Appendix D. Project Review Reports

In this appendix, we present detailed project-level desk review and on-site M&V reports for 14 PY9 projects.

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	kWh	kW	Therms	kWh	kW	Therms	kWh	kW	Therms
700006	Electric	2	3	5,180,729	621.7		5,180,729	592.1		100%	95%	
700022	Electric	1	3	1,279,388	116.6		1,249,666	115.8		98%	99%	
800012	Electric	2	Certainty	12,734,412	1,453.7		12,734,412	1,453.7		100%	100%	
800857	Electric	2	3	5,690,659	660.0		5,381,188	625.1		95%	95%	
800973	Electric	1	3	1,537,506	175.5		1,345,373	153.6		88%	88%	
801148	Electric	1	3	866,580	129.4		866,580	129.4		100%	100%	
801286	Electric	1	2	157,832	18.0		380,153	43.4		241%	241%	
900003	Electric	2	2	860,005	98.2		860,005	98.2		100%	100%	
900009	Electric	1	Certainty	8,793,460	1,056.7		7,377,903	866.9		84%	82%	
900018	Electric	2	3	4,443,303	513.6		4,443,303	513.6		100%	100%	
900020	Electric	1	Certainty	3,453,185	405.3		3,435,763	392.2		99%	97%	
900021	Gas	1	2			79,900			-			0%
900047	Electric	1	1	20,523	5.2		23,538	6.4		115%	123%	
900056	Gas	2	1			7,560			5,093			67%
900066	Electric	1	2	161,147	18.4		29,797	3.4		18%	18%	
900075	Gas	2	3			196,485			238,339			121%
900081	Electric/Gas	2	Certainty/3	11,521,308	1,315.2	200,985	3,484,393	397.8	409,349	30%	30%	204%

Project ID	Sample			Ex Ante Savings			Ex Post Savings			Realization Rate		
	Fuel Type	Wave	Stratum	kWh	kW	Therms	kWh	kW	Therms	kWh	kW	Therms
900093	Gas	1	2			112,790			66,396			59%
900094	Gas	1	2			14,870			8,008			54%
900137	Electric	1	2	271,230	31.3		104,527	12.1		39%	39%	
900180	Electric	1	1	76,685	8.9		76,791	8.9		100%	100%	
900198	Electric	1	3	1,708,493	196.2		1,768,322	201.9		104%	103%	
900215	Gas	1	1			12,885			13,869			108%
900427	Electric	2	3	1,501,998	139.2		1,501,998	139.2		100%	100%	
900601	Gas	1	2			26,751			25,173			94%
900604	Electric	1	3	1,200,000	-		975,415	-		81%		
900606	Electric	1	3	1,350,168	-		1,350,168	-		100%		
900607	Electric	2	2	1,251,431	142.9		1,045,629	127.5		84%	89%	
900784	Electric	2	3	2,045,922	233.6		2,045,922	233.6		100%	100%	
900816	Gas	2	2			74,810			71,821			96%
901012	Gas	2	3			126,678			57,670			46%
901381	Electric	2	Certainty	10,299,120	2,063.1		9,237,629	1,720.0		90%	83%	
901440	Electric	2	2	865,019	-		854,932	-		99%		
901508	Electric	2	1	150,440	17.2		150,440	17.2		100%	100%	
901527	Electric	2	1	40,635	7.0		42,666	8.5		105%	122%	
901588	Electric	2	3	2,744,707	313.3		2,744,707	313.3		100%	100%	
901685	Electric	2	2	501,072	58.8		501,072	58.8		100%	100%	
901989	Electric	SEM	2	739,223	1.0		739,223	-		100%	0%	
901993	Electric	SEM	2	596,383	10.3		596,383	-		100%	0%	
901994	Electric	SEM	1	363,785	148.1		363,785	148.1		100%	100%	

Note: While savings for multiple fuel types are presented in the site visit reports below, 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.

Project 800012

Project ID#:	800012
Measure:	New Air Compressors
Facility Type:	Industrial
End Use:	Process

Measure Description

This project consisted of installing (3) new low pressure air compressors to act as trim compressors for the (21) existing single-speed compressors. The proposed compressors are 1,500 HP each, and the existing single-speed compressors are 4,000 HP each. Controls will be installed to automatically turn the new compressors on and off as needed.

Summary of the Ex Ante Calculations

The baseline energy use of the compressed air plant was determined to be the post-implementation energy use of the plant after a previous project was completed, which involved rebuilding multiple air compressors. The baseline average demand of the compressed air plant for this project is 36,042 kW, yielding baseline annual energy use of 315,732 MWh. To determine the post-implementation energy use of the compressed air plant, trended data of the current draw of all air compressors in the plant was used. The trended data covers a period of two weeks in January 2017. Using a voltage of 4,160 and a power factor of 0.87, the average post-implementation demand of the compressed air plant was calculated to be 34,589 kW, a reduction of 1,454 kW compared to the baseline demand. Multiplying the post-implementation demand by 8,760 hours per year yields a post-implementation annual energy use of 302,997 MWh, a reduction of 12,734 MWh compared to the baseline energy use.

The ex ante savings for this project are presented below in Table 1.

Table 2. Ex Ante Savings

	Demand Savings (kW)	Annual Energy Savings (MWh)
New Air Compressors	1,454	12,734

Measurement and Verification Plan

IPMVP Option A, Partially Measured Retrofit Isolation, will be used to establish savings for this project. Note that on-site metering will not be possible as all of the compressors operate on medium voltage (4,160V).

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 three (3) new 1,500 HP air compressors have been installed and are functioning as intended. The site representative will be interviewed concerning the control of the existing compressors as well as how the new compressors are controlled. The project documentation indicates that only two of the three new compressors would be used as trim compressors at any given time, so the customer will be asked if one of them is a backup unit, or if there are times that all three of the new compressors operate simultaneously. The customer will be asked to confirm that there have been no significant changes to the compressed air usage between when the trended data used for the pre-implementation energy use calculations was collected and when the trended data for the post-implementation energy use calculations was collected, and asked if updated trends of the operation of the compressors can be obtained. In addition, the site representative will be interviewed to ensure that no other major work has been completed in the compressed air plant that would cause any changes in the operation of the compressors or the operating efficiencies of the compressors. The site representative will also be asked if there are any seasonal variations in the compressed air use of the facility, or if the compressed air use is consistent throughout the year.

Description of Verification

A site visit was completed on September 28, 2017. During the site visit it was found that a total of two new 1,500 HP single-speed trim air compressors were installed, and the customer explained that both of them run most of the time. The site contact explained that the trim compressors turn on and off automatically based on the air pressure in the local supply header. The new compressors were both found to be Ingersoll-Rand units.

The site contact was asked if any other work had been completed in the compressed air plant between when the previous project was completed and when the trim compressors were installed, and they specified that no other work had been completed that would have impacted the operation of the compressors, and there had been no other changes made at the facility that would have had any significant impacts on the compressed air energy use. They explained that after the new trim compressors were installed, multiple baseload compressors had been rebuilt with new components to improve their performance and efficiency, so any trended data collected during the site visit would not be representative of how the compressed air system operated after the completion of the project. The customer also explained that there are no significant seasonal variations in the compressed air use of the facility, only that the compressors typically run a little less efficient during the summer due to the hotter, more humid outdoor air that is being brought in taking more energy to compress. At the time of the site visit the compressed air plant as a whole was operating at about 7.1 CFM per kW, and the customer said that during the summer it is usually around 7.2.

Summary of Ex Post Calculations

Pre- (from the previous project completed at the facility) and post-implementation compressed air trended data is used in the ex post savings calculations. The same trended compressed air data was used in the ex ante savings calculations.

The algorithms, data, and methodology used in the ex ante savings was reviewed and found to be appropriate based on information collected during the site visit. Therefore, no changes were made to the ex ante savings analysis.

The ex ante and ex post savings for this project are summarized below in Table 3.

Table 3. Summary of Ex Ante & Ex Post Savings

	Demand Savings (kW)	Annual Energy Savings (MWh)
Ex Ante	1,454	12,734
Ex Post	1,454	12,734
Realization Rate	100%	100%

Project 800973

Project Details	
Measures:	Air Compressor Replacement, Refrigerated Dryer, Compressor Controls
Facility Type:	Industrial
End Use:	Process

Measure Description

This project consists of the replacement of one 150-HP single-speed single-stage air compressor (assumed) with one 300-HP single-stage single-speed air compressor. A new compressor sequencer and flow controller was also installed. A standard dryer was replaced with a refrigerated dryer. The project invoice included a new 10,000-gallon storage tank, but this was not discussed in the measure calculations. The facility has two additional air compressors that will remain in place. Details of the existing and proposed compressors are provided in Table 4.

Table 4. Existing and Proposed Air Compressors

Description – Existing	Full-Load kW	Full-Load CFM
Gardner Denver 200 HP	168	802
Ingersoll Rand 150 HP	128	743
Quincy 350 HP	294.7	1504
Total	**590.7**	**3,049**
Description - Proposed	**Full-Load kW**	**Full-Load CFM**
Gardner Denver 200 HP	168	802
Quincy 350 HP	294.7	1504
Quincy QSI 1500, 350 HP	261.7	1521
Total	**724.4**	**3,827**

Details of the existing and proposed dryers are provided in Table 5.

