Appendix G: Site Visit Reports

Project Level Results

The following table summarizes the project level results of the evaluation team's site visit analysis. Projects are listed by project identification number.

Table 1. Summary of Project-Level Site Visit Results

Project ID	Sample			Ex Ante Savings			Ex Post Savings			Realization Rate		
	Fuel Type	Wave	Stratum	kW	kWh	Therm	kW	kWh	Therm	kW	kWh	Therm
700021	Electric	1	3	590	4,240,078	0	452	3,245,402	0	77%	77%	N/A
700418	Electric	1	3	142	1,063,296	0	146	1,246,695	0	103%	117%	N/A
700659	Electric	1	1	7	42,682	0	1	13,014	0	12%	30%	N/A
700696	Gas	1	2	-13	-60,314)	40,749	-11	-48,367	23,696	83%	80%	58%
700773	Gas	1	2	52	529,329	19,408	7	58,974	0	13%	11%	0%
701170	Electric	1	3	164	1,433,398	0	164	1,433,398	0	100%	100%	N/A
800008	Gas	2	Certainty	0	0	250,000	0	0	304,947	N/A	N/A	122%
800026	Electric	1	3	763	6,683,947	0	768	6,727,252	0	101%	101%	N/A
800033	Electric	1	3	563	4,797,293	0	575	4,897,575	0	102%	102%	N/A
800040	Electric	1	2	49	551,997	0	41	376,047	0	84%	68%	N/A
800053	Electric	2	2	181	1,517,097	0	181	1,517,097	0	100%	100%	N/A
800059	Gas	2	2	0	0	34,839	0	0	52,054	N/A	N/A	149%
800070	Electric	2	2	561	4,917,561	0	646	5,659,299	0	115%	115%	N/A
800071	Electric	2	2	1,230	10,771,178	0	1,230	10,771,178	0	100%	100%	N/A
800073	Electric	1	3	248	1,858,538	0	258	2,257,496	0	104%	121%	N/A
800114	Gas	1	1	0	20,808	370	0	4,721	0	N/A	23%	0%
800121	Electric	1	1	0	20,738	433	0	26,870	433	N/A	130%	100%
800127	Electric	1	2	66	578,160	0	68	545,809	0	103%	94%	N/A
800207	Gas	1	2	0	0	11,069	0	0	8,214	N/A	N/A	74%

Project ID	Sample			Ex Ante Savings			Ex Post Savings			Realization Rate		
	Fuel Type	Wave	Stratum	kW	kWh	Therm	kW	kWh	Therm	kW	kWh	Therm
800223	Electric	1	2	66	688,609	0	66	750,080	0	100%	109%	N/A
800264	Gas	1	1	0	30,608	683	0	40,908	244	N/A	134%	36%
800291	Electric	1	3	93	815,644	0	72	626,590	0	77%	77%	N/A
800377	Electric	1	1	2	12,539	0	2	15,913	0	120%	127%	N/A
800397	Gas	1	2	0	0	21,982	0	0	9,443	N/A	N/A	43%
800546	Gas	1	2	0	0	5,920	0	0	3,881	N/A	N/A	66%
800575	Electric	2	2	193	1,692,730	0	64.4	655,820	0	33%	39%	N/A
800592	Electric	2	2	115	1,167,422	0	115.0	1,167,422	0	100%	100%	N/A
800596	Gas	2	2	0	0	6,658	0	0	8,701	N/A	N/A	131%
800597	Electric	2	1	28	187,137	0	31	247,761	0	113%	132%	N/A
800622	Electric	1	2	48	580,521	0	49	444,934	0	103%	77%	N/A
800715	Dual	1	E2/G2	52	456,854	18,140	53	467,692	18,140	102%	102%	100%
800793	Electric	2	1	14	70,306	0	13	62,566	0	90%	89%	N/A
800879	Gas	1	2	0	0	5,138	0	0	5,138	N/A	N/A	100%
800904	Electric	1	2	34	190,667	0	30	184,193	0	90%	97%	N/A
800926	Gas	1	2	0	0	13,104	0	0	945	N/A	N/A	7%
800962	Electric	1	1	1	12,190	0	3	26,331	0	216%	216%	N/A
801387	Gas	2	1	0	0	325	0	0	111	N/A	N/A	34%
900015	Dual	2	E1/G2	7	56,627	6,009	7	57,970	6,009	102%	102%	100%
Total				5,255	44,927,639	434,826	5,030	43,480,637	441,956	97% (weighted)	98% (weighted)	118% (weighted)

Note: Although site visit data includes both electric and gas savings where available, only the savings and realization rates associated with the fuel type for which the project was sampled are used for analysis of overall program results.

700021 Project Information

Project ID#:	700021
Measure:	Process Fan VFDs
Ex Ante Savings:	Industrial
Facility Type:	Process

Measure Description

This project includes the installation of VFDs on two existing 1500 HP process fans at an industrial facility. Prior to the completion of the project, the fans were run at full speed and dampers were used to control the airflow.

Summary of the Ex Ante Calculations

Custom calculations were included with the project documentation.

The project documentation includes the daily average current draw for each of the fan motors during 1-week periods before and after the completion of the project. The data from before the completion of the project is from May 4, 2014 thru May 10, 2014, and the post-implementation data is from November 16, 2015 to November 22, 2015. The fans operate on 4160V circuits, and the power factor is assumed to be 0.80. The average demand of each fan during the pre- and post-implementation metered periods were determined with the following equation:

$$Demand\ (kW) = \frac{Amps \times Volts \times Power\ Factor \times \sqrt{3}}{1000}$$

With this, the total average baseline demand of the fan motors was found to be 1,829.47 kW, and the total average post-implementation demand was found to be 1,239.09 kW, a reduction of 590.38 kW. This is the ex ante demand savings for this project.

To determine the annual energy use of the fan motors, the calculated average demand is multiplied by the annual operating hours, which is specified to be 7,182. With this, it was found that prior to the completion of the project the fan motors had an annual energy consumption of 13,139,247 kWh, and with the installed VFDs the annual energy consumption was reduced to 8,899,168 kWh, yielding savings of 4,240,078 kWh. This is the ex ante energy savings for this project.

The ex ante calculations are summarized below in Table 2 and the ex ante savings are summarized in Table 3.

Table 2. Summary of Ex Ante Calculations

	Fan #420	Fan #481
Average Baseline Amps	130.8	186.6
Average VFD Amps	97.6	117.4
Annual Operating Hours	7,182	7,182
Baseline Demand (kW)	753.9	1,075.5
VFD Demand (kW)	562.3	676.8
Baseline Annual Energy Use (kWh)	5,414,770	7,724,477
VFD Annual Energy Use (kWh)	4,038,573	4,860,595

Table 3. Summary of Ex Ante Savings

	Demand Savings (kW)	Annual Energy Savings (kWh)	Gas Savings (Therms)
Process Fan VFDs	590.38	4,240,078	0

Measurement and Verification Plan

IPMVP Option A, partially measured retrofit isolation, was used to establish savings for this project. The evaluation team established the following measurement and verification (M&V) plan for this site:

A site visit will be performed during which the installation of the new VFDs will be verified by inspection. The customer will be asked to verify that the fans used dampers to control the airflow prior to the completion of the project. If possible, the fan motor nameplate will be checked to verify they are 1500 HP each. The customer will be interviewed about the control and operation of the fans, including the operating schedule, if there are any seasonal variations in the operation of the fans, if there have been any significant changes in the production levels of the facility since the completion of the project that would affect the operation of the fans, and what inputs are used to modulate the speed of the fans. We will ask the customer if trended data of the operation of the fans is available from the most recent months, and if any additional data is available about the operation of the fans prior to the completion of the project. If trended data of the current draw of the fans is available, the customer will also be asked if the voltage and power factor is measured and trended as well.

Description of Verification

The evaluation team completed a site visit on July 26, 2016. This project was the installation of VFDs on two roller mill fan motors in a cement plant. The plant operates 24 hours per day, 7 days per week.

These specific fan motors are estimated to run 7,182 hours per year. Essentially the fans run 24//7 but there are times when the production demand or maintenance needs mean the fans will be shut down. The site contact explained that the demand for material will be less in winter months.

The new VFD drives allow the fan dampers to run wide open all the time. The site contact provided trend data for fans after the retrofit and these showed the dampers were 100% open. This can be compared to values seen on the site log pre-retrofit that showed dampers at 50-60% open. The site contact explained that the production process is limited by the kiln operation and not the roller mills. The mills can be run at maximum production and the product can be stored in stock piles until needed. The mills pull fine dust from the roller mills based on weight so once it has been crushed to an appropriate size it will be pulled from the mill. The plant engineer explained that with the dampers wide open the motors actually run fewer hours for the same amount of product.

Both fans and VFDs were physically verified. One fan motor is rated at 1500 HP with a 1.15 safety factor. The other motor is rated at 1750 HP with a 1.10 safety factor. There is a third 1500 HP motor that serves as a spare. A spot-check of the VFD controllers showed the values in Table 4. The power factor assumed in the calculations was 0.80 which is slightly higher than the values observed in the spot check.

Table 4. Summary VFD Settings Obtained On Site

	Frequency (Hz)	% Speed	Leg 1 Amps	Leg 2 Amps	Leg 3 Amps	Power Factor	kW
Fan 1 (Assumed 420)	51.5	85.9	114	115	113	.74	603
Fan 2 (Assumed 481)	51.8	86.4	141	138	142	.75	758

The data provided in the project documentation did not include process information. It was not obvious that the load on the motors were similar in the baseline and proposed cases. While the site contact was able to provide post retrofit data that included the feed rate to the roller mill, he could not do that for the pre-retrofit condition. An additional nine days of post-retrofit data was obtained after the site visit.

Summary of Ex Post Savings Calculations

We determined the ex post savings for this project using the trended data provided with the project documentation and the information collected during the site visit. The ex post savings calculations used the same methodology as the ex ante calculations. The power factors were reduced to the values observed during the site visit and shown in Table 3. The additional post-retrofit data was averaged with the ex ante post-retrofit data. The result is that the average fan amps increased for both fans in the retrofit condition. The baseline demand and VFD demand decreased due to the lower power factor. A summary of the ex ante and ex post data and calculations is provided in Table 5.

Table 5. Summary of Ex Ante and Ex Post Data and Calculations

	Ex Ante		Ex Post	
	Fan #420	Fan #481	Fan #420	Fan #481
Average Baseline Amps	130.8	186.6	130.8	186.6
Average VFD Amps	97.6	117.4	106.7	126.7
Annual Operating Hours	7,182	7,182	7,182	7,182
Power Factor	0.8	0.8	0.740	0.750
Baseline Demand (kW)	753.9	1,075.5	697.4	1,008.3
VFD Demand (kW)	562.3	676.8	568.9	684.9
Baseline Annual Energy Use (kWh)	5,414,770	7,724,477	5,008,662	7,241,697
VFD Annual Energy Use (kWh)	4,038,573	4,860,595	4,086,003	4,918,954

We calculated ex post savings using the data from Table 5,. The ex ante and ex post savings for this project are summarized below in Table 6.

