570
3 (Springfield)	730
4 (Belleville)	1,035
5 (Marion)	903

CF = Summer peak coincidence factor (varies by cooling equipment type)

Table 36. Coincidence Factors for Air Sealing Measures

Cooling Equipment	CF
Central Air Conditioner	0.68
Heat Pump	0.72

F_e = Furnace fan energy consumption as a percentage of annual fuel consumption = 3.14%

A.5 Attic and Wall Insulation Algorithms

The evaluation team determined ex post attic and wall insulation savings using the algorithms below. All variable assumptions are from the IL-TRM V5.0 unless otherwise referenced.

Equation 6. Attic Insulation Algorithms

Energy Savings: $\Delta kWh = \Delta kWh\_cooling + \Delta kWh\_heating$

$$\Delta kWh\_cooling = (((1/R\_old - 1/R\_new) * A\_attic * (1 – Framing\_factor_{attic})) * 24 * CDD * DUA)/(1{,}000 * \eta Cool) * ADJ_{WallAtticCool}$$

Demand Savings: $\Delta kW = (\Delta kWh\_cooling/FLH\_cooling) * CF$

Gas Savings (gas heat): $\Delta Therms = (((1/R\_old - 1/R\_new) * A\_attic * (1 – Framing\_factor_{attic}) * ADJ_{attic}) * 24 * HDD)/(\eta Heat * 100{,}067\ Btu/therm) * ADJ_{WallAtticHeat}$

$$\Delta kWh\_heating\ (gas\ heat\ furnace\ fan\ run\ time\ reduction) = \Delta Therms * F_e * 29.3$$

Equation 7. Wall Insulation Algorithms

Energy Savings: $\Delta kWh = \Delta kWh\_cooling + \Delta kWh\_heating$

$\Delta kWh_cooling = ((((1/R_old - 1/R_new) * A_wall * (1 – Framing_factor_{wall})) * 24 * CDD * DUA)/(1{,}000 * \eta Cool)) * ADJ_{WallAtticCool}$Demand Savings: $\Delta kW = (\Delta kWh\_cooling/FLH\_cooling) * CF$

Gas Savings (gas heat): $\Delta Therms = (((1/R\_old - 1/R\_new) * A\_wall * (1 – Framing\_factor_{wall}) * ADJ_{wall}) * 24 * HDD)/(\eta Heat * 100{,}067\ Btu/therm) * ADJ_{WallAtticHeat}$

$$\Delta kWh\_heating\ (gas\ heat\ furnace\ fan\ run\ time\ reduction) = \Delta Therms * F_e * 29.3$$

Where:

R_old = Total attic or wall assembly R-value prior to installing insulation. For attic insulation we used actual preexisting R-values provided in the program tracking database. The total assembly preexisting R-value for wall insulation is R-5 (per IL-TRM V5.0).

R_new = Total attic or wall assembly R-value after the installation of additional insulation. For attic insulation we used actual post-retrofit R-values provided in the program tracking database. The total assembly R-value for wall insulation is R-16 (which includes R-5 [uninsulated wall] and added R-11).

A_wall = Total area of insulated wall (sq. ft.)

A_attic = Total area of insulated attic (sq. ft.)

Framing_factor = Adjustment to account for area of framing

Table 37. Framing Factors for Attic and Wall Areas

Measure	Framing Factor
Attic Insulation	0.07
Wall Insulation	0.25

$ADJ_{WallAtticCool}$ = Adjustment for cooling savings from basement wall insulation to account for prescriptive engineering algorithms over claiming savings = 80%

$ADJ_{WallAtticHeat}$ = Adjustment for wall and attic insulation to account for prescriptive engineering algorithms over claiming savings = 60%

CDD = Cooling Degree Days (applied per participant based on project location)

Table 38. Cooling Degree Days by Climate Zone

Climate Zone	Conditioned CDD
1 (Rockford)	820
2 (Chicago)	842
3 (Springfield)	1,108
4 (Belleville)	1,570
5 (Marion)	1,370

DUA = Discretionary Use Adjustment = 0.75

ηCool = SEER of cooling system (applied per participant based on existing equipment age provided in database)

Table 39. ηCool for Attic and Wall Insulation Measures

Cooling Equipment Age	SEER
Before 2006	10.0
2006–2014	13.0
Central AC after 1/1/2015	13.0
Heap Pump after 1/1/2015	14.0

Cooling Equipment Age	SEER
Unknown[a]	11.6

[a] For measures where the cooling equipment age is not provided in the database (n=4), we calculated an average cooling efficiency based on SEER values derived from measures with cooling equipment age information (n=31).