Table 5. Existing and Proposed Dryers

Description – Existing	Capacity, CFM	Purge %	Refrig. kW	Sys. Eff. (CFM/kW)
HRD 1710 Heatless Dryer	1710	100%	0	5.4
Description - Proposed	**Capacity, CFM**	**Purge %**	**Refrig. kW**	**Sys. Eff. (CFM/kW)**
RNC-1250 Refrigerated Dryer	1250	0%	7.29	5.4

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 and system pressure for each of the existing compressors over a 1-week period, from August 28 to September 4, 2015. This metered data was used along with compressor data sheets to estimate individual compressor airflow and overall airflow.

Project calculations subtract a constant value of 267 CFM from the total plant air flow to represent baseline conditions for the retrofit, indicating the presence of another project at the facility to reduce leaks. This adjusted flow is then used with compressor data sheets to estimate average demand. The data showed an average demand of 419.5 kW. This demand value was multiplied by 8,760 hours per year of operation to yield 3,675,013 kWh of annual energy use. The average system pressure was 108 psig.

To determine the average demand of the compressors after the completion of the project, the calculations correct for the adjusted air flow, reducing the air pressure from the measured value to a constant value of 100 psig. It appears the flow controller will be able to maintain a constant system pressure of 100 psig.

The revised air flow was used with compressor data sheets to estimate average demand assuming compressors are loaded in an efficient manner. For the analysis, the new compressor was loaded until demand exceeded its capacity. The 350-HP Quincy compressor was base loaded with the new compressors providing trim capacity. The smaller 200-HP Gardner Denver compressor was only used at maximum demand conditions. The data showed an average demand of 284.22 kW. This demand value was multiplied by 8,760 hours per year of operation to yield 2,489,746 kWh of annual energy use.

The system capacity of the existing HRD 1710 dryer was provided as 1,710 CFM, and the purge rate was estimated at 15%. The compressor system efficiency was assumed to be 5.4 CFM/kW, and the dryer was assumed to run 8,760 hours per year. Using these values, the baseline energy consumption was calculated as follows:

$$kWh = 15\% \times 1710\ CFM \div 5.4\ kW/CFM \times 1 \times 8760\ hour/year$$

This yielded an annual energy use estimate of 416,000 kWh for the baseline condition.

The new refrigerated dryer has a rated demand of 7.29 kW. The dryer was assumed to run at full capacity for 8,760 hours per year. Using these values, the annual energy use of the new dryer was estimated at 63,860.4 kWh (7.29 kW times 8,760 hours).

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

The ex ante savings for this project are presented below in Table 6.

Table 6. Summary of Project Savings

	Demand Savings (kW)	Annual Energy Savings (kWh)
Compressed Air Upgrades	175.51	1,537,506

Measurement and Verification Plan

IPMVP Option A, Partially Measured Retrofit Isolation, will be 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 sequencer and flow controller will be inspected to verify that they are in use. The control type for each compressor will be verified. 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 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 compressors. 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

A site visit was completed on October 24, 2017. The site contact was interviewed and the installation of the new compressed air equipment, air storage tank, and controls were verified. The existing compressors were found to be controlled based on pressure set points. The compressors were always set to “run” mode and turn on/off based on the pressure in the line.

The new QSI 1500 air compressor operates as the lead compressor until it cannot keep up with the air demand. At that point, a second compressor turns on and acts as the lead compressor while the new QSI 1500 compressor operates as the trim. The compressors are controlled with the new sequencer and flow controller. The flow controller was set to 112 psi during the site visit which is greater than the 100 psig set point that is used in the ex ante savings analysis.

A 10,000 gallon compressed air storage tank was also confirmed to be installed at the facility. The new storage tank reduces the large air demand that is seen by the compressors. Before the tank was installed, the compressors were having trouble keeping up with air demand during peak times and excessively cycling at other points throughout the day.

Energy loggers were not installed at the insistence of the site contact.

Calculation Description

The ex ante savings calculations and methodology was reviewed and found to be appropriate. Therefore, the ex ante analysis was used as the basis for the ex post calculations. One adjustment was made to the ex ante calculations which reduced the ex ante energy and demand savings. The compressed air set point for the flow controlled was adjusted from 100 psig to 112 psig. During the site visit, the pressure set point was found to be 112 psig. The customer said the pressure in the plant is 110 psig. This adjustment reduces the ex ante savings for the air compressor (Measure 1) savings 21.93 kW and 192,132 kWh, which results in a realization rate of 83.8% for both the energy and demand savings. No adjustments were made to the ex ante savings for the new air dryer (Measure 2). Table 7 shows the savings for each of the two measures.

Table 7. Summary of Measure Level Savings

Measure	Ex Ante		Ex Post		Realization Rate	
	kW	kWh	kW	kWh	kW	kWh
1 – New Compressor	135.30	1,185,267	113.37	993,134	83.8%	83.8%
2 – New Air Dryer	40.21	352,240	40.21	352,240	100%	100%

The total ex ante and ex post savings are shown in Table 8.

Table 8. Summary of Project Savings

	Demand Savings (kW)	Annual Energy Savings (kWh)
Ex Ante	175.51	1,537,506
Ex Post	153.58	1,345,373
Realization Rate	87.5%	87.5%

Project 900009

Project Details	
Measure:	Bag House Fan Upgrades
Facility Type:	Industrial
End Use:	Process

Measure Description

This project consisted of improving the mechanical efficiency of three bag house fans, as well as installing variable frequency drives on those fans. The bag house system is required to move a total of 584,000 CFM of air, and the total fan HP upgraded was 3,718 HP. The mechanical upgrades were stated to improve the fan efficiency from 37% up to 70%. The variable frequency drives were estimated to save an additional 10% of the fan energy usage.

Summary of the Ex Ante Calculations

The ex ante calculations were provided in the project documentation. The savings for this project were based on the metered bag house usage from January 2017 compared to January 2016 as the baseline month. The total energy usage per ton production (kWh/mton) was determined for both months to be 20 kWh/mton and 32.7 kwh/mton, respectively. This resulted in a 38.1% improvement in energy usage per unit production.

The percent savings was multiplied by the measured baseline bag house fan energy consumption to determine the annual savings for the project. The fans were assumed to operate 8,322 hours per year. Since these fans run at very constant loads, the demand savings were calculated by dividing the energy savings by the hours of operation.

The ex ante savings for this measure are presented in Table 9.

Table 9. Ex Ante Savings

	Demand Savings (kW)	Annual Energy Savings (kWh)
Bag House Fans Upgrades	1,057	8,793,460

Measurement and Verification Plan

IPMVP Option A, Partially Measured Retrofit Isolation, will be used to establish savings for this project. No logging will be performed due to the equipment being high voltage equipment and the facility not allowing any logging of the equipment.

During the site visit, the equipment will be inspected and if possible, make and model information for the fans and motors will be collected. The VFD screens will be inspected to record the fan operating power and the percent speed during the time of the site visit.

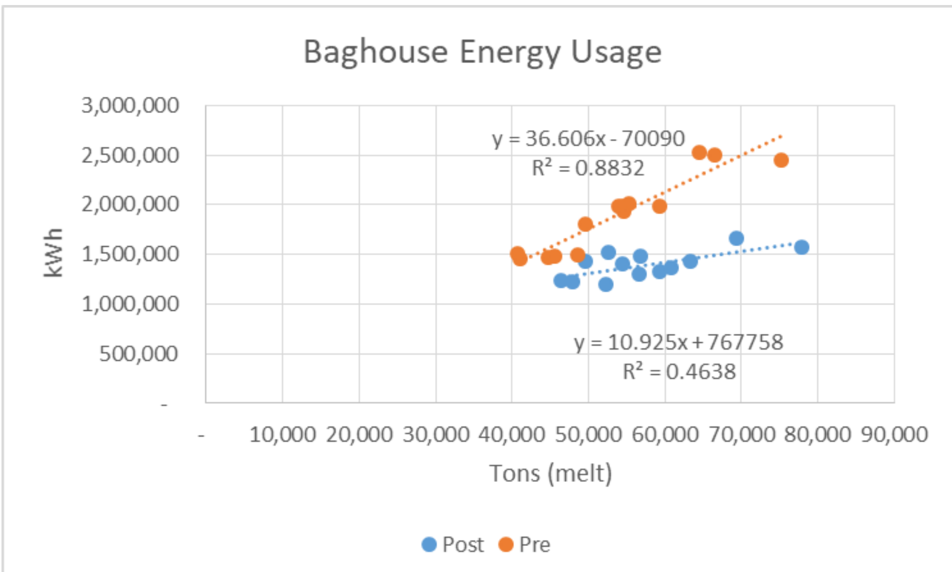
The site representative will be interviewed about the typical operation of the fans and the process they serve. Data concerning the fan operating speeds, fan power, and monthly summary usage, similar to the ex ante provided data, will be requested. The site representative will be interviewed concerning the facility's expected operation over the course of the next year and concerning their previous year's operation. Finally, the background of the additional axial motor installed will also be investigated with the customer. The reasoning for the installation of this additional motor, as well as its function and operation will be discussed to ensure its effect on the bag house is properly accounted for in the ex post analysis.

Description of Verification

A site visit was not completed for this project because the site contact could not be reached to schedule the visit. Not all items described in the measurement and verification plan could be addressed without completing the site visit.

A desk review of the project was completed. This include a review of ex ante calculations and receipts for equipment and services included in the project. The ex ante calculation provided metered energy usage for the project pre and post retrofit. Additional energy data, similar to the data used in the ex ante analysis, was provided to the evaluation team. The additional energy and production data was used in the ex post analysis. The data is shown in Figure 1. This represents 13 months of pre and post-case energy usage.

Figure 1. Pre- and Post- Baghouse Energy Usage



This data was used to create trend lines correlating energy usage to the production metric of tons melted.