Table 6. Summary of Project Savings

	kW	kWh	Therms
Ex Ante	590.38	4,240,078	0
Ex Post	451.88	3,245,402	0
Realization Rate	76.5%	76.5%	N/A

700696 Project Information

Project ID#:	700696
Measure:	Air Turnover Units
Ex Ante Savings:	Warehouse
Facility Type:	HVAC

Measure Description

This project includes the replacement of unit heaters in a warehouse with (3) air turnover units. The warehouse has an area of 304,215 square feet and 22 foot ceilings.

Summary of the Ex Ante Calculations

Custom calculations were included with the project documentation.

The savings for this project were determined by calculating the pre-implementation and post-implementation envelope heating loss of the building. The calculations assume an average heating season outdoor air temperature of 40ºF, 5,400 hours per year of heating system operation, and a heating system efficiency of 80%. The baseline air stratification inside the building is estimated to be 1ºF per foot prior to the completion of the project, and with the completion of the project the air at the roof is estimated to be 2ºF warmer than the air at ground level. To determine the total heat loss of the building, the heat transfer through the roof, exterior walls, and the slab floor is calculated with the following equation:

$$Heat\ Loss = \frac{1}{R - value} \times Area \times \left(T_{setpoint} + T_{stratification} - OAT\right)$$

In the heat loss calculations it is assumed that the roof has an R-value of 17, the walls have an R-value of 12, and the slab floor has an R-value of 0.8. The baseline temperature stratification value for the roof heat loss is 22ºF, and that for the heat loss through the walls is 11ºF (half the stratification for the roof). The temperature stratification value for the floor is 0ºF, and the temperature set point for the facility is specified to be 68ºF.

The ventilation heat loss was calculated with the following equation:

$$Heat\ Loss = Vent_{CFM/sf} \times Area \times T_{setpoint} + T_{stratification} - OAT$$

The baseline temperature stratification for ventilation is 11ºF, and the ventilation rate is specified to be 0.0675 CFM per square foot.

The total baseline heat loss rate of the facility was multiplied by 5,400 hours per year, and with a heating system efficiency of 80% the baseline annual gas use of the facility was found to be 128,850 therms.

To determine the post-implementation energy use, the same equations were used but the roof temperature stratification was reduced to 2ºF, and the wall and ventilation temperature stratification was set to 1ºF. The resulting post-implementation annual gas use is 88,101 therms, a reduction of 40,749 therms compared to the baseline gas use. This is the ex ante annual gas savings for this project.

The ex ante calculation assumes the air turnover units installed with this project have a total fan motor power of 21 HP, whereas the unit heaters that were removed had a total fan motor power of 4 HP. Because the fan motors of the new units are larger, they are expected to use more electricity than the unit heaters did. To determine the annual energy use of the fan motors, the following equation was used:

$$Energy\ use\ (kWh) = Fan\ HP \times \frac{0.746\ kW}{HP} \times Load\ Factor \times Hours$$

The project documentation indicates that the unit heater fans operate an estimated 1,400 hours per year, whereas the air turnover unit fans operate 5,400 hours per year. A load factor of 75% was assumed for the unit heaters, and no loading factor was used in the energy calculation for the air turnover units. With this the fan energy consumption of the unit heaters was found to be 3,133 kWh per year, and the fan energy consumption of the air turnover units was found to be 63,447 kWh, an increase of 60,314 kWh. Because the fan energy use increased as a result of this project, it is a savings penalty (negative) for this project. The ex ante demand penalty for this project is simply the difference in the demand of the fan motors between the unit heaters and the air turnover units, which increased from 2.98 kW to 15.67 kW.

The ex ante savings for this project are summarized in Table 7.

Table 7. Summary of Ex Ante Savings

	Demand Savings (kW)	Annual Energy Savings (kWh)	Gas Savings (therms)
Air Turnover Units	-12.68	-60,314	40,749

Measurement and Verification Plan

The evaluation team used IPMVP Option C, Whole Facility, to establish savings for this project. We developed the following M&V plan for this project.

A site visit will be performed during which the installation of the new air turnover units will be verified by inspection. The customer will be asked about the unit heaters that were in place prior to the completion of the project, and the control and operation of the new units:

- How were the unit heaters controlled?
  - If thermostat control, where was the thermostat located? Were there any temperature sensors besides what is built into the thermostat?
  - Was there any night setback control?
  - Where were unit heaters located?
  - Are the model numbers of the unit heaters available?
- How are the air turnover units controlled?
  - Do the fans operate continuously during the heating season?
  - Are the air turnover units used during the cooling season for air circulation, air conditioning, etc.?
  - If thermostat control, were any additional temperature sensors installed? Is there any night setback or is the temperature manually adjusted back at night?
  - If EMS control, are trends of the operation of the units available?
- Is the thermal efficiency of the new units specified in the product literature or on the unit nameplates?

- Have any additional changes been made to the facility since the completion of the project that would affect the electric and gas use of the facility?
- When was the project work completed?

The project documentation includes billed electricity and gas use information from prior to the completion of the project, which shows that between November 2013 and October 2014 the facility used 603,176 kWh and 87,146 therms. The ex ante electric penalty for this project is approximately 10% of the billed electricity use during this 12-month period, and the ex ante gas savings is approximately 47% of the gas use during this 12-months period, so the electric penalty and the gas savings resulting from this project should be clearly visible in the bills for the facility.

Description of Verification

The evaluation team completed a site visit on July 27, 2016. The project vendor provided information and guided the walk through. His understanding was that the building was unoccupied prior to the installation. However, utility records show significant gas and electric usage. An additional attempt was made to ask the customer about prior usage of the building but no additional information was obtained. Therefore, it is not clear what the gas and electric usage was intended for prior to the installation of the air turnover units.

The space does not have air conditioning. During the site walk through the old unit heaters were observed abandoned in place. The model numbers of the units were not available. The thermostats for the unit heaters were located on nearby I-Beams approximately 14 feet off the floor. There were no automatic setback controls or additional sensors for the unit heaters.

The facility is intended for small parts assembly and painting. Additional equipment was installed that was not part of this project. Large paddle ceiling fans were installed over a work area that was approximately 10% of the overall space. These fans will provide destratification as well but were not included in the application. It appeared they were used to create air movement and cooling in summer. Paint booths were installed and assembly areas were set up. New lighting with occupancy sensors was also installed. The new paint booths will affect the gas usage by increasing the amount of make-up air that is conditioned.

The new air turnover units were physically verified. The units were installed in December of 2015. The vendor confirmed the units are natural gas indirect fired units rated at 82% efficiency. The units do not provide DX cooling and do not pull in any outdoor air. The return air is located at the bottom of the unit and air discharges out of the top. The air flow is sized for 2.5 air changes per hour.

There are two thermocouples located in the air inlet. One is for occupied hours and should be set for 65 F in winter and the second is for night setback and should be set for 55°F in winter. The occupants can adjust the temperatures themselves so they could be set higher or lower than those assumed settings.

In winter, the fans are set in auto mode and only come on when the units call for heating. There is a timeclock on the units so the units can be scheduled, but the vendor was not able to bring up the schedule. There is no building energy management system so no operating trends could be obtained. In summer, the units are controlled manually to create air movement. During the site visit the outdoor air temperature was in the high 80's and the units were running.

The vendor explained that the savings analysis did not use the existing unit heaters as the baseline. They used new Reznor unit heaters sized based on ASHRAE 90.1 requirements. The units included in the baseline calculations were 92% efficient with ½ HP motors. A Reznor unit with an 80% efficiency rating and similar heat output have 1 HP motors. This is the baseline efficiency required by code for unit heaters.

The vendor confirmed the assumption that air stratification of 1ºF per foot of wall height would occur without destratification fans.

Calculation Description

We obtained billing data for this project. Since the project was completed in December 2015 there were only three months of heating data. In addition since the usage was not clear in the base case, the regression analysis would not be helpful in estimating savings.

The ex post savings were calculated using bin data and the reduction in temperature differential achieved by destratification. There were some key differences in the assumptions used as well. The assumptions used in the ex post analysis were based on measurements taken during the site visit. A summary of the key differences in assumptions is included in Table 8.

Table 8. Summary of Ex Post Savings

Assumptions	Ex Ante	Ex Post	Unit
Footprint	304,215	310,508	sqft
Building Height	22	24	ft
Perimeter	2,480	2,229	ft
Total Wall Area	48,537	42,413	sqft
Heating Season Hours	5,400	4,580	hrs/yr
Temp Set Point	68	65	ºF
Ceiling Temp Base	90	84	ºF
Ceiling Temp Proposed	70	65	ºF
Average Wall Temp Base	79	76	ºF
Average Wall Temp Proposed	69	65	ºF
Winter OAT	40	Bin Data	ºF
Ventilation Load	0.0675	Ignored	cfm/sqft
ATU Efficiency	80	82	%
Baseline Unit Htr Eff	92	80	%
Baseline Fan Motors	4	8	HP
Proposed Fan Motors	21	21	HP

The main reason the electrical impact changed is that the ex ante baseline unit heaters were above code minimum efficiency and had smaller motors. The motors were twice as large in the ex ante analysis as the ex post analysis.

The changes in heating load were based on multiple factors. The ventilation heating load in the ex post case was ignored because there was no outdoor air supplied by the air turnover units. The heating season hours were higher in the ex ante case than in the ex post case. The temperature differentials used in the equations were different as well. The methodology used in the ex ante case was based on bin data while the ex ante calculation used an average winter temperature. Finally, the ex ante calculation was not based on the entire wall but only the area above the thermocouple for the heaters.

A summary of the ex post savings can be found in Table 9.