HDD = Heating Degree Days (applied per participant based on project location)

Table 40. Heating Degree Days by Climate Zone

Climate Zone	Conditioned HDD
1 (Rockford)	5,352
2 (Chicago)	5,113
3 (Springfield)	4,379
4 (Belleville)	3,378
5 (Marion)	3,438

ηHeat = Efficiency of space heating equipment (applied per participant based on existing equipment age provided in database)

Table 41. ηHeat for Attic and Wall Insulation Measures

Existing Heating Equipment	Equipment Age	COP
Heat Pump	Before 2006	1.70
	2006–2014	1.92
	2015 and beyond	2.40
Electric Resistance	N/A	1.00
Gas Furnace	N/A	0.72

FLH_cooling = Full Load Cooling Hours (applied per participant based on project location)

Table 42. FLH_cooling by Climate Zone

Climate Zone	FLH_cooling
1 (Rockford)	512
2 (Chicago)	570
3 (Springfield)	730
4 (Belleville)	1,035
5 (Marion)	903

CF = Summer peak coincidence factor (varies by cooling equipment type)

Table 43. Coincidence Factors for Attic and Wall Insulation Measures

Cooling Equipment	CF
Central Air Conditioner	0.68
Heat Pump	0.72

F_e = Furnace fan energy consumption as a percentage of annual fuel consumption = 3.14%

A.6 Rim Joist Insulation Algorithms

The evaluation team calculated ex post rim joist insulation savings using the algorithms below. The IL-TRM does not provide algorithms specifically for rim joists; therefore, we applied the basement sidewall insulation algorithms to determine rim joist savings. All variable assumptions are from the IL-TRM V5.0 unless otherwise referenced.

Equation 8. Rim Joist Insulation Algorithms

Energy Savings: *ΔkWh = ΔkWh_cooling + ΔkWh_heating*

$$\Delta kWh\_cooling = (((((1/R\_old\_AG_{RimJoist}) - (1/(R\_added + R\_old\_AG_{RimJoist}))) * L\_rimjoist * H\_rimjoist * (1 - Framing\_factor)) * 24 * CDD * DUA)/(1{,}000 * \eta Cool)) * ADJ_{basementcool}$$

$$\Delta kWh\_heating\ (electric\ heat) = (((((1/R\_old\_AG_{RimJoist}) - (1/(R\_added + R\_old\_AG_{RimJoist}))) * L\_rimjoist * H\_rimjoist * (1 - Framing\_factor)) * 24 * HDD)/(3{,}412 * \eta Heat) * ADJ_{basementheat})$$

Demand Savings: *ΔkW = (ΔkWh_cooling/FLH_cooling) * CF*

$$\text{Gas Savings (gas heat): } \Delta Therms = (((((1/R\_old\_AG_{RimJoist})) - (1/(R\_added + R\_old\_AG_{RimJoist}))) * L\_rimjoist * H\_rimjoist * (1 - Framing\_factor)) * 24 * HDD)/(100{,}067 * \eta Heat) * ADJ_{basementheat})$$

$$\Delta kWh\_heating\ (gas\ heat\ furnace\ fan\ run\ time\ reduction) = \Delta Therms * F_e * 29.3$$

Where:

$R\_old\_AG_{RimJoist}$ = R-value of existing foundation wall assembly above grade

Table 44. Rim Joist above Grade R-Value

Variable	R-Value
$R\text{-value}_{Joist}$ (1.5")	1.88
$R\text{-value}_{outdoor\ air\ film}$	0.17
$R\text{-value}_{wallboard}$	0.45
$R\text{-value}_{indoor\ air\ film}$	0.68
Total R-value	3.18

Source: ASHRAE Fundamentals, 2013 Section 27.3.

R_added = R-value of additional insulation (per implementer) = R-11

L_rimjoist = Total linear feet of installed insulation (ft.)

H_rimjoist = Height of floor joist in which insulation is installed = 0.85 ft. (average of 2x10 and 2x12 framing)

Framing_factor = Adjustment to account for area of framing = 0.05 (average of joists going from front to back to house (1.5" for every 16" = 0.094) and the continuous joists from side-to-side (0).