Although a minor energy consumption, the project included two, 20-ton direct expansion air condition units for the room housing the variable speed drive units. The units had an EER of 11 with supply fans rated at 5 HP.

Calculation Description

Since the project did not result in a change in production, the average production levels from the pre and post-retrofit periods was used to estimate the average annual production level. The average monthly production level was calculated to be 56,724 tons melted. This value was used in the pre and post retrofit trends to calculate the annual energy consumption. the ex ante assumption of 8,322 hours of operation, the kW was calculated by dividing kWh by annual operating hours. The results of this analysis are shown in Table 10.

Table 10. Pre- and Post- Energy Consumption

Avg. Monthly Production (Tons)	Annual kWh (Pre-Retrofit)	Annual kWh (Post-Retrofit)	Project kWh Savings	Project kW Savings
56,724	24,076,222	16,649,623	7,426,598	892.41

The additional cooling load was calculated using rules of thumb. It was assumed that there were two cooling units but that one would be used as a backup because of the importance of the system. The equivalent full load cooling hours was assumed to be 1,700 hours. The fans were assumed to run 2,800 hours per year based on an additional 1,100 equivalent full load hours of heating. The additional energy usage for the air conditioning units was calculated at 48,495 kWh and an additional 25.55 kW demand. These values were subtracted from the fan savings to arrive at overall ex post savings of 7,377,903 kWh and 866.86 kW.

Table 11 provides a summary of project savings.

Table 11. Summary of Project Savings

	Demand Savings (kW)	Annual Energy Savings (kWh)
Ex Ante	1,057	8,793,460
Ex Post	867	7,377,903
Realization Rate	82.0%	83.9%

Project 900018

Project Details	
Measure:	New Compressed Air Dryers
Facility Type:	Industrial
End Use:	Process

Measure Description

This project consisted of installing (13) new cycling refrigerated compressed air dryers to replace (2) existing externally heated desiccant dryers and (7) existing blower purge desiccant dryers.

Summary of the Ex Ante Calculations

The annual energy use of the existing compressed air dryers was determined using a combination of metered data and rated capacities. Table 12 provides a summary of the existing dryers.

Table 12. Summary of Existing Compressed Air Dryers

Dryer Unit(s)	Type	Capacity (CFM)
PH-1	Externally Heated	4,500
PH-2, PH-3	Blower Purge	4,500
PH-4	Externally Heated	4,000
PH-5, PH-6, JV-7, JV-8	Blower Purge	6,000
JV-9	Externally Heated	4,600
JV-10	High Pressure Blower Purge	2,100

For the externally heated desiccant dryers (units PH-1, PH-4, JV-9), the flow rate of purge air was determined from short-term trended data, which showed an average flow of 401 cubic feet per minute (CFM) for PH-1, which is rated at 4,500 CFM (8.9% purge air). The purge air for JV-9 is assumed to be the same (401 CFM), and the purge air for unit PH-4 (rated at 4,000 CFM) was determined to be 356 CFM by using the purge air rate calculated for PH-1 (8.9%). The energy use associated with the purge air use for each compressor was determined using a specific energy use of 5.43 CFM per kW, and the dryers are assumed to operate continuously. The average demand of the electric heater for PH-1 was determined using short-term trends of the current draw of the heater, which was found to be 47.1 amps. Using a voltage of 460V, the demand of the heater was calculated to be 37.5 kW. The demand of the heater for unit JV-9 is assumed to be the same, the demand of the heater for unit PH-4 is specified to be 42 kW, but no information was provided as to the source of this value. The heaters are assumed to operate 75% of the time (6,489 hours/year), as the dryers are noted to run sweep air 25% of the time and the heaters do not operate during that time.

The existing blower purge desiccant dryers (units PH-2, PH-3, PH-5, PH-6, JV-7, and JV-8) consist of two units rated at 4,500 CFM and four units rated at 6,000 CFM. Short-term trended data shows the sweep air purge to be 640 CFM for one of the units rated at 6,000 CFM. The sweep air purge airflow for the 4,500 CFM blower purge desiccant dryers was assumed to be the same as the measured purge airflow for the 4,500 CFM externally heated desiccant dryers, which is 401 CFM. The energy use associated with the sweep air purge airflow was determined using a specific energy use of 5.43 CFM per kW, and the units are assumed to be in sweep mode 25% of the time (2,163 hours/year). Short-term trends of the current draw of the blower show that one of the units with a rated capacity of 4,500 CFM draws an average of 15.4 amps. The electric demand (kW) of the blower was calculated assuming 460V and a power factor of 0.85, yielding a demand of 10.4 kW. The blower demand for dryers rated at 6,000 CFM is specified to be 25.2 kW, but no information was provided about the source of this figure. The annual energy use of the blowers was determined assuming that the blowers operate 75% of the time (6,489 hours/year).

The ex ante savings calculations indicate that units JV-7 and JV-8 have electric heaters, while the other blower purge dryers (PH-2, PH-3, PH-5, and PH-6) have steam heaters. The average operating demand of the electric heaters is specified to be 83.4 kW - the source of this figure is not specified. The electric heaters are assumed to operate 75% of the time (6,489 hours/year). The baseline natural gas use for dryers with steam heating was calculated by determining an electrical equivalent and then converting it to therms, using a conversion factor of 0.03413 therms per kWh. The source of the electrical equivalent appears to be short-term trends of amperage data for one of the dryers with electric heaters. It appears that a units error is causing the average steam heater equivalent to be higher than it should be; the average amperage of the electric heaters is being reported as the equivalent electric demand. The average demand of the equivalent heaters is multiplied by 8,652 hours per year to determine the annual equivalent heating load, which is then converted to therms.

The facility also has one (1) high pressure blower purge desiccant dryer rated at 2,100 CFM. The baseline energy use for this unit was determined in the same manner as the other blower purge desiccant dryers, but the sweep air purge airflow is specified to be 147 CFM (calculated assuming sweep air to be 7% of rated capacity), the blower demand is specified to be 12.0 kW (based on nominal horsepower of 15), and the demand of the electric heater for the dryer is specified to be 50 kW (no source specified).

The baseline equipment and its operation is summarized below in Table 13.

Table 13. Summary of Baseline Equipment Operation

Dryer Unit	Type	Capacity (CFM)	Blower kW	Sweep Air CFM	Purge CFM	Heater kW	Total Annual kWh	Total Annual Therms
PH-1	Externally Heated	4,500	-	-	401	37.5	882,444	-
PH-2	Blower Purge	4,500	10.4	401	-	-	227,410	32,180
PH-3	Blower Purge	4,500	10.4	401	-	-	227,410	32,180
PH-4	Externally Heated	4,000	-	-	356	42	0	-
PH-5	Blower Purge	6,000	25.2	640	-	-	418,462	42,906
PH-6	Blower Purge	6,000	25.2	640	-	-	418,462	42,906
JV-7	Blower Purge	6,000	25.2	640	-	83.4	959,645	-
JV-8	Blower Purge	6,000	25.2	640	-	83.4	959,645	-
JV-9	Externally Heated	4,600	-	-	401	37.5	882,444	-
JV-10	High Pressure Blower Purge	2,100	12.0	147	-	50	461,084	-
Total		**48,200**	**133.7**	**3,509**	**1,158**	**333.9**	**5,437,005**	**150,171**

To determine the energy use of the new cycling refrigerated dryers, the rated full-load demand of the dryers was multiplied by the percent loading that each of the new compressors is expected to operate at. The new dryers consist of eight (8) units rated at 5,200 CFM with a full-load demand of 30.6 kW, two (2) low pressure units rated at 3,200 CFM with a full-load demand of 18.4 kW, and three (3) high pressure units rated at 3,500 CFM with a full-load demand of 18.4 kW.

According to the ex ante calculations, dryer JV-9 will remain in place, and will operate with a purge airflow of 322 CFM and an electric heater average demand of 50 kW. To determine the annual energy use of this compressor, an efficiency of 5.2 CFM per kW is assumed, and it is expected that the purge will be enabled 18% of the time. The heater energy use is determined by multiplying the demand of the heater by 18% and by 75%, the reasoning for which was unclear from the ex ante savings calculations spreadsheet.

The post-implementation dryers and their operation are summarized below in Table 14.

Table 14. Summary of Post-Implementation Equipment and Operation

Dryer Unit	Type	Capacity (CFM)	Rated kW	% Loading	Purge CFM	Heater kW	Total Annual kWh
C-1	Refrigerated	5,200	30.6	76.2	-	-	201,618
C-2	Refrigerated	5,200	30.6	0	-	-	-
C-3	Refrigerated	5,200	30.6	80.2	-	-	212,361
C-4	Refrigerated	5,200	30.6	0	-	-	-
C-7	Refrigerated	5,200	30.6	80.2	-	-	212,361
Low Pressure #1	Refrigerated	3,200	18.4	48.3	-	-	76,812
Low Pressure #2	Refrigerated	3,200	18.4	0.3	-	-	497
High Pressure #1	Refrigerated	3,500	18.4	71.8	-	-	114,258
High Pressure #2	Refrigerated	3,500	18.4	0	-	-	-
C-10	Refrigerated	5,200	30.6	80.2	-	-	212,361
C-13	Refrigerated	5,200	30.6	0	-	-	-
C-14	Refrigerated	5,200	30.6	76.2	-	-	201,618
High Pressure #3	Refrigerated	3,500	18.4	0	-	-	-
JV-9	Externally Heated	4,600	-	0	401	37.5	154,838
Total	-	**63,100**	**336.8**	-	**401**	**37.5**	**1,386,725**

The ex ante savings for this project are the difference between the baseline total electrical energy and gas use and the post-implementation use.