Table 9. Summary of Ex Post Savings

	kW	kWh	Therms
Ex Ante	-12.68	-60,314	40,749
Ex Post	-10.56	-48,367	23,696
Realization Rate	83.3%	80.2%	58.2%

800008 Project Information

Project ID#:	800008
Measure:	Regenerative Thermal Oxidizer
Ex Ante Savings:	Industrial
Facility Type:	Process

Measure Description

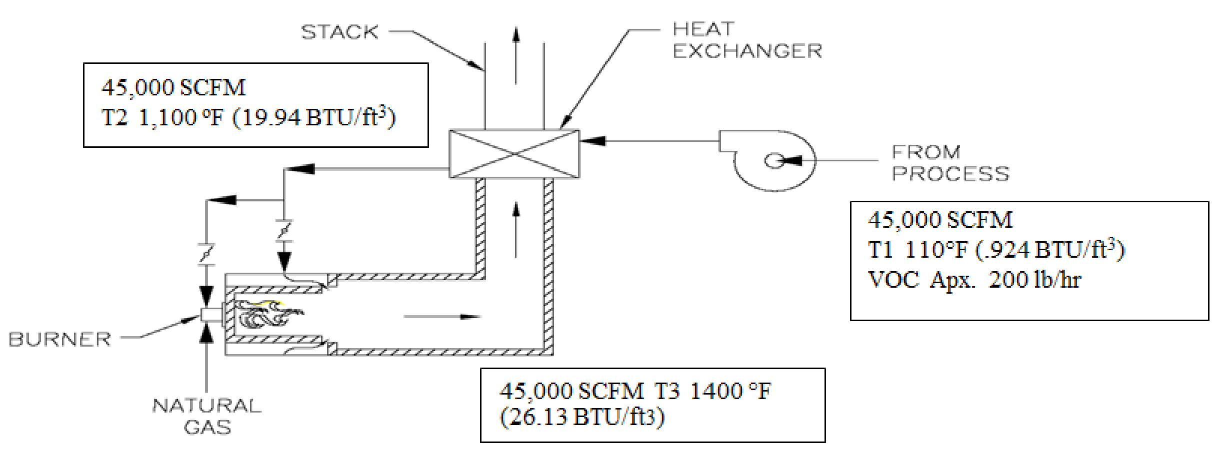
This project includes the installation of a regenerative thermal oxidizer (RTO) at an industrial facility. The RTO is being installed rather than a recuperative thermal oxidizer to burn off Volatile Organic Compounds (VOCs) from printing processes.

Summary of the Ex Ante Calculations

Custom calculations were included with the project documentation.

The baseline for this project is a recuperative thermal oxidizer with a heat exchanger effectiveness (HEX) of 76.7%. The gas use calculations utilize a combustion chamber air temperature (T_3) of 1,400°F with a specific enthalpy (T_{3H}) of 26.13 Btu/ft^3 and an airflow rate of 45,000 SCFM, a process airflow of 45,000 SCFM at a temperature (T_1) of 110°F and a specific enthalpy of 0.924 Btu/ft^3 with a VOC flow of 200 lbs/hr, and a heat exchanger outlet flow rate of 45,000 SCFM with a temperature (T_2) of 1,100°F and a specific enthalpy of 19.94 BTU/ft^3. The following diagram was included with the calculations:

Figure 1 Recuperative Thermal Oxidizer Diagram



The following equation was used to determine the baseline gas use:

$$Gas\ Use\ (therms) = \left(T_{3H} \times Flow \times \frac{60min}{hour} \times (1 - HEX)\right) - VOC \times Q_{VOC}$$

The result is a baseline gas use of 137.8 therms per hour. The unit is expected to operate 15 hours per day, 7 days per week, 52 weeks per year, which is equivalent to 5,460 hours per year. The resulting annual baseline gas use is 752,454 therms.

The post-implementation gas use for the project was determined using guidance from a publication of the Institute of Clean Air Companies (ICAC). The following equations are used in the analysis:

$$Q_I = F_1 \times 1.10 \times (T_O - T_I)$$

$$Q_{CC} = F_{CC} \times 1.10 \times (T_O - T_A)$$

$$Q_{RL} = surface\ area\ of\ shell\ (ft^2) \times \frac{200BTU/hr}{ft^2}$$

$$Q_{VOC} = VOC \times H_C \times (\%DEST/100)$$

$$Total\ Energy\ Consumption\ (Q_T) = Q_I + Q_{CC} + Q_{RL} - Q_{VOC}$$

Where:

Q_I = the energy required to raise the temperature of the process air (with VOCs) from inlet temperature to average outlet temperature (BTU/hr)

Q_{CC} = the energy required to heat the combustion air to the required temperature (BTU/hr)

Q_{RL} = the radiation heat loss from the RTO (Btu/hr)

Q_{VOC} = the energy released from the oxidation of VOCs (BTU/hr)

F_1 = process air flow (SCFM)

F_{CC} = combustion air flow (SCFM)

T_I = RTO inlet air temperature (°F)

T_A = Ambient or combustion air temperature (°F)

T_O = average RTO outlet air temperature (°F)

1.10 = conversion factor

VOC = flow of VOCs to oxidizer, lbs/hr

H_C = Heat of Combustion of VOCs (weighted average)

%DEST = guaranteed destruction rate of VOCs

For the ex ante savings calculations the process air flow (F_1) is 45,000 SCFM, the combustion air flow (F_{CC}) is 1,000 SCFM, the RTO inlet temperature (T_1) is 110ºF, the ambient air temperature (T_A) is 80ºF, and the average RTO outlet temperature (T_O) is 250ºF. The weighted average heat of combustion of VOCs is specified to be 12,000 Btu/lb, the VOC flow rate is 100 lbs/hr, and the guaranteed VOC destruction rate is 98%. Using these values, the annual gas consumption of the RTO was found to be 422,014 therms.

The difference between the gas use of the recuperative thermal oxidizer and the regenerative thermal oxidizer is 330,440 therms, and an uncertainty factor of 75.66% was applied to yield an adjusted ex ante savings of 250,000 therms per year.

The ex ante savings are summarized in Table 10.

Table 10. Summary of Ex Ante Savings

	Demand Savings (kW)	Annual Energy Savings (kWh)	Gas Savings (therms)
Regenerative Thermal Oxidizer	0	0	250,000

Measurement and Verification Plan

The IPMVP Option used to analyze this project was dependent on the information provided by the customer. The evaluation plan developed the following M&V plan for this project.

If a recuperative thermal oxidizer was in place prior to the completion of this project and no other significant changes have been made at the facility that would affect the billed gas use, IPMVP Option C will be used. Otherwise, IPMVP Option A, partially measured retrofit isolation, will be used to establish savings for this project.

A site visit will be performed during which the installation of the new RTO will be verified by inspection. The customer will be asked about the system that was in place prior to the completion of the project, and if any information is available about its operation or gas use. This may include but is not limited to the heat exchanger inlet and outlet temperatures (if a recuperative thermal oxidizer system was in place), the rate at which VOCs were burned off, the airflow rates thru the system, and the effectiveness of the system. The customer will also be asked about the operation and control of the new system, and if any trended data is available of the operation of the unit, such as trends of temperature readings, airflow rates, gas use, air temperatures, or VOC levels. The customer will be asked if there are any seasonal variations in the production levels of the facility and the operation of the RTO, and if there are any other systems in place to burn VOCs, such as other RTOs or recuperative thermal oxidizers. If so, they will be asked how the airflow going to each machine is controlled.

If a recuperative thermal oxidizer was in place previously and no other significant changes have been made at the facility that would affect the gas use, the customer will be asked if the RTO is on its own gas meter, and if so, the meter number will be recorded and the customer will be asked if they can provide gas billed data for the RTO. If additional equipment that uses gas is on the same meter as the RTO, the customer will be asked to provide details about the gas use of the other equipment to ensure the other equipment has no impact on the gas savings determined for the installation of the RTO. The customer will be asked about when the project work was started and completed, so that the correct pre/post cutoff point in the billed use can be determined.

Description of Verification

A site visit was completed on July 18, 2016. The site representative explained that the new regenerative thermal oxidizer was not installed to replace an existing system, but was installed as part of a process change – the facility replaced a water-based printing system with a solvent-based printing system, and a thermal oxidizer was not needed for the water-based system. The site representative also explained that the system is in operation continuously, and there are no seasonal variations in the operation of the equipment or the production levels of the facility. At the time of the site visit it was found that the bed temperature of the RTO was 1488ºF and the natural gas valve position was at 2.8% open. Trended data of inlet and outlet temperatures were gathered, along with trends of the blower fan motor VFD speed.

Calculation Description

The calculations completed for the ex ante savings were reviewed, and the methodology used in the calculations was found to be sound. The ex ante calculations were used as a starting point for the ex post savings calculations.

The trended data provided by the site representative shows that the average inlet temperature of the regenerative thermal oxidizer is 94.65ºF, and the average operating outlet temperature is 190.42ºF. The trends were also used to determine that the average blower fan motor speed is 47%. In the savings calculations the rated airflow rates of the oxidizer system were multiplied by 47% to determine the average operating airflow rates. The operating hours in the savings calculations was also updated to reflect continuous operation (8,760 hours/year). All other variables used in the savings calculations that could not be verified or recorded during the site visit were checked and found to be reasonable. The system was found to run more hours per year at lower loading that what is specified in the ex ante savings calculations, which causes a decrease in the savings for this project.

Finally, the uncertainty factor used in the ex ante savings calculations was removed, causing the savings for this project to increase.

With these adjustments made to the savings calculations, it was found that the baseline recuperative thermal oxidizer system would have an annual gas consumption of 446,585 therms, and the installed regenerative thermal oxidizer is expected to have an annual gas consumption of 141,638 therms.

The resulting annual gas savings for this project is 304,947 therms. The ex post gas savings for this project are greater than the ex ante savings because the uncertainty factor was removed from the savings calculations, and because the system was found to be in operation more hours per year than what is specified in the ex ante savings calculations.

The ex ante and ex post savings for this project are summarized below in Table 11.

Table 11. Summary of Project Savings

	kW	kWh	Therms
Ex Ante	0	0	250,000
Ex Post	0	0	304,947
Realization Rate	N/A	N/A	122%

800026 Project Information

Project ID#:	800026
Measure:	ECM 1: Refurbish/Replace Cooling Tower Pumps ECM 2: Reducing Head Pressure ECM 3: Pump Efficiency Increase from System Pressure Reduction
Ex Ante Savings:	Industrial
Facility Type:	Process Cooling

Measure Description

This project includes the completion of three process cooling system measures at an industrial facility. A summary of these measures and the resulting savings are provided below.

- **ECM 1: Refurbish/Replace Cooling Tower Pumps** - This measure consists of the refurbishment or replacement of cooling tower pumps. The project documentation indicates that the existing pumps have an operational efficiency of 67%, and that refurbishment or replacement of the pumps with the same size impeller will result in an operational efficiency of 82.8%. Trended data included with the project documentation shows that there are a total of (31) pumps, and that (23) of them are typically in operation at a time. The project documentation also specifies that the pumps operate to provide approximately 140,000 GPM and the average total current supplied to the pump motors is 5,364 Amps.

- **ECM 2: Reducing Head Pressure** - This measure consists of reducing the condenser water head pressure by 2.1 PSI, which will result in the flow rate provided by the operating pumps to increase. This will in turn allow (1) pump to turn off, so (22) pumps will typically operate at a time rather than (23) at a time. The energy savings for this measure is equal to the annual energy use of the (1) pump that no longer operates as a result of the completion of the measure.

- **ECM 3: Pump Efficiency Increase from System Pressure Reduction** - This measure covers secondary savings resulting from the completion of ECM 2. The reduction in the condenser water head pressure will cause the operating pumps to run more efficiently. The project documentation states that the head pressure reduction will cause the efficiency of the operating pumps will increase from 82.8% to 84.2%, thus they will require less energy to provide the same flow of condenser water.