$ADJ_{basementcool}$ = Adjustment for cooling savings to account for prescriptive engineering algorithms over claiming savings = 0.80

$ADJ_{basementheat}$ = Adjustment for heating savings to account for prescriptive engineering algorithms over claiming savings = 0.60

CDD = Cooling Degree Days (applied per participant based on project location)

Table 45. Cooling Degree Days by Climate Zone

Climate Zone	Unconditioned CDD
1 (Rockford)	263
2 (Chicago)	281
3 (Springfield)	436
4 (Belleville)	538
5 (Marion)	570

DUA = Discretionary Use Adjustment = 0.75

ηCool = SEER of cooling system (applied per participant based on existing equipment age provided in database)

Table 46. ηCool for Rim Joist Insulation Measures

Cooling Equipment Age	SEER
Before 2006	10.0
2006–2014	13.0
Central AC after 1/1/2015	13.0
Heap Pump after 1/1/2015	14.0
Unknown[a]	11.6

[a] For measures where the cooling equipment age is not provided in the database (n=2), we calculated an average cooling efficiency based on SEER values derived from measures with cooling equipment age information (n=31).

HDD = Heating Degree Days (applied per participant based on project location)

Table 47. Heating Degree Days by Climate Zone for Unconditioned Basement

Climate Zone	Unconditioned HDD
1 (Rockford)	3,322
2 (Chicago)	3,079
3 (Springfield)	2,550
4 (Belleville)	1,789
5 (Marion)	1,796

ηHeat = Efficiency of space heating equipment (applied per participant based on existing equipment age provided in database)

Table 48. ηHeat for Rim Joist Insulation Measures

Existing Heating Equipment	Equipment Age	COP
Heat Pump	Before 2006	1.70
	2006–2014	1.92
	2015 and beyond	2.40
Electric Resistance	N/A	1.00
Gas Furnace	N/A	0.72

FLH_cooling = Full Load Cooling Hours (applied per participant based on project location)

Table 49. FLH_cooling by Climate Zone

Climate Zone	FLH_cooling
1 (Rockford)	512
2 (Chicago)	570
3 (Springfield)	730
4 (Belleville)	1,035
5 (Marion)	903

CF = Summer Peak Coincidence Factor (varies by cooling equipment type)

Table 50. Rim Joist Insulation Coincidence Factors

Cooling Equipment	CF
Central Air Conditioner	0.68
Heat Pump	0.72

F_e = Furnace fan energy consumption as a percentage of annual fuel consumption = 3.14%

A.7 Crawl Space Insulation Algorithms

The evaluation team calculated the ex post crawl space insulation savings using the algorithms below. All variable assumptions are from the IL-TRM V5.0 unless otherwise referenced.

Equation 9. Crawl Space Insulation Algorithms

Energy Savings: *ΔkWh = ΔkWh_cooling + ΔkWh_heating*

$$\Delta kWh\_cooling = (((((1/R\_old\_AG) - (1/(R\_added + R\_old\_AG))) * LF * H\_AG * (1 - Framing\_factor)) * 24 * CDD * DUA)/(1{,}000 * \eta Cool)) * ADJ_{cool}$$

$$\Delta kWh\_heating\ (electric\ heat) = [(((((1/R\_old\_AG) - (1/(R\_added + R\_old\_AG))) * LF * H\_AG * (1 - Framing\_factor)) + ((1/R\_old\_BG - (1/R\_added + R\_old\_BG))) * LF * H\_BG * (1 - Framing\_factor))) * 24 * HDD]/(3{,}412 * \eta Heat) * ADJ_{heat})$$

Demand Savings: *ΔkW = (ΔkWh_cooling/FLH_cooling) * CF*

Gas Savings (gas heat): $\Delta Therms = [(((((1/R\_old\_AG)-(1/(R\_added + R\_old\_AG)))* LF * H\_AG * (1 - Framing\_factor)) +((1/R\_old\_BG - (1/R\_added + R\_old\_BG))) * LF * H\_BG * (1 - Framing\_factor))) * 24*HDD]/(100{,}067 * \eta Heat) * ADJ_{heat})$

$$\Delta kWh\_heating\ (gas\ heat\ furnace\ fan\ run\ time\ reduction) = \Delta Therms * F_e * 29.3$$