The ex ante savings for this project are presented below in Table 15.

Table 15. Ex Ante Savings

	Demand Savings (kW)	Annual Energy Savings (kWh)	Gas Savings (therms)
New Compressed Air Dryers	513.56	4,443,303	150,171

Measurement and Verification Plan

IPMVP Option A, Partially Measured Retrofit Isolation, will be used to establish savings for this project.

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 customer will be asked to confirm that the old compressed air dryers consisted of (3) externally heated desiccant dryers (one of which should still be in place), (6) blower purge dryers, and one high pressure blower purge dryer. The customer will be asked about how the old dryers were sequenced, and also about how the new dryers are sequenced. The make and model numbers of the new dryers will be recorded, along with any relevant nameplate specifications (such as full-load demand, airflow capacity, etc.). The dew point setpoint of the dryers will be recorded, and the customer will be asked about the air compressors that serve the dryers. It should be noted that the project documentation indicates that the compressors were also recently replaced, so information should be collected about the operation of the old compressors as well as the new compressors. The customer will be asked if the old compressors and the new compressors have inlet modulation, inlet guide vanes, variable speed drives, or any other flow/speed control mechanisms.

The source of the air used by the compressors will be noted (indoors, outdoors, or a mixture), and the customer will be asked to confirm that there have been no significant changes to the compressed air usage since the completion of the project. The customer will be asked if the dryers and air compressors are monitored and/or controlled with a central control system or energy management system, and if so, if any trended data is available about the operation of the equipment. The customer 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.

If trended data of the operation of the dryers is not available, the customer will be asked if energy loggers can be installed to monitor the operation of the dryers for a minimum of two weeks, and at the time of energy logger installation spot-measurements of the demand of the dryers will be taken using a NIST-calibrated power meter.

Description of Verification

A site visit was completed on September 28, 2017. The site contact was interviewed and the installation of the new compressed air dryers was verified. The new compressed air dryers were confirmed to be the following:

- (8) 5,200 CFM cycling refrigerated dryers
- (3) 3,500 CFM cycling refrigerated dryers
- (2) 3,200 CFM cycling refrigerated dryers

The site contact was able to confirm that the existing compressed air dryers comprised of (3) externally heated desiccant dryers, (6) blower purge dryers, and one high pressure blower purge dryer. One externally heated desiccant dryer is still in place and is used as a backup.

The facility has a low pressure and high pressure compressed air system. Three of the new air dryers will serve the high pressure system while the rest serve the low pressure system. Each of the air dryers serve a single compressor which is also how the air dryers were configured before the project.

Energy loggers were not installed during the site visit at the insistence of the site contact.

Calculation Description

The ex ante savings analysis was reviewed and found to be representative of the dryer operation that was observed during the site visits. Post-case metered data was used to determine the operation and power consumption of the new compressors.

Since the ex ante saving analysis was found to be representative of the typical operation for the compressed air dryers at the facility, no changes were made to the saving analysis. The realization rates for the energy, demand, and gas savings are 100%.

The ex ante and ex post savings are shown in Table 16.

Table 16. Summary of Project Savings

	kW	kWh	Therms
Ex Ante	513.56	4,443,303	150,171
Ex Post	513.56	4,443,303	150,171
Realization Rate	100%	100%	100%

Project 900020

Project Details	
Ex Ante Measure:	Replace Bean Flaking Rolls
Facility Type:	Industrial
End Use:	Process

Measure Description

This project includes the completion of (1) process measure at an industrial facility. This measure involves the replacement of (4) existing Bauermeister double stand flaking rolls with (4) 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.

Summary of the Ex Ante Calculations

The project documentation includes operating data for (3) 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 (10) of the new Buhler flaking rolls from October 23, 2016 to November 6, 2016 was also included in the project documentation, which shows they operate with an average current draw of 200.0 Amps, and the units are specified to each process an average of 521 metric tons per day. The savings calculation uses 460 V, and assumes a power factor of 0.9. 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 6.61 kWh per metric ton.

To determine the post-implementation energy use of the flaking rolls, the expected average operation of the new flaking rolls (521 mt/day) was used along with the measured energy use of 6.61 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 8,340,743 kWh and a post-implementation annual energy use of 4,887,558 kWh. The resulting savings is 3,453,185 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 979.0 kW and the demand of the installed machines is 573.7 kW, yielding demand savings of 405.3 kW.

The ex ante savings for this project are summarized below in Table 17.

Table 17. Summary of Project Savings

	Demand Savings (kW)	Annual Energy Savings (kWh)
Replace Bean Flaking Rolls	405.3	3,453,185

Measurement & Verification Plan

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 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 includes trended data of the current draw for each of the (4) 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 other 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

A site visit was completed on September 28, 2017. The customer explained that a total of seven bean flaking rolls had been installed since the end of the previous program year, but only four of them were claimed in the rebate application because that is the quantity of new flaking rolls that will are fully-loaded all the time. The other three flaking rolls act as backup units in case one of the other flaking rolls requires maintenance or there is a need for a temporary increase in throughput from the flaking rolls.

The customer confirmed that all of the flaking rolls operate continuously apart from any maintenance work, and that the throughput of the machines is consistent throughout the year. They also confirmed that the power factor at the flaking rolls is in the 0.88 to 0.90 range.

Summary of Ex Post Calculations

To determine the ex post savings for this project, the pre-implementation and post-implementation trended data included in the ex ante savings calculations was used. Upon review of the trended data, it was found that the pre-implementation trended data includes some short periods during which the demand of the fan motor is nearly zero, indicating that the fan was briefly turned off for some reason or there was an error in reading or recording the data. Based on the information provided by the customer it is known that the fan operates nearly continuously, only being shut down for periods of routine maintenance (which are typically just a few days per year) or in the event of an emergency. Because of this, it was determined that the trended data showing nearly zero demand should not be included in the savings calculations. Similarly, the first few data points of post-implementation trended data shows a much lower electrical demand compared to the remainder of the trended data, with the remaining data showing little change in the demand of the fan motor. The pre- and post-implementation trended data is shown graphically in Figure 2 and Figure 3.

Figure 2. Pre-Implementation Trended Data

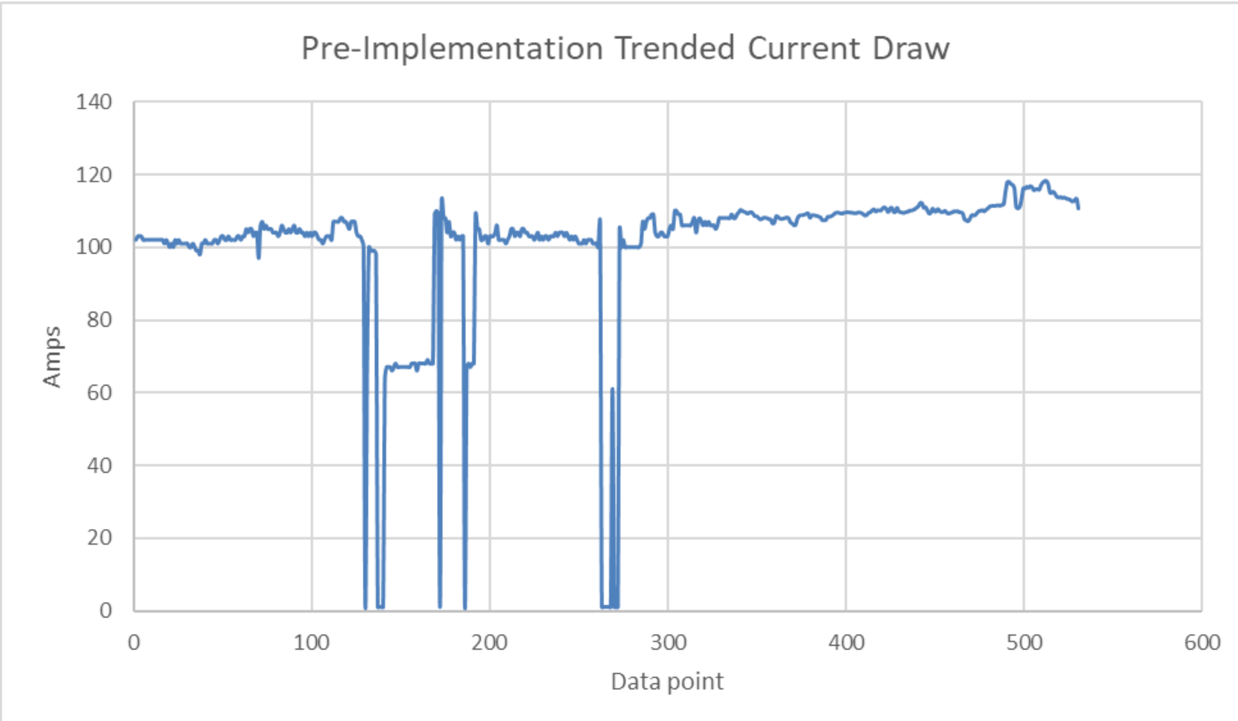
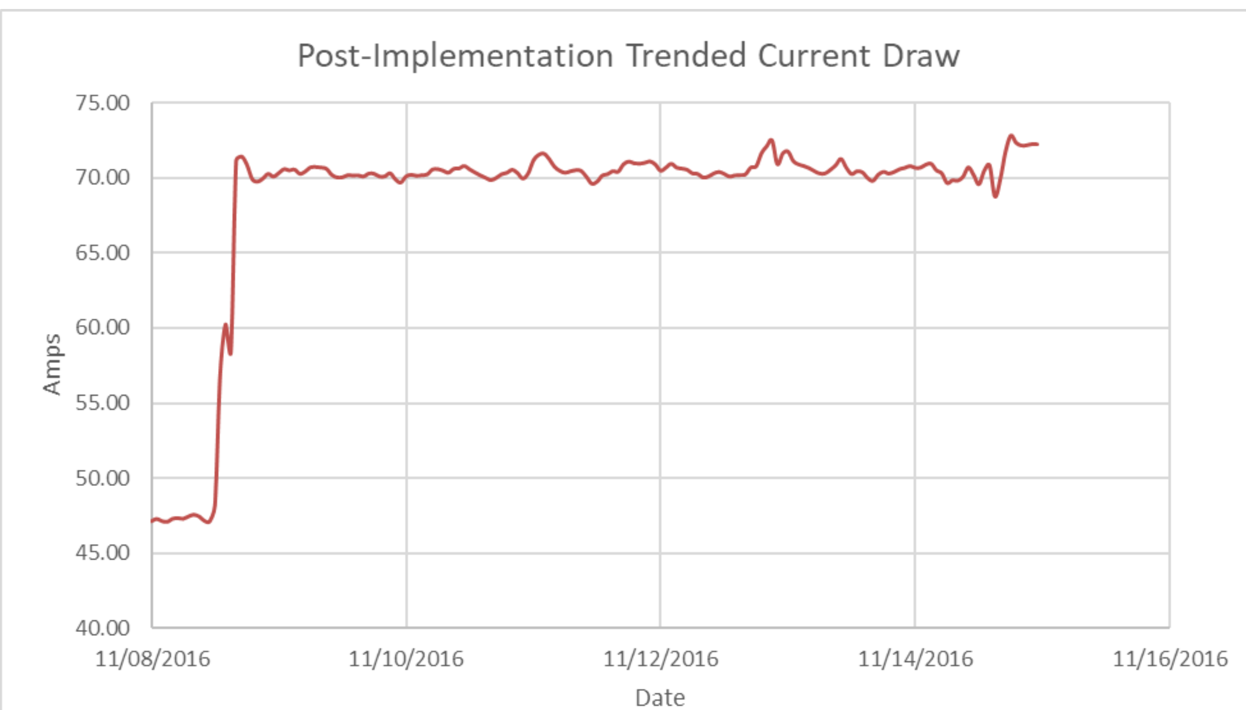