Summary of the Ex Ante Calculations

Custom calculations were included with the project documentation.

The project documentation includes approximately two months of trended data of the current draw of each pump motor involved in this project – one month of data from before the completion of the project, and 1 month of data from afterwards. The trended data is at one hour intervals, and is from March 2, 2015 to April 1, 2015 for the baseline, and March 2, 2016 to April 1, 2016 for the post implementation period.

With both the pre-implementation and post-implementation trended data, the total pump demand during each 1-hour trend interval was determined using the following equation:

$$Demand\ (kW) = Amps \times Volts \times Power\ Factor \times \sqrt{3}$$

The power factor used in the energy calculations is 0.85 and the voltage is 460V.

The average pre-implementation demand of the pumps was found to be 3,844.48 kW and the average post-implementation demand was found to be 3,081.47 kW, a reduction of 763.01 kW. This is the ex ante demand savings for this project. The project documentation indicates that the condenser water system involved in this project operates continuously (8,760 hours/year), so to determine the annual energy savings the average demand savings was multiplied by 8,760 hours, yielding 6,683,947 kWh. The ex ante savings for this project are summarized below in Table 12.

Table 12. Summary of Project Savings

	Demand Savings (kW)	Annual Energy Savings (kWh)	Gas Savings (therms)
ECM 1: Refurbish/Replace Cooling Tower Pumps	763.01	6,683,947	0
ECM 2: Reducing Head Pressure			
ECM 3: Pump Efficiency Increase from System Pressure Reduction			

Measurement and Verification Plan

The evaluation team used IPMVP Option A, partially measured retrofit isolation, to establish savings for this project. Below we outline the M&V plan developed for the project.

A site visit will be performed during which the condenser water system will be inspected, and the customer will be interviewed about its operation and control. Specifically, the customer will be asked if there are any seasonal variations in the operation of the process cooling system, if the condenser water head pressure is ever changed throughout the year or if any sort of reset schedule is used to control the head pressure, and if any additional changes have recently been made to the system. If any additional changes have been made to the system, the customer will be asked to provide details so that any effects the changes may have on the energy use of the condenser water pumps can be accounted for in the ex post analysis.

The customer will be asked if a full year of trended data of the operation of the condenser water pumps is available from prior to the completion of the project, which could be used to quantify any seasonal variations in the operation of the pumps. The customer will also be asked if trended data is available from the most recent months of operation. If trended data of the power factor and voltage of the condenser water pumps is available, that will also be requested.

The customer will be asked to confirm that a total of (31) condenser water pumps were involved in this project. The sizes of the pumps involved in this project will be collected, to ensure that the trended amperage is reasonable for each pump.

Description of Verification

We completed a site visit on August 19, 2016. The site representative was interviewed about the control and operation of the cooling tower pumping system, and they explained that pumps are manually enabled and disabled by the system operator based on the demand of the system. The cooling system is used for process cooling only, and is in operation all the time. The pumps involved in this project serve 14 cooling tower cells, and all run in parallel. The pumps and pump motors were inspected, and it was found that each pump is rated at 7,000 GPM at a rated head of 107 feet and 1,180 RPM. Each pump is driven by a 250 HP motor with a rated efficiency of 95.0%. The pumps are all single-speed, and do not have any throttling valves or other flow control mechanisms.

We asked the site representative about any seasonal variations in the operation of the cooling tower pumps, and they explained that fewer pumps run during the winter, but that throughout the year there are usually 25 to 28 pumps running at any given time. The site representative was also asked about the efficiency of the pumps before and after the completion of the project. The customer explained that the baseline efficiency was determined from in-field testing done by the contractor for the project, and that the post-case efficiency is the original manufacturer's rated efficiency for the pumps, as all of the pumps were brought back to factory specs with the rebuilding that was done. The control screen for the cooling tower loop showed a pump differential pressure of 45 PSI. The site representative specified that the power factor throughout the facility is typically 0.85.

The site representative was asked if updated trends of the current provided to each of the condenser water pump motors could be gathered, but he explained that because more extensive trends are not available from prior to the completion of the project, they would be unable to provide trends that would be of any use for analysis of the project savings. Additionally, he noted that the trended data provided in the project documentation is from a "shoulder" month, so it can be considered representative of the average operation throughout the year.

Calculation Description

We determined the ex post savings for this project using the trended data provided with the project documentation and the information collected during the site visit. Trended data was included with the project documentation that specifies the current draw of each of the condenser water pump motors. The trended data has a time interval of one hour and includes one month of data from before the project was completed and 1 month of data from after the project was completed. Using the pre-implementation data, the total current draw of the pumps at each sample point was found, and it was determined that over the trended data period, the pump motors had an average total current draw of 5,680 Amps. Using 460 Volts, a power factor of 0.85, and 8,760 hours per year of operation, it was found that the baseline pumps use 33,697,571 kWh and have an average electrical demand of 3,847 kW. Completing a similar analysis using the post-implementation trended data yields an average current draw of 4,546 Amps, annual energy use of 26,970,319 kWh, and an average electric demand of 3,079 kW. The resulting savings for this project are 768 kW and 6,727,252 kWh.

The ex post savings calculations are very similar to the ex ante calculations. In the trended data provided in the project documentation, a pump not in operation was represented in the trended current data with a "1". These "1" placeholders were used in the ex ante savings calculations as an actual current draw measurement for the pump motors, whereas in the ex post savings calculations the placeholder "1"s were removed from the trended data, as it is expected that the pump motors have no current draw when not in operation. This causes a reduction in both the pre-case and post-case calculated energy use, but the post-case energy use reduction was larger than the pre-case energy use reduction. This results in a small increase in the savings for this project.

The ex ante and ex post savings for this project are summarized below in Table 13.

Table 13. Summary of Project Savings

	kW	kWh	Therms
Ex Ante	763.01	6,683,947	0
Ex Post	767.95	6,727,252	0
Realization Rate	100.6%	100.6%	N/A

700004 Project Information

Project ID#:	800033
Measure:	Replace Bean Flaking Rolls
Ex Ante Savings:	Industrial
Facility Type:	Process

Measure Description

This project includes the completion of one process measure at an industrial facility. This measure involves the replacement of (6) existing Bauermeister double stand flaking rolls with (6) new Buhler single stand flaking rolls. Per the manufacturer's specifications, the new flaking rolls use 6.75 kWh per metric ton of material processed, whereas the existing flaking rolls use approximately 11.3 kWh per metric ton (mt).

Summary of the Ex Ante Calculations

Custom calculations were included with the project documentation.

The project documentation includes operating data for three of the existing Bauermeister flaking rolls, and shows that they have an average operating current draw of 139.3 Amps and each process 212.6 metric tons per day. Trended data of the current draw for all six of the new Buhler flaking rolls from October 22, 2015 to November 4, 2015 was also included in the project documentation, which shows they operate with an average current draw of 209.8 Amps, and the units are specified to each process an average of 544 metric tons per day. The project documentation does not specify what voltage or power factor was assumed in the energy calculations, but show that the specific energy use of the existing units is approximately 11.3 kWh per metric ton, and the specific energy use of the new units is 6.63 kWh per metric ton. The specific energy use of the new units (6.63 kWh/mt) is slightly less than what is specified by the equipment manufacturer (6.75 kWh/mt), so the manufacturer-specified value was used in the ex ante calculations to provide a conservative savings estimate.

The flaking rolls are expected to operate for 8,520 hours per year (24 hours/day, 355 days/year). The facility has a total of 14 bean flaking rolls, and the 6 new flaking rolls have a larger capacity than the 6 units being replaced. Because of the larger capacity of the new units the customer was able to shift some of the production load from the remaining eight older machines to the newer machines in order to maximize the energy savings from this project. To determine the post-implementation energy use of the flaking rolls, the expected average operation of the new flaking rolls (495 mt/day) was used along with their rated energy use of 6.75 kWh/mt in the following equation:

$$Annual\ Energy\ Use(kWh) = Qty \times MT/day \times Days/yr \times kWh/MT$$

This equation was also used to determine the baseline energy use for this project, wherein the specific energy use was changed to 11.3 kWh/mt. These calculations yield a baseline annual energy use of 11,914,155 kWh and a post-implementation annual energy use of 7,116,863 kWh. The resulting savings is 4,797,293 kWh. Because the bean flaking rolls operate nearly continuously, the demand savings is determined simply from the hourly processing capacity multiplied by the specific energy use of the machines, as shown in the following equation:

$$Demand\ (kW) = Qty \times MT/hr \times kWh/MT$$

The baseline demand of the existing machines is 1,398.38 kW and the demand of the installed machines is 835.31 kW, yielding demand savings of 563.06 kW.

The ex ante savings for this project are summarized below in Table 14.

Table 14. Summary of Project Savings

	Demand Savings (kW)	Annual Energy Savings (kWh)	Gas Savings (therms)
Replace Bean Flaking Rolls	563.06	4,797,293	0

Measurement and Verification Plan

IPMVP Option A, partially measured retrofit isolation, was used to establish savings for this project. We developed the following M&V plan for this project.

A site visit will be performed during which the bean flaking rolls will be inspected, and the customer will be interviewed about their operation and control. Specifically, the customer will be asked to verify that the new flaking rolls run nearly continuously, and that the new units are being run near their rated capacity. The project documentation indicates that there are (8) existing flaking rolls that will remain after the completion of this project, and that some of the process load will be shifted off of those machines due to the increased capacity of the new machines. The customer will be asked if the existing (8) machines are run at full capacity and cycled to cut down on their operating hours, if they are run continuously and are throttled in some way to process material at a slower rate, or if some of the existing machines are no longer used.

The project documentation includes trended data of the current draw for each of the (6) new flaking rolls, and the customer will be asked if the most recent trended data is available, as well as production data from the same time period. If the voltage or power factor is trended, it will also be requested. The customer will be asked if any information is available about the energy use or production levels of the flaking rolls that were replaced, or if data is available for any of the other (8) old flaking rolls that are still in operation that would be representative of the operation of the units that were removed. The customer will also be asked if there are any seasonal variations in the operation of the equipment or if there have been any significant increases or decreases in production levels since the completion of the project.

Description of Verification

We completed a site visit on August 19, 2016. The site representative was interviewed about the control and operation of the bean flaking rolls, and they explained that the new bean flaking rolls run at their rated capacity all the time, with no seasonal variations. The flaking rolls are occasionally shut down for maintenance, but it is expected that each unit operates 355 days out of the year. The site representative was asked if production data was available, and if there have been any significant changes in production levels since the completion of the project. They explained that no production or throughput data for the bean flaking rolls was available, and that the flaking rolls process the same amount of product as they did prior to the completion of the project. The new bean flaking rolls were inspected and confirmed to be Buhler OLFB-821 units. The site representative also explained that the remaining eight Bauermeister bean flaking rolls were in the process of being removed and replaced with additional Buhler units.