Where:

R_old_AG = Above-grade existing R-value of crawl space = 1.0

R_old_BG = Below-grade existing R-value of crawl space insulation (assume 2.0' below grade) = 5.41

R_added = R-value of additional insulation (per implementer) = R-11

ADJ_{cool} = Adjustment for cooling savings to account for prescriptive engineering algorithms over claiming savings = 0.80

ADJ_{heat} = Adjustment for heating savings to account for prescriptive engineering algorithms over claiming savings = 0.60

LF = Total linear feet of installed insulation (sq. ft.) (from database)

H_AG = Height of crawl space wall above grade = 1.0 foot

H_BG = Height of crawl space wall below grade = 2.0 feet

Framing_factor = Adjustment to account for area of framing = 0 (spray foam)

CDD = Cooling Degree Days (applied per participant based on project location)

Table 51. Cooling Degree Days by Climate Zone

Climate Zone	Unconditioned CDD
1 (Rockford)	263
2 (Chicago)	281
3 (Springfield)	436
4 (Belleville)	538
5 (Marion)	570

DUA = Discretionary Use Adjustment = 0.75

ηCool = SEER of cooling system (applied per participant based on existing equipment age provided in database)

Table 52. ηCool for Crawl Space Insulation Measures

Cooling Equipment Age	SEER
Before 2006	10.0
2006–2014	13.0
Central AC after 1/1/2015	13.0

Heap Pump after 1/1/2015	14.0
Unknown[a]	11.6

[a] For measures where the cooling equipment age is not provided in the database (n=2), we calculated an average cooling efficiency based on SEER values derived from measures with cooling equipment age information (n=31).

HDD = Heating Degree Days (applied per participant based on project location)

Table 53. Heating Degree Days by Climate Zone for Unconditioned Basement

Climate Zone	Unconditioned HDD
1 (Rockford)	3,322
2 (Chicago)	3,079
3 (Springfield)	2,550
4 (Belleville)	1,789
5 (Marion)	1,796

ηHeat = Efficiency of space heating equipment (applied per participant based on existing equipment age provided in database)

Table 54. ηHeat for Crawl Space Insulation Measures

Existing Heating Equipment	Equipment Age	COP
Heat Pump	Before 2006	1.70
	2006–2014	1.92
	2015 and beyond	2.40
Electric Resistance	N/A	1.00
Gas Furnace	N/A	0.72

FLH_cooling = Full Load Cooling Hours (applied per participant based on project location)

Table 55. FLH_cooling by Climate Zone

Climate Zone	FLH_cooling
1 (Rockford)	512
2 (Chicago)	570
3 (Springfield)	730
4 (Belleville)	1,035
5 (Marion)	903

CF = Summer Peak Coincidence Factor (varies by cooling equipment type)

Table 56. Crawl Space Insulation Coincidence Factors

Cooling Equipment	CF
Central Air Conditioner	0.68
Heat Pump	0.72

F_e = Furnace fan energy consumption as a percentage of annual fuel consumption = 3.14%

Appendix B. Cost-Effectiveness Inputs

Table 57 presents total gross impacts for AIC cost-effectiveness calculations. These values differ from those included in the main report due to the inclusion of heating penalties for lighting measures.[3] Overall, the application of waste heat factors reduces total gross therm savings by 3%.

Table 57. PY9 HES Program Gross Impacts (Including Heating Penalties)

	kWh	kW	Therms
Gross Savings	39,114	18.85	10,997
Lighting Heating Penalty	0	0	-284
Total Gross Savings with Heating Penalty	39,114	18.85	10,713

Lighting Heating Penalty

The inclusion of waste heat factors for lighting is based on the concept that heating loads are increased to supplement the reduction in heat that was once provided by the existing lamp type. We applied the heating penalty to 385 lamps based on heating fuel type and installed lamp type. The heating fuel type is natural gas for 73% (281 lamps) of the installed lighting measures. For the remaining 104 lamps with unknown space heating fuel types, we applied waste heat factors assuming gas heating as directed per the IL-TRM V5.0. We did not apply a heating penalty for non-gas and non-electric heating measures. The total heating penalty for lighting measures is 284 therms.

[3] Heating penalties are not included in savings calculations for goal attainment purposes per AIC and ICC Staff agreement.

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