Figure 3. Post-Implementation Trended Data



All of the trended amperage data supplied in the project files was used in the ex post calculation. The ex ante calculation did not use all of the amperage data for Flakers 1-4. Amperage data from 10/8/2016-10/22/2016 was not used. Based on conversations with the customer during the site visit, there does not appear to be any reason to exclude the data from 10/8/2016 to 10/22/2016. Therefore, the ex post calculation included the amperage data. This adjustment slightly increased the post-case power from 200 kW to 201 kW, which reduced the energy and demand savings.

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

Table 18. Summary of Ex Ante & Ex Post Savings

	Demand Savings (kW)	Annual Energy Savings (kWh)
Ex Ante	405.3	3,453,185
Ex Post	392.2	3,435,763
Realization Rate	96.8 %	99.5%

Project 900021

Project Details	
Ex Ante Measure:	Retro-commissioning
Facility Type:	Hospital
End Use:	HVAC

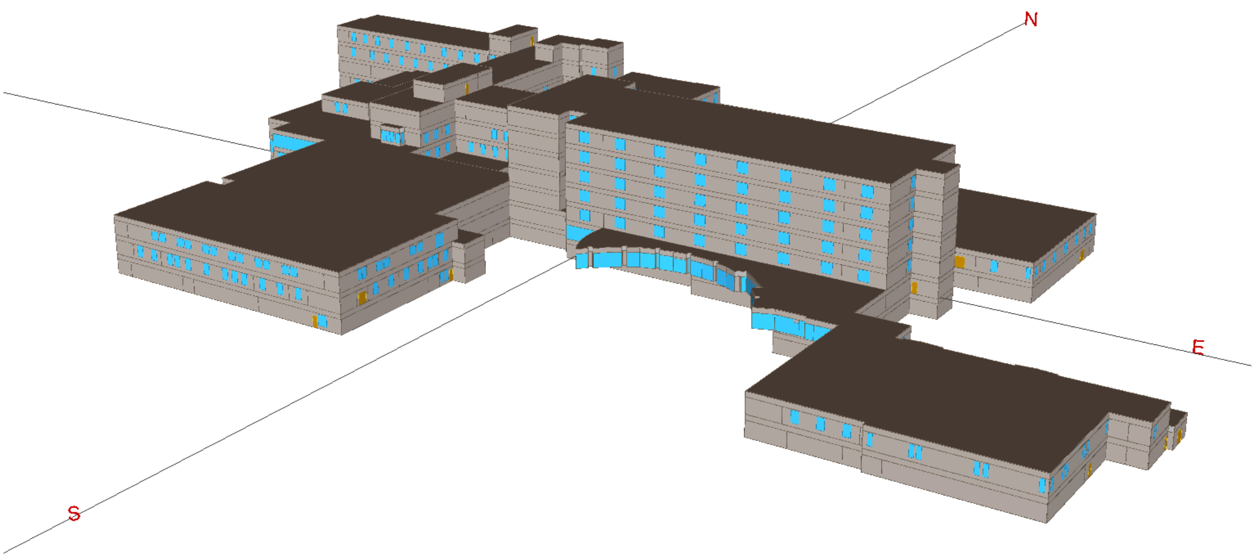
Measure Description

This project includes the completion of numerous retro-commissioning measures at a large hospital. In total, (23) different measures were completed at the facility. They include calibrating control points, scheduling, and adding reset controls. The most significant measures were converting the constant volume (CV) system to a variable air volume system (VAV), and upgrading the terminal units to DDC controls.

Summary of the Ex Ante Calculations

The ex ante savings for this measure were calculated using a building simulation completed in eQuest. Based on the descriptions in the summary files, it appears that each measure was modeled individually within the simulation, and parametric model runs were completed to determine the savings for each measure.

Figure 4. eQuest Modeled Building



The overall facility usage was calibrated within the model to ensure it was built reasonably. Both the electric and natural gas usage were compared within the project documentation.

Figure 5. Modeled vs. Actual Energy Usage (kWh)

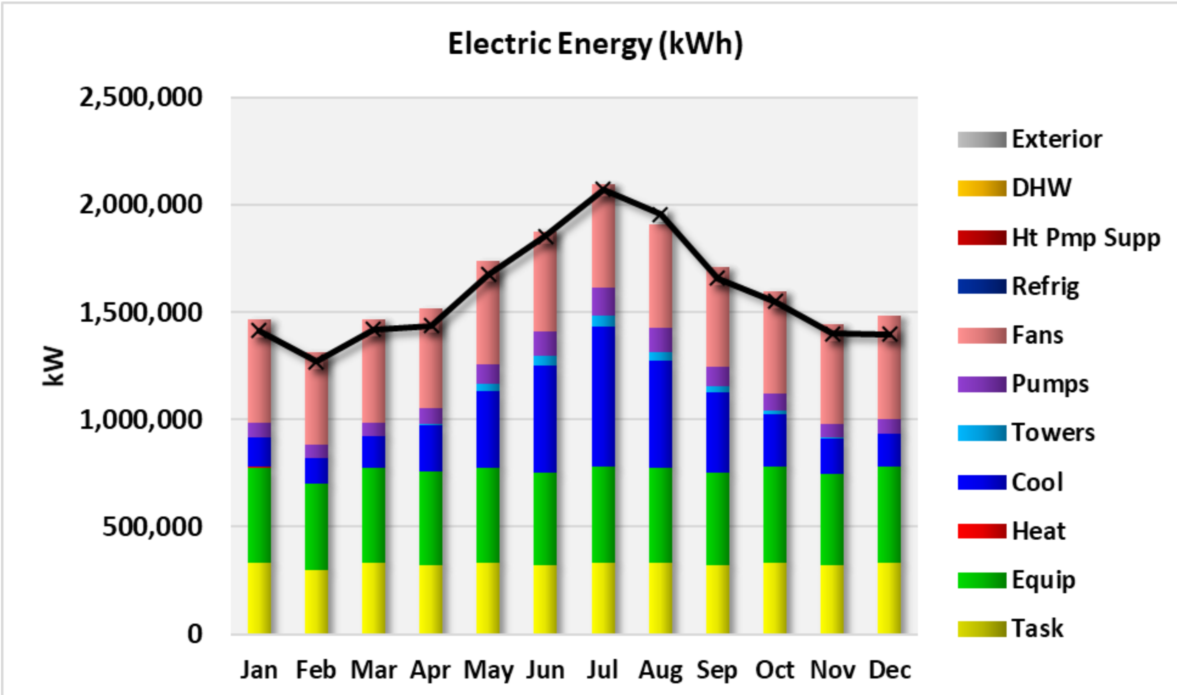
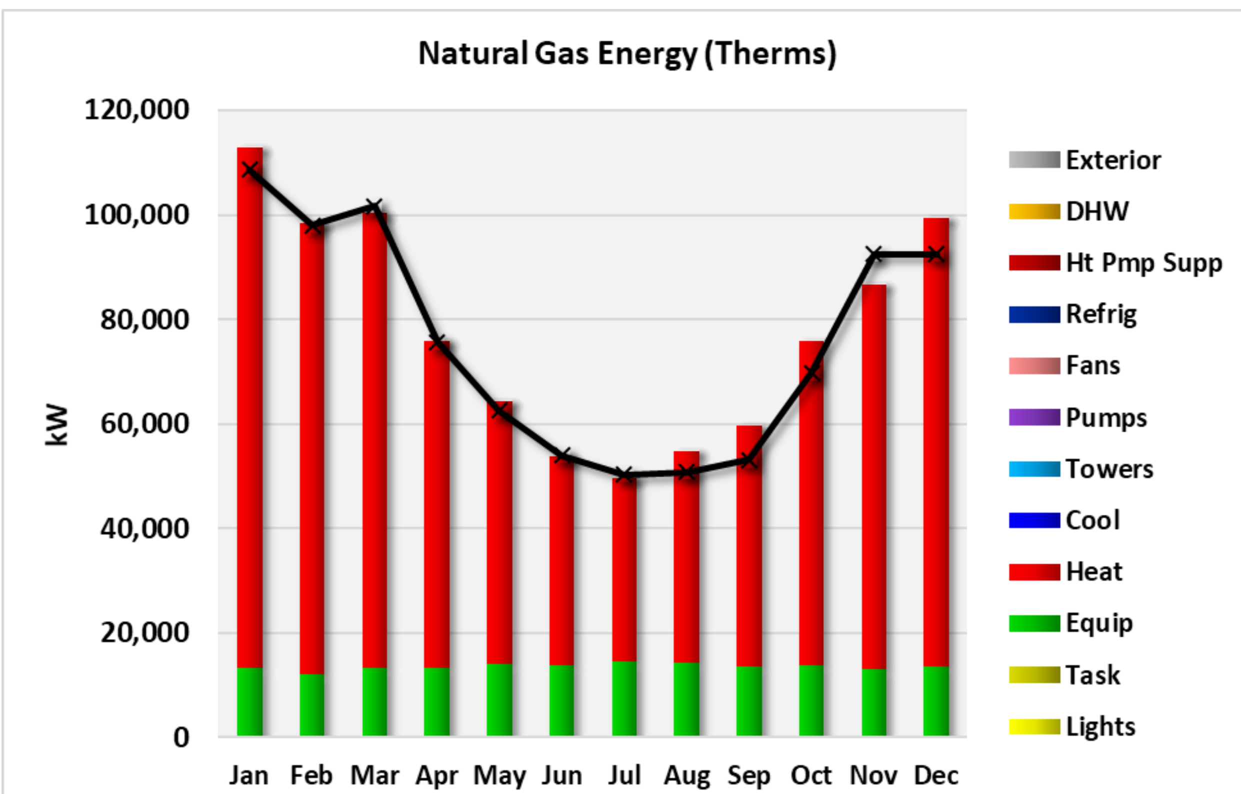