Calculation Description

The project documentation includes power (kW) readings taken on three of the existing Bauermeister bean flaking rolls and all six of the new Buhler units. This data indicates that the Bauermeister units had an average operating electrical demand of 99.9 kW, and the new Buhler units have an average operating electrical demand of 150.3 kW. The Bauermeister units each have a rated capacity of 212.6 metric tons per day, whereas the Buhler units are expected to each process 495 metric tons per day. Based on the electrical demand and rated capacity of the units, it was determined that the existing flaking rolls use 11.274 kWh per metric ton, and the new flaking rolls use 6.629 kWh per metric ton.

Because the new bean flaking rolls have a higher capacity than the units being replaced, most of the production load of the remaining eight Bauermeister rolls was shifted to the new units so that the new units run at full capacity all the time.

To determine the energy use of the new flaking rolls, the calculated energy use per metric ton was multiplied by the expected daily production of each unit (495 metric tons per day), the quantity of new units (6), and the number of days per year of operation (355). The resulting savings are 2% greater than the ex ante savings because the calculated specific energy use of the installed rollers (6.63 kWh/mt) was used rather than the manufacturer-specified specific energy use (6.75 kWh/mt).

The ex ante and ex post savings for this project are summarized below in Table 15.

Table 15. Summary of Project Savings

	kW	kWh	Therms
Ex Ante	563.06	4,797,293	0
Ex Post	574.83	4,897,575	0
Realization Rate	102%	102%	N/A

800059 Project Information

Project ID#:	800059
Project:	Heating System Upgrade
Ex Ante Savings:	Hospital
Facility Type:	Heating

Measure Description

This project includes a heating system upgrade at a hospital campus. The project also included an expansion which increased the square footage of conditioned space. The original amount of conditioned space was 909,505 SF. A new patient care tower and surgery area of 151,320 SF was added so the new conditioned space is 1,060,825 SF.

The project completed over a two year period so the savings were prorated for the amount of work completed each year. This project covers the savings achieved when the last 11% of the heating system was started up. The initial 89% savings was claimed in the prior year.

The existing equipment includes three 700 BHP steam boilers (one standby) for humidification, process, preheat, and steam to water heat exchangers for building heat; (3) high efficiency hot water boilers (one standby) for building heat; and a 100 ton heat recover chiller connected to the hot water heating system.

The project included removing a 700 BHP steam boiler and all steam to water heat exchangers. The new equipment includes two 4000 MBH condensing hot water boilers for building heat; removal of the steam to water heat exchangers; and installation of an additional 100 ton heat recovery chiller; and installation of two 150 HP vertical steam tube boilers to replace one 700 BHP steam boiler.

Summary of the Ex Ante Calculations

Custom calculations were based on a Trane Trace energy model. The overall project savings was estimated at 326,965 therms per year. The amount claimed in the initial rebate was based on completed SF that was completed by 5/31/15 or 89% of total savings. This rebate covers the remaining 11% of savings or 34,939 therms per year.

The ex ante savings for this project are summarized below in Table 16.

Table 16. Summary of Project Savings

	Demand Savings (kW)	Annual Energy Savings (kWh)	Gas Savings (therms)
Heating System Upgrade	0	0	34,839

Measurement and Verification Plan

The evaluation team used the following M&V plan for this project. IPMVP Option A, partially measured retrofit isolation, was used to establish savings for this project.

A site visit will be performed during which the installation of the new equipment will be verified by inspection. This will included obtaining nameplate data for (2) 4000 MBH condensing hot water boilers to replace steam to water heat exchangers; installation of (1) additional 100 ton heat recovery chiller; installation of (2) 150 HP vertical steam tube boilers to replace (1) 700 BHP steam boiler. The customer will be asked to confirm that one 700 BHP steam boiler was removed and that the steam- to-water heat exchangers were removed.

Finally, the startup date of the new system will be confirmed; the gas and electric meter numbers for the facility will be recorded; and request will be made for a copy of the energy model used to estimate overall savings.

Description of Verification

The evaluation team completed a site visit on September 14, 2016, during which a facility engineer provided access to the central plant where the boilers and heat recovery chiller are located. Nameplate data was collected for all new equipment. The nameplate data matched project documentation.

The facility engineer explained the new vertical steam tube boilers where the old 700 BHP steam boiler was located. The remaining two steam tube boilers were physically verified. These boilers operate at 80 psig and rated for 24,000 lb/hr. In the summer only one boiler is needed and the load is approximately 5,000 lb/hr. In the winter the load will increase to 30,000 lb/hr.

Combustion efficiency tests were reviewed for the vertical steam tube boilers. The boiler efficiency for these boilers was listed at 86% on the project documentation. The actual testing documentation showed the efficiency ranged from 84.3 (low load) to 80.2 (high load) on one boiler. It showed 81.1 (low load) to 79.2 (high load) for the second boiler. These lower efficiencies will lower overall system efficiencies because the model assumed these boilers would achieve 86% efficiency.

The two new condensing boilers are part of a set of 5 condensing boilers on site. Prior to the installation of the condensing hot water boilers, the buildings were heated with steam through shell and tube heat exchangers. These condensing boilers are part of an effort to completely replace all the steam-to-water heat exchangers.

One heat recovery chiller was located in the boiler room. The facility contact explained there is an additional identical unit located on the roof of the building. This matches the project documentation that states there was one existing unit and this project would include an additional unit. There were no concerns about the operation of the heat recovery chillers.

The leaving water temperature of the hot water condensing boilers was observed to be 143F. The facility engineer stated the set point used to be 180 F with the hot water boilers. They have been converting the radiators in the spaces so the leaving water temperature can be reduced. The project documentation listed the boiler leaving temperature as 180 F with a return water temperature of 160 F. Dropping the boiler leaving water temperature will increase the boiler efficiency and resulting overall system heating efficiency.

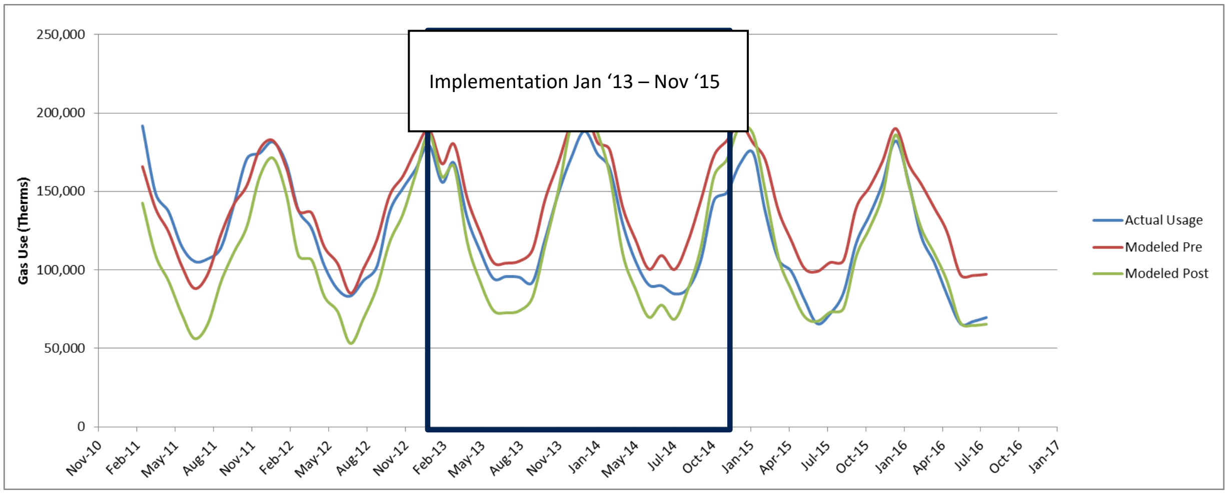
The gas meter was physically verified outside the building. The facility engineer confirmed this is the only gas meter for the facility. The facility engineer was not able to provide the energy model during the site visit.

The overall heating system upgrade project started in 2013. The original facility size was 909,505 square feet. The patient tower was completed and occupied in November 2015. This space increased the overall facility size to 1,060,825 square feet.

Summary of Ex Post Savings Calculations

To determine the gas savings for this project, a billed data regression was completed, in which the gas use of the facility was normalized to local historical weather data. The billed data regression completed for this project takes into account the weather-dependency of the gas use, and the number of days in each month. The modeled baseline and post-case gas use compared to the actual billed use is shown below in Figure 2.

Figure 2. Modeled and Billed Gas Use Comparison



The monthly regression results are shown in Table 17.

Table 17. Summary of Billed Regression

Month	CDD 45F	HDD 45F	Pre Therms	Post Therms	Adj. Post	Savings
1	1	713	200,300	206,776	177,281	23,019
2	15	573	173,927	173,186	148,482	25,444
3	151	142	162,630	139,270	119,404	43,226
4	312	36	142,006	113,860	97,619	44,388
5	616	0	124,742	93,432	80,105	44,637
6	878	0	103,860	73,265	62,814	41,046
7	970	0	101,202	69,480	59,569	41,633
8	901	0	105,804	74,163	63,584	42,220
9	655	0	118,236	87,893	75,356	42,881
10	271	5	147,925	117,257	100,531	47,394
11	138	140	158,092	135,370	116,060	42,032
12	19	383	183,084	172,373	147,785	35,299
Total			1,721,808	1,456,324	1,248,588	**473,219**

To check the accuracy of the modeled gas use compared to the actual gas use, the coefficient of variance (CV) was found for both the baseline and the post-case. The CV should be less than 20% for modeled use to be considered a "good" fit, and the CV values for the baseline and post-case gas use were found to be 8.8% and 4.8%, respectively, both within the target CV of 20%.

The building size increased from 909,505 to 1,060,825 square feet, which is an increase of 17% in the conditioned area. The energy usage in the post case was divided by 1.17 to account for this increase. Once the post Therms has been adjusted for the increased area, the overall savings are estimated at 473,219 Therms.

Since this project is only part of a larger project, the overall savings should be compared to the initial savings estimate of 326,965 therms per year. Given this criteria the savings achieved in this project were greater than the initial estimate. The specific savings for this rebate must be compared to the original prorated amount of 11% of overall savings. This would equate to 11% of 473,219 therms, or 54,054 therms.

The higher savings achieved by this project may have been due to changes in how the hot water boilers are controlled. Since the boiler hot water leaving temperature is lower than originally planned, the heating system savings will be higher than projected by the model.

The ex ante and ex post savings for this project are summarized below in Table 18.

Table 18: Realization Rate Summary

	Demand Savings (kW)	Annual Energy Savings (kWh)	Gas Savings (therms)
Ex Ante	0	0	34,839
Ex Post	0	0	52,054
Realization Rate	N/A	N/A	149%

800070 Project Information

Project ID#:	800070
Measure:	Waste Heat Systems
Ex Ante Savings:	Industrial
Facility Type:	Process

Measure Description

This project includes the completion of one process measure at an industrial facility. This measure involves the conversion of five waste heat evaporators from flooded tube circulation to a falling film configuration. This work will allow the waste heat system circulation pumps to operate at a lower load, resulting in energy savings.

Summary of the Ex Ante Calculations

Custom calculations were included with the project documentation.

The project documentation includes trended operating data for the circulation pumps in all five waste heat evaporator systems. The 5 systems have a total of 16 circulation pumps involved in this project. The savings for this project were determined with two weeks of trended amp data for each pump from before the completion of the project and two weeks of trended amp data from after the completion of the project. To determine the power draw of the pumps the average demand was determined with the following equation:

$$Power\ (kW) = Amps \times \frac{460\ Volts}{1{,}000} \times 0.87\ PF \times \sqrt{3}$$

A summary of this trended data is provided below in Table 19.

Table 19. Summary of Trended Data

Pump #	Pre		Post	
	Avg Amps	Avg kW	Avg Amps	Avg kW
1-1A	203.0	140.6	119.9	83.0
1-1B	186.1	128.8	117.6	81.4
1-2	223.0	154.4	200.2	138.6
2-1A	206.8	143.2	104.1	72.1
2-1B	235.9	163.4	105.3	72.9
2-2	216.1	149.6	223.9	155.0
3-1A	217.3	150.4	98.5	68.2
3-1B	224.6	155.5	120.8	83.6
3-2A	179.8	124.5	218.9	151.6
3-2B	263.6	182.5	228.6	158.2
4-1A	148.7	102.9	99.5	68.9
4-1B	147.8	102.3	106.5	73.7
4-2	242.9	168.1	210.4	145.7
5-1A	207.4	143.6	110.7	76.7
5-1B	195.6	135.4	112.1	77.6
5-2	212.0	146.7	200.4	138.7
Total	3,310.6	2,292.1	2,377.5	1,646.0

The pumps are expected to operate continuously (8,760 hours/year), so to determine the annual savings for this project the demand reduction was multiplied by 8,760 hours. It should be noted that in the ex ante savings calculations, the trended data for Pump 3-1A was not included, so during the site visit the customer will be asked if this was done for a reason, or if it is an error in the calculations. The ex ante calculations show that the average demand of the circulation pumps was reduced by 561.37 kW, yielding annual energy savings of 4,917,561 kWh.

The ex ante savings for this project are summarized below in Table 20.

Table 20. Summary of Project Savings

	Demand Savings (kW)	Annual Energy Savings (kWh)	Gas Savings (therms)
Waste Heat Evaporators	561.37	4,917,561	0

Measurement and Verification Plan

The evaluation team developed the following M&V plan for this project. IPMVP Option A, partially measured retrofit isolation, was used to establish savings.

A site visit will be performed during which the waste heat systems will be inspected, and the customer will be interviewed about their operation and control. Specifically, the customer will be asked to verify that the waste heat systems run continuously, and that the waste heat systems are being run to meet the same loads as they did prior to the completion of the project. The customer will also be asked to confirm that there are no seasonal variations in the use or operation of the waste heat evaporator systems, and that they are never throttled in some way or cycled off during periods of lower production.

The project documentation includes trended data of the current draw for each of the waste heat circulation pumps, and the customer will be asked if the most recent trended data is available, as well as production data from the same time period. If the voltage or power factor is trended, it will also be requested. The customer will be asked if any information is available about the energy use or production levels of the waste heat systems prior to the completion of the project. The customer will also be asked if there are any seasonal variations in the operation of the equipment or if there have been any significant increases or decreases in production levels since the completion of the project.

Description of Verification

A site visit was conducted on August 24, 2016. During the visit the waste heat systems were inspected, and a site representative pointed out the evaporator units that were involved in this project. A sample of the circulation pumps were inspected, and were found to range from 125 HP to 200 HP. The circulation pumps are all single-speed, and it was confirmed that none of the pumps or pump motors were replaced or modified with this project. During the site visit it was found that waste heat system #3 has 5 pumps (whereas the ex ante calculations only specify 4 pumps), and the site representative explained that one of the pumps had been involved in a pilot waste heat evaporator project 2 years ago, so it was not included in this project. The site representative explained that no other changes have been made to the waste heat systems, they confirmed that the systems operate nearly continuously (only shut down for short periods of maintenance & repair), and confirmed that all of the circulation pumps included in the trended data were directly affected by the project. The site representative was also able to confirm that the power factor of 0.87 and voltage of 460V used in the ex ante savings calculations were accurate.

Summary of the Ex Post Calculations

To determine the ex post savings calculations for this project, the calculations completed for the ex ante savings were used as a starting point.

The only major change made to the savings calculations for this project is that one of the pumps in waste heat system #3 was added to the savings calculations. The trended data for the pump that was added to the savings calculations indicates that the current draw of the pump motor reduced from 217.3 Amps to 98.5 Amps as a result of this project being completed, and yields annual energy savings of 741,738 kWh. It is suspected that the savings for this pump were not included in the ex ante savings calculations simply due to an algorithm error.

Including the savings from this pump in the savings for the project results in an ex post annual energy savings of 5,659,299 kWh, yielding a realization rate of 115%. The ex ante and ex post savings for this project are summarized below in Table 21.

Table 21. Summary of Project Savings

	Demand Savings (kW)	Energy Savings (kWh)	Gas Savings (therms)
Ex Ante	561.37	4,917,561	0
Ex Post	646.04	5,659,299	0
Realization Rate	115%	115%	N/A

800071 Project Information

Project ID#:	800071
Measure:	Air Compressor OEM Optimization
Ex Ante Savings:	Industrial
Facility Type:	Process

Measure Description

This project consisted of re-working four of the facility's 21 centrifugal compressors. The (4) compressors that were re-worked were the worst performers out of the (21) compressors. Of the (21) compressors, the facility historically operates (16) compressors continuously. Based on the historical usage of the equipment, re-working the worst compressors would essentially bring them up from zero hours of operation and shift all of the other compressors in the sequence down by (4) compressors.

Summary of the Ex Ante Calculations

The ex ante calculations were provided in the project documentation. The ex ante calculations essentially calculated the savings by taking the average kW of the pre-case metered data and the average kW of the post-case metered data and subtracted the post-case average from the pre-case average to determine the power reduction resulting from the completion of the project. The pre-case total plant average demand was found to be 37,272.00 kW and the post-implementation total plant average demand was found to be 36,042.41 kW, a reduction of 1,229.59 kW.

To determine the annual energy savings for this project the demand reduction of 1,229.59 kW was multiplied by 8,760 hours, as the compressor plant is in operation continuously. The resulting annual energy savings is 10,771,178 kWh.

The Ex Ante savings for this project are presented below in Table 22.

Table 22. Ex Ante Savings

	Demand Savings (kW)	Annual Energy Savings (kWh)	Gas Savings (therms)
Air Compressor OEM Optimization	1,229.59	10,771,178	0

Measurement and Verification Plan

The evaluation team developed the following M&V plan for this project. IPMVP Option A, Partially Measured Retrofit Isolation, was used to establish savings.

For the evaluation of this project, a site visit will be completed, the equipment and compressed air system will be inspected, and the site representative will be interviewed. The equipment will be inspected to make sure that the specific four compressors have been re-worked and are now being operated near the beginning of the sequence. The site representative will be interviewed concerning which compressors have been taken offline and what the power draw of the system was before and after the project, as well as the CFM levels at those times. If trended data is available, it will be collected. In addition, the site representative will be interviewed concerning any other projects being completed at the facility that may influence the possibility of collecting updated information. The site representative will also be asked if there are any seasonal variations in the compressed air use of the facility, or of the compressed air use is consistent throughout the year.

Description of Verification

A site visit was conducted on August 24, 2016. The compressors in the plant are numbered 1 thru 21, and the site representative confirmed that the compressors rebuilt for this project were units 1, 4, 5, and 18. The sequencing of the compressors was checked, and the compressors involved in this project were found to be at positions 4, 5, 7, and 9 in the sequence. A minimum of 13 compressors are in operation at any given time, so all of the compressors involved in this project should operate continuously. The site representative explained that the compressors are run to maintain a target pressure of 95 PSI, and confirmed that no other work was done with the compressors between the time that the pre-implementation trended data was gathered and the time that the post-implementation data was gathered. They also confirmed that there are no significant seasonal variations in the compressed air use of the facility.

Summary of Ex Post Calculations

The trended compressed air flow rates from before and after the completion of the project were analyzed, and it was found that the average flow rate after the project is within 3% of the average flow rate before the completion of the project, so no adjustments will be made to normalize the energy use of the compressors based on flow rates.

The equations used in the ex ante calculations to determine the energy use of the compressors from the trended amp data were also reviewed and found to be reasonable.

All of the information provided in the project documentation and ex ante savings calculations was found to be consistent with the information gathered during the site visit, and the ex ante savings calculations were found to be reasonable and accurate. There are no adjustments to make to the savings calculations for this project.

The ex ante and ex post savings for this project are summarized below in Table 23.

Table 23. Summary of Project Savings

	Demand Savings (kW)	Energy Savings (kWh)	Gas Savings (therms)
Ex Ante	1,229.59	10,771,178	0
Ex Post	1,229.59	10,771,178	0
Realization Rate	100%	100%	N/A

800073 Project Information

Project ID#:	800073
Measure:	Lighting Replacement
Ex Ante Savings:	1,858,538 kWh; 247.81 kW
Facility Type:	Manufacturing/Industrial

Measure Description

The customer removed 910 metal halide or T12 fixtures and replaced them with 488 6-lamp, 4-foot T5 fixtures and lamps.

Summary of the Ex Ante Calculations

The ex ante savings for this project are 247.81 kW and 1,858,538 kWh.

The baseline for this project was considered to be the existing lighting, which included:

- (850) 400W metal halide, input 458 watts
- (15) Twin 400W metal halide, input 916 watts
- (45) 8-foot T12 fixtures, input 129 watts

The proposed condition for this project is (488) 6-lamp, 4-foot T5 fixtures with input rating of 330 watts each.

It was assumed that all of the lights would operate 7,500 hours per year in the baseline and proposed conditions.

Baseline demand kW and energy use was calculated using the total fixture input power operating for 7500 hours per year.

$$Baseline\ kW = \sum(Fixture\ Baseline\ Input\ Watts) \div 1000$$

$$Baseline\ kWh = Baseline\ kW\ x\ 7500\ hours$$

Proposed demand kW and energy use was calculated using the total fixture input power operating for 7500 hours per year.

$$Proposed\ kW = \sum(Fixture\ Proposed\ Input\ Watts) \div 1000$$

$$Proposed\ kWh = Proposed\ kW\ x\ 7500\ hours$$

The energy and demand savings for this measure were determined as follows:

$$Energy\ savings\ (kWh) = (Baseline\ kWH) - (Proposed\ kWh)$$

$$Demand\ savings\ (kW) = Baseline\ Demand\ (kW) - Proposed\ Demand\ (kW)$$

The resulting ex ante savings for this measure is presented in Table 24.