Figure 6. Modeled vs. Actual Gas Usage



A summary of the modeled measures was also included with the project documentation. The parametric runs appear to have been stepped through from start to finish, with the final model run determining the savings for all combined measures, and the project as a whole. A summary of the included measures can be seen in Table 19.

Table 19. Measure Savings Summary

RCx EEM #	Project Name	kWh/yr savings	Therms/yr savings
29AH3-1	Calibrate Mixing Dampers	14,106	-163
52AH2-6	Calibrate OA Damper	1,382	647
52AH4-6	Calibrate OA Damper	1,826	871
70AH7-1	Expand DAT Reset Range	6,770	727
70AH8-1	Expand DAT Reset Range	6,770	727
70AH9-1	Expand DAT Reset Range	6,770	727
70AH10-1	Expand DAT Reset Range	6,770	727
70AH11-1	Expand DAT Reset Range	6,770	727
70HRU1-1	Discharge Air Temperature Reset	4,271	2,169
82AH1-4	Calibrate Mixing Dampers	9,554	-195
82AH2-2	Convert CV Dual Duct to VAV	514,034	24,011
91RTU1-1	Schedule Unit Off (College of Nursing)	34,514	4,115
91RTU2-1	Schedule Unit Off (CON Library & Comp. Lab)	18,574	2,125
91RTU3-1	Schedule Unit Off (IS)	30,404	3,244
94AH3-3	Calibrate OA Damper	1,434	-8
01AH1-2	Upgrade AHU and Terminal Units to DDC	414,996	29,137
03HX1-1	Schedule Heat Exchanger and Pumps Off	24,506	0
03HX1-2	Expand Hot Water Reset Range	0	988
05AH3-1	Discharge Air Temperature Reset	67,785	6,480
05AH3-2	Reduce Discharge Static Pressure Set point	401	-8
05AH3-3	Calibrate Outside Air Damper	1,769	3,065
05AH3-4	Adjust Economizer Changeover Setpoint	4,207	(19)
05AH4-2	Discharge Static Pressure Reset	8,560	(194)
		kWh/yr savings	**Therms/yr savings**
	Selected Custom Project Totals	**1,186,173**	**79,900**

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)
Hospital RCx	135.41	1,186,173	79,900

Measurement & Verification Plan

IPMVP Option A, Partially Measured Retrofit Isolation, will be used to establish savings for this project. Additionally, IPMVP Option D, Whole Building Simulation, will also be used to validate and verify the measure level savings estimates.

A site visit will be performed during which the completed measures will be verified to have been implemented. The customer will be interviewed regarding the completion dates for each measure. Control setpoints both before and after the project was completed will also be obtained from the customer or the facilities building automation system (BAS). These will be confirmed against the measure level assumptions used in the building simulations.

The customer will be interviewed in detail regarding the previous operation of the facilities systems and controls. The assumptions listed in the completed RCx report will be verified. These assumptions will be used to validate (and if necessary, update) the building simulations to validate the energy savings. Finally, the customer's billed usage history will be obtained and a billed regression will be completed. While not definitive, this will provide further validation of the modeled energy and natural gas savings.

Description of Verification

A site visit was completed on July 21, 2017. The site contact was interviewed regarding the start and completion data of the RCx project. The building automation system (BAS) was used to confirm operating set points, setbacks, and schedules for several of the units.

The customer was asked about the conversion of CV dual duct to VAV for 82AH2. He confirmed that the conversion was made and was in operation. He also confirmed that DDC controls were installed on the units for 01AH1. The VAV boxes that are served by 01AH1 were operated with pneumatic and other electric controls and were not able to be controlled with the BAS until they were upgraded to DDC.

The site contact noted that a new 5,115 sf surgery unit was added after the completion of the RCx project.

Calculation Description

A billed regression analysis was used to calculate the electrical and gas savings for the project. One year pre- and post-case billed usage was used in the analysis. Billed usage during the implementation phase of the project was not used. A balance point temperature of 65°F was used in addition to local and TMY3 weather data. Heating and cooling degree days were calculated based on the 65°F balance point temperature for each savings analysis – electric and gas.

A new 5,115 sf surgical unit was built after the completion of the RCx project. In order to account for the additional energy usage in the post-case, typical energy intensities of 2.1 therms/sf and 16 kWh/sf for inpatient hospitals were subtracted from the post-case billed usage in the savings analyses.

The ex post billed regression calculated 154.5 kW and 1,353,390 kWh in electrical savings, which result in a 114% realization rate for both the energy and demand savings.

The ex post savings analysis for the gas savings did not show any savings based on the billed regression. Figure 7 shows the weather normalized monthly energy use and corresponding heating degree days for the pre and post periods.

Figure 7. Pre/Post Monthly Gas Usage vs. Heating Degree Days

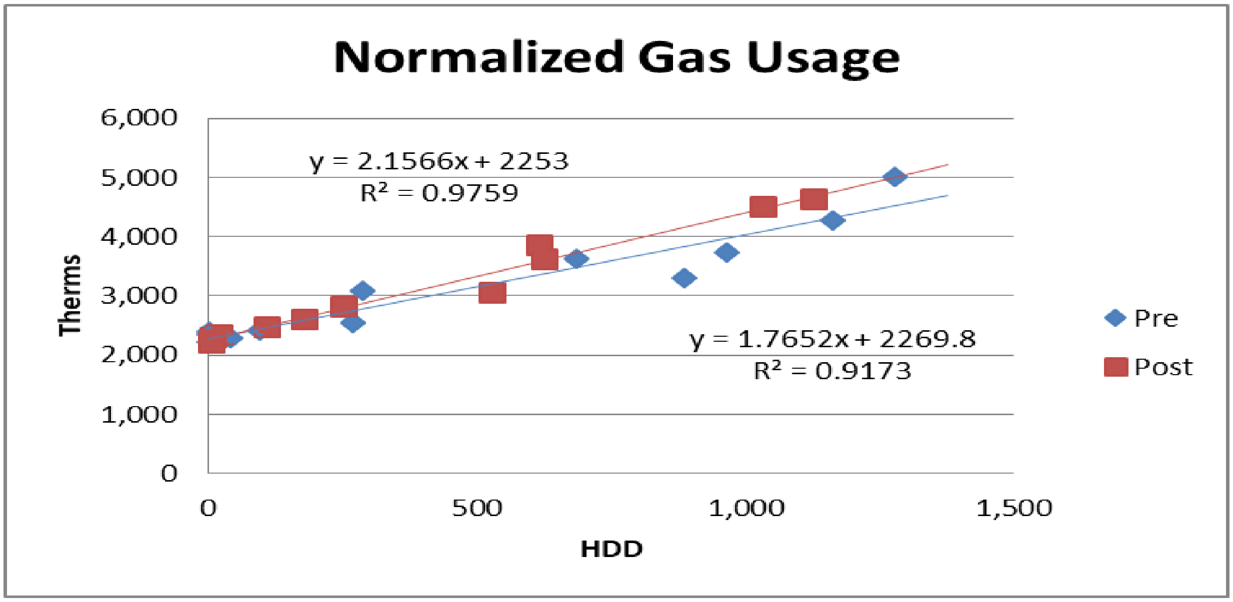


Figure 7 shows the weather normalized energy usage is greater in the post-case when compared the to the pre-case. The eQuest model was not provided with the project documentation; however, the parametric data extract from the eQuest and HVAC equipment specifications were reviewed to determine the appropriateness of the measure level savings for the large measures.