Table 24. Summary of Project Savings

Measure	kWh	kW
Lighting Replacement	1,858,538	247.81

Measurement and Verification Plan

The evaluation team developed the following M&V plan for this project. IPMVP Option A, Partially Measured Retrofit Isolation, was used to establish savings for this measure.

A site visit will be completed, during which the customer will be interviewed about the work that was completed for this project. The customer will be asked if the lighting hours of operation have changed since the time of the application. During the site visit the following information will be collected and/or verified:

- Verify make and model of the new light fixtures
- Verify type and wattage of baseline fixtures
- Verify hours of operation

The customer will be interviewed regarding the lighting hours of operation. If they operate on a regular schedule, such as 24/7, then no light metering will be required. However, if the lights are operated sporadically, HOBO U12 light intensity loggers, or HOBO UX90 Lighting On/Off loggers will be installed in each area to monitor lighting operation and hours of use. As an alternative, U12 loggers with CTs may be installed in lighting panels to monitor lighting operation.

The data will be analyzed to establish the hours of operation for each major area affected by the project. The results will be used, along with the verified fixture type and counts, to calculate annual energy use for the baseline and proposed conditions.

To determine the summer peak demand savings for this project, the average operation of the installed lights will be found for periods from 4-7 PM Monday thru Friday during the summer months.

$$Demand\ savings\ (kW) = (Baseline\ kW - Installed\ kW) \times metered\ peak\ period\ \%\ operation$$

Description of Verification

Since no additional information was available, it was assumed that the occupancy sensors were covered under the prescriptive program so those savings were not included in this assessment.

The baseline and proposed hours for this measure were changed to 8,760 based on the feedback from the site contact.

Because occupancy sensors were not included in this assessment, the average operation of the installed lights for periods from 3-6 PM Monday thru Friday during the summer months will be 100%. This is the same as the ex ante calculation.

The installed kW was adjusted to the lower fixture count determined during the site visit.

Summary of Ex Post Savings Calculations

A summary of the Ex Post savings can be found in Table 25. The revised savings reflects the higher operating hours and lower fixture count.

Table 25. Summary of Ex Post Savings

	Demand Savings (kW)	Energy Savings (kWh)	Gas Savings (therms)
Ex Ante	247.81	1,858,538	0
Ex Post	257.71	2,257,496	0
Realization Rate	104.0%	121.5%	N/A

800575 Project Information

Project ID#:	800575
Measure:	Air Compressor Replacements, Flow Valve Repair, Compressor Controls
Ex Ante Savings:	Industrial
Facility Type:	Process

Measure Description

This project consists of the replacement of three single-speed single-stage air compressors with (2) two-stage single-speed air compressors and (1) two-stage VFD air compressor, the repair of an existing compressed air flow controller, and the installation of new air compressor controls. The facility has two additional air compressors that will remain in place. Details of the existing and proposed compressors are provided below in Table 26 and Table 27.

Table 26. Existing Air Compressors

Description	Full-Load kW	Full-Load CFM
Atlas Copco GA160	172.00	925
Quincy QSI1000	193.00	1,003
Ingersoll Rand EP150	131.30	690
Ingersoll Rand XF200	172.33	1,004
DS201	111.90	688
Total	**780.52**	**4,310**

Table 27. Proposed Air Compressors

Description	Full-Load kW	Full-Load CFM
Ingersoll Rand XF200	172.33	1,004
Ingersoll Rand R160ie	175.00	1,030
Ingersoll Rand R160ie	175.00	1,030
Ingersoll Rand R160ne	185.00	1,060
DS201	111.90	688
Total	**819.23**	**4,812**

Summary of the Ex Ante Calculations

To determine the average demand of the compressors prior to the completion of the project, the project documentation includes metered data of the current draw for each of the existing compressors over a 1-week period, from April 8 – 15, 2015. This metered data shows that the compressors have a total average current draw of 928.82 Amps. Using a power factor of 0.85 and 460V, the average demand of these compressors was calculated to be 629.01 kW. This demand value is multiplied by 8,760 hours per year of operation to yield 5,510,111 kWh of annual energy use.

To determine the average demand of the compressors after the completion of the project, the project documentation includes metered data of the current draw for each of the new compressors over a 1-week period, from April 21 – 28, 2016. This metered data shows that the compressors have a total average current draw of 643.48 Amps. Using a power factor of 0.85 and 460V, the demand of these compressors was calculated to be 435.77 kW. This demand value is multiplied by 8,760 hours per year of operation to yield 3,817,381 kWh of annual energy use.

The difference in average demand of the air compressors between the baseline and installed system is 193.23 kW, which is the ex ante demand savings for this project. The difference between the annual energy use of the baseline system and the system with the new compressors installed is the ex ante savings for this project, 1,692,730 kWh.

The resulting ex ante savings for this project is presented below in Table 28.

Table 28: Summary of Project Savings

	kWh	kW
Baseline	5,510,111	629.01
Post-case	3,817,381	435.77
Savings	1,692,730	193.23

Measurement and Verification Plan

The evaluation team developed the following M&V plan for this project. IPMVP Option A, Partially Measured Retrofit Isolation, was used to establish savings for this measure.

A site visit will be completed, during which the customer will be interviewed about the work that was completed for this project. During the site visit the installation of the new compressors and compressor controls will be verified, and the flow controller will be inspected to verify that it is in use. The customer will also be asked about seasonal variations in production, plant shutdowns, and whether the conditions observed during the monitoring period for the vendor audit and the ex post verification are representative of typical operating conditions.

To verify the control and operation of the air compressors, data loggers will be installed to monitor the current draw or energy use of each individual compressor. HOBO external-input loggers will be installed with current transducers to monitor the amperage of the single-speed compressors, and a Dent ElitePro energy meter will be installed to monitor the energy use of the VFD air compressor. The loggers will record amps at 5-minute intervals and be left in place for a minimum of two weeks. Instantaneous measurements of voltage, amps, power, and power factor will be taken at the time of deployment or removal in order to calibrate logged amperage.

The data collected will be analyzed to determine the operating conditions of the compressors under post-retrofit conditions. The data will also be used to confirm annual hours of operation.

Logged amperage and instantaneous measurements will be used to calculate average post-case compressor power. The results will be extrapolated to annual operation to establish total post-case energy use.

Compressor CFM will be estimated from calculated power. Total air production will be compared to the baseline operation and baseline power and energy may be adjusted to match current conditions.

Description of Verification

The evaluation team completed a site visit on August 23, 2016. A site engineer and the maintenance manager were available to answer questions on the project. The new compressors and system controller were installed in the fall of 2015. Previously the plant had been leasing compressors to meet demand which helped justify the investment in new more efficient compressors. The system operating pressure has not been changed with this project but the maintenance manager stated the pressure is steadier with the new system controls. The desired system operating pressure is 92 psig.

The plant uses the compressed air for air powered conveyors, nozzles, machines and purge air. The facility runs 24 hours a day, 5 days per week and uses Saturdays to run about 1/3 of the equipment for any catchup work that is needed. The facility is rarely run on Sundays. There are no seasonal fluctuations with production demands.

The maintenance manager explained that the old flow control valve is not used anymore and is bypassed. He explained that the valve used to shut off when the pressure set point was met but the control of the compressors was erratic with that method. The new system controller controls the compressor sequencing and the system is more stable now. A facility walk-through confirmed the control valve was left in place.

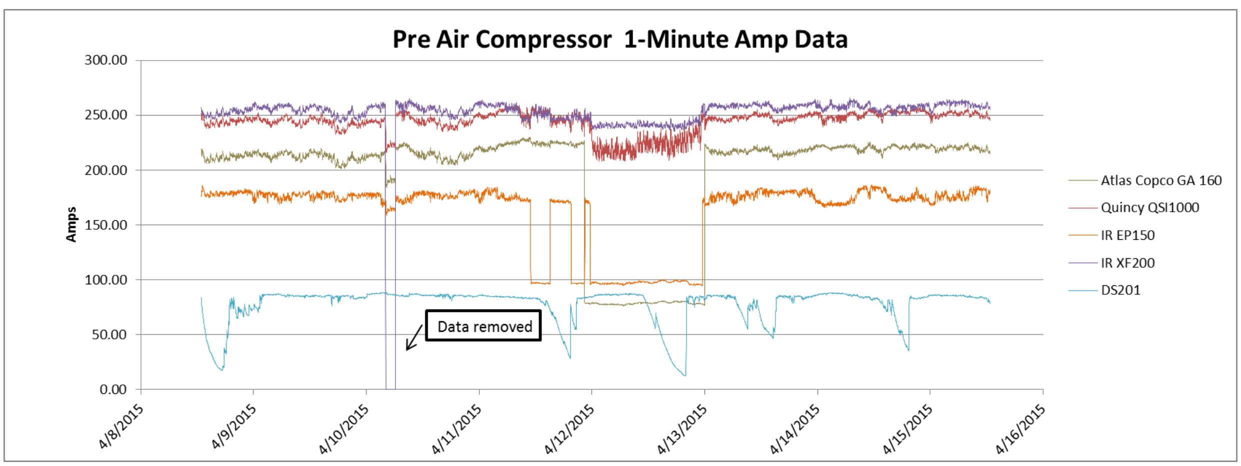
The walk-through also allowed for physical verification of the new compressors and system controller. The site contacts also estimated there was approximately 7,500 gallons of storage capacity.

All run hours of the compressors were recorded. Since the facility provided metered data both pre and post retrofit, no metering was conducted during the site visit. The site contacts were not able to provide information on compressor control.

Ex Post Calculation Description

The ex post savings for this project were determined using the trended data provided with the project documentation and the information collected during the site visit. The project documentation provided the current draw of each compressor at one minute intervals. The current data for the pre-retrofit condition is shown in Figure 3.