Based on the hourly parametric data extract from the eQuest model and equipment specifications for air handler 82AH2, the simulation model appears to model the measure savings by removing the air handling unit. The claimed savings for the measure involving 82AH2 (convert unit from CV to VAV) are 514,034 kWh and 24,011 therms. The equipment specifications for that unit include 51.58 kW in fan motors, 35,000 supply cfm, and 8,680 cfm in outside air flow. To estimate of annual electrical usage for the unit, the fan power was multiplied by 8,760 hours which results in 451,841 kWh. TMY 3 weather data was used to estimate the gas usage for the unit while conditioning 8,680 cfm of outdoor air to a discharge air temperature of 90°F, which results in 21,093 therms per year in usage. Based on the quick usage estimations, the eQuest model appears to be estimating savings greater than annual electrical and gas usage of the air handling unit.

The ex ante and ex post savings are presented in Table 21.

Table 21. Summary of Project Savings

	Demand Savings (kW)	Annual Energy Savings (kWh)	Gas Savings (Therms)
Ex Ante	135.41	1,186,173	79,900
Ex Post	154.50	1,353,390	0
Realization Rate	114%	114%	0%

Project 900075

Project Details	
Ex Ante Measure:	Heat Exchanger
Facility Type:	Industrial
End Use:	Process

Measure Description

The project includes installing a shell and tube heat exchanger to preheat the boiler feed water with air compressor cooling water.

Summary of the Ex Ante Calculations

The ex ante calculations were provided in the project documentation. The annual gas savings for this project were calculated using the following equation:

$$Savings_{Therms/yr} = \left[\frac{500\ x\ gpm\ x\ (T_{Out} - T_{In})}{\eta_{Boiler}\ x\ 100{,}000}\right] x\ Hrs/yr$$

Where:

500 = Units conversion constant

gpm = gallons per minute on tube side of heat exchanger, 111.5

T_{Out} = Outlet water temperature on tube side of heat exchanger, 95°F

T_{In} = Inlet water temperature on tube side of heat exchanger, 62°F

η_{Boiler} = Boiler efficiency, 80%

100,000 = Conversion from Btu/h to therms

Hrs/yr = Annual operating hours of air compressors, 8,544

The project documentation included pictures to confirm the inlet/outlet water temperatures and water flow (gpm). The boiler efficiency appears to be an estimate, while the annual compressor operating hours were referenced from metered data in a separate compressed air project. The ex ante savings were calculated to be 196,485 therms per year.

The ex ante savings for this measure are presented in Table 22.

Table 22. Ex Ante Savings

	Demand Savings (kW)	Annual Energy Savings (kWh)	Gas Savings (Therms)
Heat Exchanger	0	0	196,485

Measurement and Verification Plan

IPMVP Option A, Partially Measured Retrofit Isolation, will be used to establish savings for this project.

During the site visit, the equipment will be inspected and if possible, make and model information for the new heat exchanger will be collected. Pictures of the building energy management system will be taken to confirm the inlet/outlet water temperatures and the flow (gpm) on the tube side of the heat exchanger. If available, inlet and outlet water temperature trends will be collected in addition to trends of water flow (gpm) on the tube side of the heat exchanger. The trends will be used to confirm the water temperatures and flow rates used in the ex ante calculations. The operation of the air compressors and process boilers is expected to be fairly consistent throughout the year.

If inlet/outlet temperature trends from the tube side of the heat exchanger are not available, heat exchanger effectiveness and the compressor cooling water delta T will be collected to calculate the energy transfer.

The site representative will be interviewed about the typical operation of the air compressors/boilers and if the new heat exchanger replaced any other equipment that preheated the boiler feed water. An attempt will be made to confirm the boiler feed water temperature before the installation of the heat exchanger. The site representative will be asked to confirm, or provide an estimate, of the boiler efficiency. Finally, the site representative will be interviewed concerning the facility's expected operation over the course of the next year and concerning their previous year's operation.

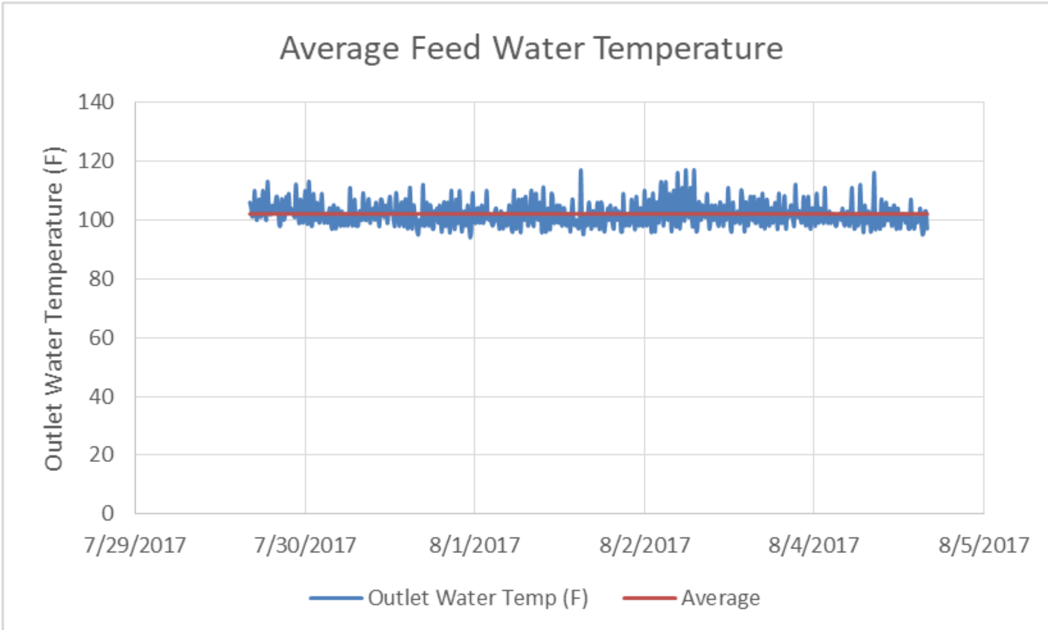
If the operation of the process boilers and air compressors varies significantly throughout the year and equipment trends are not available, a Hobo U12-012 logger and thermocouple will be attached to the supply and return pipes to log the water temperature at 15 minute intervals for a minimum of two week.

Description of Verification

A site visit was completed on September 28, 2017. The site contact was interviewed and the installation of the heat exchanger was verified. The air compressors and boiler equipment was confirmed to be part of the process equipment at the facility. The operation of the equipment is generally constant but can change throughout the day as process lines at the facility require varying amounts of steam.

The site contact was able to provided updated operating trends of the inlet and outlet water temperature on the tube (boiler feed water) side of the heat exchanger. Figure 8 shows the average outlet water temperature on the tube side of the heat exchanger.

Figure 8. Average Outlet Water Temperature (Tube Side)



The data showed that the average outlet water temperature was 102°F. The data only goes to 8/5/2017 because the facility temporarily changed the operation of the heat exchanger in order to trouble shoot some pressure problems with the boiler water tanks. The facility also had a scheduled shut down prior to 7/29/2017. Typical operation (depicted by data in the graph) is expected to begin again at the start of November. Therefore, the temperature data collected during the site visit will be used to update the ex ante calculations.

Calculation Description

The ex ante savings analysis was used as the basis for the ex post savings. The average outlet water temperature was adjusted in the saving analysis. The ex post savings were greater than the ex ante savings due to increasing the average boiler feed water temperature from 95°F to 102°F. Updated operating trends showed that the average outlet water temperature on the tube side (boiler feed water) of the heater exchanger was 102°F.

The project documentation did not include the water temperature trends that were used in the ex ante analysis. Therefore, the ex ante data was not able to be used in the ex post analysis. The ex post analysis used the same savings methodology and equations that were used in the ex ante analysis.

Increasing the boiler feed water temperature to 102°F increased the gas savings by 41,854 therms and results in a realization rate of 121%. The ex ante and ex post savings are presented in Table 23.

Table 23. Summary of Savings

	Demand Savings (kW)	Annual Energy Savings (kWh)	Gas Savings (Therms)
Ex Ante	0	0	196,485
Ex Post	0	0	238,339
Realization Rate	N/A	N/A	121%

Project 900081

Project Details	
Measure:	Industrial Refrigeration System Improvements
Facility Type:	Industrial
End Use:	Process

Measure Description

This project consists of the installation of new controls for the ammonia refrigeration system at a meat processing plant, to allow for the implementation of suction temperature and head pressure reset controls, the installation of variable speed drives on the evaporator fan motors, and tying the high-high suction into the side port of the high side compressors. Additionally, VFDs were installed on two recirculation pumps to decrease pump speed, and boiler condensate recovery and blowdown water heat recovery was done to reduce the gas use of the boilers.

Summary of the Ex Ante Calculations

There are five changes made to the refrigeration system for this project. The savings made for each change were calculated separately. These changes include fan speed reductions, raising suction temperatures and sequencing, decreasing head pressures, utilizing the side port of the compressors, and reducing the liquid recirculation pump speed.