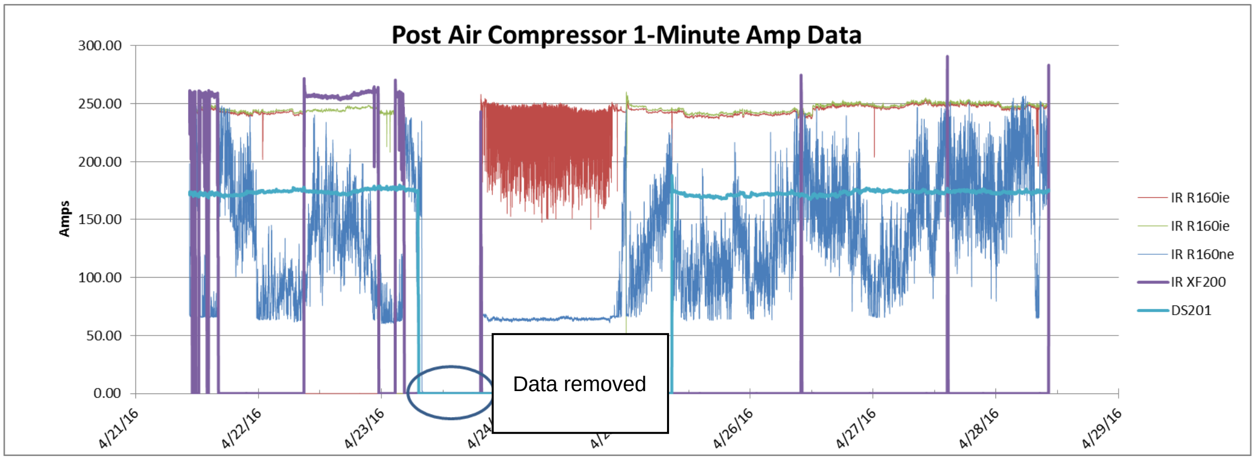
Figure 3. Pre-Retrofit 1-Minute Amp Data



For the pre case, the data looked reasonable with loads lower on Sunday April 12 when the facility was shut down. The Quincy and XF200 compressors were base loaded. There was one short period where the data for the XF200 was lost so that data was removed from the analysis. The Atlas Copco and IR EP150 compressors ran in the load/unload mode which is shown on Saturday April 11 and Sunday April 12. The last compressor, DS201, appears to run with inlet modulation with blowdown as the control mode. This compressor was running in the unloaded mode the entire test period.

The current data for the pre-retrofit condition is shown in Figure 4. It appears there was a power outage on Saturday April 23rd. This data was thrown out of the analysis. The amount of time the compressors were not operating was 11 hours of the week. The ex ante calculation did not take this outage into account. A more normal weekend operating profile would be what is seen on Sunday April 24th with the new VFD drive compressor at minimum load and the new constant speed IR 160ie compressor turning on and off to meet load. While the amp data in Figure 4 shows the VFD compressor has a minimum load, all other compressors were shut off by the new compressor control system. Therefore, all the other compressors are in the load/no-load control mode.

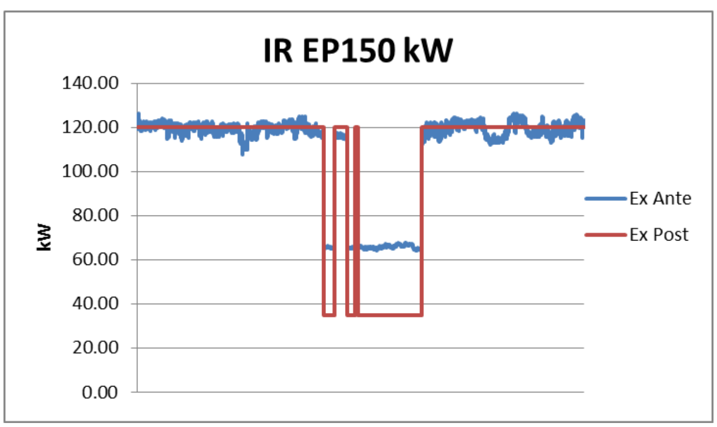
Figure 4. Post-Retrofit 1-Minute Amp Data



The ex ante demand for both the pre and post cases were calculated using 460 Volts and a power factor of 0.85. The assumption that the power factor is always 0.85 will overestimate demand. When a compressor is unloaded it is unlikely the power factor will be 0.85.

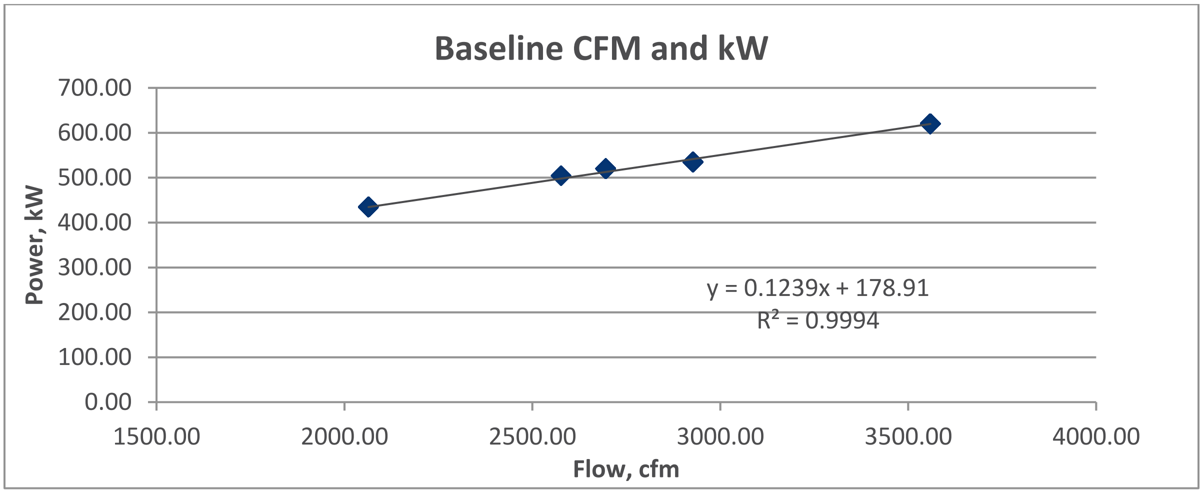
The ex post demand calculation, both pre- and post-retrofit, used CAGI data to estimate compressor demand. This reduced the compressor demand in the unloaded states but matched pretty well with the loaded condition where the power factor was much closer to a value of 0.85. An example of how this affects the calculated demand is shown in Figure 5.

Figure 5. Pre-Retrofit Calculated Demand IR EP150



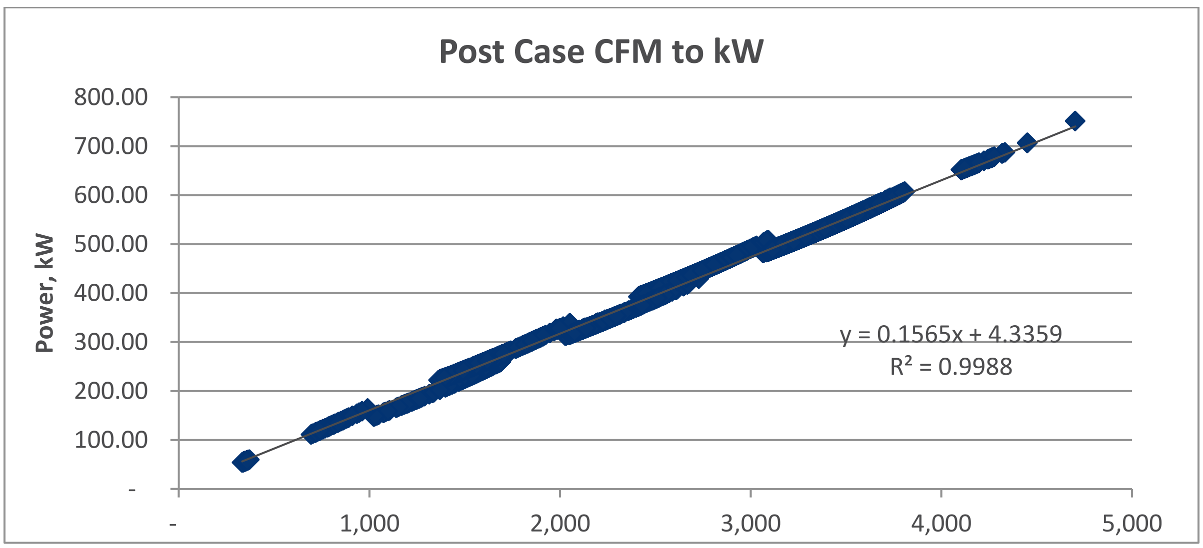
The baseline cfm was calculated using the calculated kW and compressor curves. The ex post curves estimated higher cfm for the Atlas Copco and the Quincy compressors. The curves were similar for the IR EP150 and the XF 200. Figure 6 provides the ex post system curve for all compressors operating in the baseline condition.

Figure 6. Ex Post Baseline CFM



The ex ante calculation did not estimate post-retrofit cfm. The ex post calculation estimated post -retrofit cfm using the same methodology as the baseline cfm. Figure 7 provides the ex post system curve for all compressors operating in the post-retrofit condition.

Figure 7. Ex Post Post-Retrofit CFM



For the ex post calculation, the post retrofit system cfm was 20% less than the baseline cfm. This was partly due to the system outage on Saturday April 23rd. There was no specific discussion of any measures that reduced system usage other than the system outage. Given this difference, an overall average weekly system cfm profile was calculated by combining the baseline and post-retrofit cfm data. This data was then used to calculate baseline and post-retrofit weekly demand profiles with the system curves shown in Figure 6 and Figure 7.

The average hourly demand was calculated using the weekly demand profiles. These values were multiplied by 8,760 to obtain annual energy consumption. For the baseline condition the annual energy consumption was 4,886,954 kWh. For the post-retrofit condition the annual energy consumption was 4,231,150 kWh. The annual energy savings was calculated to be 655,804 kWh.

The peak demand was calculated for the hours between 3 pm and 6 pm Monday – Friday. For the baseline condition the peak demand was 597.75 kW for the post-retrofit condition the peak demand was 533.38 kW. The demand savings was 64.37 kW.

A summary of ex post compressor savings is shown in Table 29.

Table 29. Ex Post Compressor Savings

	kWh	kW
Baseline	4,886,954	597.75
Post-case	4,231,150	533.38
Savings	655,804	64.37

The ex post savings calculations were different from the ex ante calculations in two significant ways. One key difference is that the cfm data from the pre and post case were both used when calculating the typical daily CFM profile of the system. The cfm usage after the retrofit used in the ex ante calculation was unreasonably low due to the outage on the weekend and possibly from less system usage overall. Combining the cfm data allowed a full week of typical operation to be used as the operating profile. This typical profile was then used with the system curves for the pre and post retrofit cases to predict energy consumption of a typical operating week absent any unusual low production days.

The second key difference relates to the power factor. Only current draw was collected with the ex ante metered data and the power factor of 0.85 was used at all loads. This caused the energy in the baseload case to be overestimated when the compressors were unloaded. At lower loads, such as when the compressor is unloading, the compressor power factor will be lower. This is why the baseline power consumption in the ex post calculation is lower than in the ex ante calculation.

The ex ante and ex post savings for this project are summarized below in Table 30.

Table 30. Summary of Ex Post Savings

	kW	kWh	Therms
Ex Ante	193.23	1,692,730	0
Ex Post	64.37	655,804	0
Realization Rate	33.3%	38.7%	N/A