Fan speed reductions were made to 82 fans, each 5 horsepower (HP) (for a total of 410 HP of controlled fans). The calculation specifies that the speed of each fan can be reduced to 79.8% speed for 4,317 hours per year during production times, 45% speed for 1,424 hours per year during cleanup times, and 41.6% speed for 1,602 hours per year during weekend operation. The fans are assumed to be 89% efficient and have a load factor of 80%. The demand of the fans is calculated to be reduced by 49% during production times, 91% during cleanup times, and 93% during weekends. The energy use reduction of the fans is calculated using the following equation:

$$Savings\ (kWh) = \frac{Total\ Fan\ HP \times Hours \times Load\ Factor \times \%demand\ reduction}{motor\ efficiency} \times 0.746\frac{kW}{HP}$$

The savings for the production periods, cleanup periods, and weekends are calculated separately, and the total resulting fan energy savings is 1,348 MWh.

The savings for raising the suction temperatures and sequencing is calculated separately for the low temp boosters, the standard temp boosters, and the compressors. The refrigeration system contains thirteen compressors, two standard temp boosters, and four low temp boosters. This equipment is summarized in Table 24.

Table 24. Summary of Refrigeration System Compressors

Unit Tag	Type	Motor HP	Tons @ Operating Conditions
C-1	Compressor	800	594.7
C-2	Compressor	800	594.7
C-3 Swing	Compressor	800	593.8
C-4	Compressor	500	371.9
C-16	Compressor	700	538.4
C-18	Compressor	700	513.7
CV-1	Compressor	200	156.7
CV-2	Compressor	200	157.3
CV-3	Compressor	200	157.4
CV-4	Compressor	200	156.8
CV-6	Compressor	200	155.8
CV-7	Compressor	200	156.9
CY-10	Compressor	200	157.3
B-7	Low Temp Booster	500	445.6
B-6	Low Temp Booster	500	445.2
B-5	Low Temp Booster	500	445.2
B-4	Low Temp Booster	500	445.6
B-2	Standard Temp Booster	400	402.1
B-1	Standard Temp Booster	125	130.8

The operating power of the low temperature boosters is specified to be 1,327.5 kW, and the boosters are expected to operate during production times for 4,692 hours per year, yielding an annual production energy use of 6,229 MWh. The ex ante calculation file indicates that suction pressure curves were used to determine the savings for raising the suction temperature, and determined savings of 2.91% per degree Fahrenheit. The suction temperature change for this project is specified to be 5.62 degrees, so the resulting savings is 16.4%. Multiplying the baseline annual energy use of the low temperature boosters by this value yields savings of 1,019,230 kWh for production periods.

The rated cooling capacity of the standard temperature booster B-1 is specified to be 402.1 tons, and from the suction pressure curves, it is expected that raising the suction temperature will increase the capacity by 6.8% to 429 tons, changing the full-load efficiency of the booster from 0.581 kW/ton to 0.552 kW/ton. The total load of the standard temp boosters is specified to be 497 tons, leaving 67 tons to be provided by booster B-2. From the suction pressure curves, it is expected that the efficiency of B-2 at this load is 0.773 kW/ton. The total demand of both standard temperature boosters is calculated to be 289 kW, so their overall efficiency at a load of 497 tons is 0.582 kW/ton. This is a 10.3% reduction compared to the baseline efficiency of 0.648 kW/ton specified in the calculation spreadsheet (the baseline demand of the boosters being 321.9 kW). To determine the annual energy saving for these boosters during production times, the baseline demand (321.9 kW) was multiplied by the expected annual production operating hours (4,692), and multiplied by the percentage reduction in demand calculated as described above. The resulting savings for the standard temperature boosters during production times is 154,966 kWh.

To develop an operating profile for the refrigeration compressors during production periods, a bin analysis is done based on the outside air temperature. For the baseline compressor operation, the discharge condensing temperature resets linearly between 80.2ºF and 92.8ºF as the outside air temp goes between -2.3ºF and

92.3ºF, and the discharge pressure resets linearly between 139 PSI and 181 PSI over the same outdoor temperature range. The efficiency of the compressors is specified to be 0.93 kW/ton at a condensing temperature of 92ºF, and improves by 1.5% per degree Fahrenheit reduction in condensing temperature. This results in a maximum efficiency of 0.771 kW/ton in the lowest temperature bin to 0.947 kW/ton in the highest temperature bin. The total cooling load of the compressors is shown to be nearly constant, changing by less than 40 tons from the lowest to highest temperature bins, with an average load of 5,555 tons. To determine the total annual energy use of the compressors during production times, the tonnage for each bin is multiplied by the estimated efficiency of the compressors (kW/ton) for each bin, and multiplied by the number of production hours in each bin. The resulting baseline annual energy use of the compressors during production times is 23,788 MWh.

The ex ante savings calculations include two sets of data that contains the operating tons and operating demand of each compressor, from which the operating efficiencies of the compressors can be calculated. The source of this information is not noted in the calculation file, but the calculations suggest that one set of data is from prior to the project implementation, and one is from after the completion of the project. This data indicates that the weighted average efficiency of the compressors improved from 0.934 kW/ton to 0.904 kW/ton, which equates to a reduction of 3.2%. To calculate the annual production time energy savings for the compressors, the baseline annual energy use is multiplied by this percent reduction, yielding annual production savings of 767,885 kWh.

The savings calculations for raising the suction temperature and sequencing were repeated for the cleanup periods. During cleanup periods, which total 1,565 hours per year, the demand of the low temperature boosters is specified to be 722.9 kW. The suction temperature change is specified to be 15.18 degrees, and from the suction pressure curves, this yields savings of 44.2%. The resulting low temperature booster savings is 499,853 kWh. The standard temperature booster demand is specified to be 296 kW (source not specified), and by changing the suction temperature by 4.48ºF, the suction pressure curves indicate savings of 13%. The resulting savings for the standard temperature boosters is 60,361 kWh.

To determine the savings for raising the suction temperature and sequencing on the compressors during cleanup times, a bin analysis was used just as it was for the production periods. For the cleanup periods, the discharge temperature resets between 80.2ºF and 93.4ºF as outdoor air goes from -3.5ºF to 80.6ºF, and the discharge pressure resets between 139 PSI and 176.3 PSI. The resulting compressor efficiency goes from 0.821 kW/ton at the lowest outdoor air temperatures to 1.001 kW/ton at the highest temperatures. The cooling load during cleanup periods is 3,826 tons for all temperature bins, and covers a total of 1,565 hours per year. The compressor efficiency improvement during cleanup periods was assumed to be the same as the efficiency improvement calculated for production periods (3.2%), and the resulting compressor savings is 171,001 kWh.

The savings calculations for raising the suction temperature and sequencing were also repeated for the weekend operation. During weekend operation, which total 2,503 hours per year, the demand of the low temperature boosters is specified to be 322.6 kW. The suction temperature change is specified to be 23.02 degrees, and from the suction pressure curves this yields savings of 67.0%. The resulting low temperature booster savings is 541,116 kWh. The standard temperature booster demand is specified to be 295 kW (source not specified), and by changing the suction temperature by 4.48ºF, the suction pressure curves indicate savings of 13%. The resulting savings for the standard temperature boosters is 96,322 kWh.

To determine the savings for raising the suction temperature and sequencing on the compressors during weekend operation, a bin analysis was used in the same manner as it was for the production periods. For the weekend operation, the discharge temperature resets between 80.2ºF and 92.2ºF as outdoor air goes from -3.9ºF to 91.4ºF, and the discharge pressure resets between 139 PSI and 172.5 PSI. The resulting compressor efficiency goes from 0.756 kW/ton at the lowest outdoor air temperatures to 0.933 kW/ton at the highest temperatures. The cooling load during cleanup periods is 3,233 tons for all temperature bins, and covers a total of 2,503 hours per year. The compressor efficiency improvement during weekend operation is assumed to be the same as the efficiency improvement calculated for production periods (3.2%), and the resulting compressor savings is 215,520 kWh.

To calculate the savings from decreasing head pressure, a bin analysis was completed based on outdoor air temperature. This bin analysis shows that the proposed condensing temperature is 72ºF at outdoor temperatures of 55ºF and below, and linearly increases to 92.6ºF at an outdoor air temperature of 92.3ºF. The efficiency of the compressors is calculated assuming a 1.5% improvement per degree Fahrenheit reduction in condensing temperature, compared to the baseline condensing temperature of 92ºF. The efficiency values calculated in the bin analysis for raising the suction temperature are used as the baseline values for this measure, which range from 0.771 kW/ton at the lowest outdoor temperature to 0.947 kW/ton at the highest temperature. The proposed condensing temperatures result in efficiency values of 0.650 kW/ton for all outdoor temperature bins 55ºF and below, and increases linearly to 0.938 kW/ton at an outdoor temperature of 92.3ºF. To determine the baseline compressor energy consumption during production times, the refrigeration load in each temperature bin is multiplied by the baseline efficiency and the number of production hours in the bin, and the proposed energy use is calculated in the same manner using the updated calculated efficiency values. The resulting compressor savings during production times is 4,474 MWh. Due to the decreased head pressure, the condenser fans will need to operate more, and it was determined that the fan demand would need to change from 69.2% of full-load to 85.8%. This results in an increase in condenser fan energy use of 184 MWh. The resulting net production savings is 4,290 MWh.

The savings calculations for decreasing head pressure were repeated for the cleanup periods. During cleanup periods, the proposed condensing temperature is 72ºF for all outdoor temperature bins up to 55ºF, and then resets linearly to 90.2ºF at an outdoor temperature of 80.6ºF. The baseline condensing temperature during cleanup periods is 87ºF, for which the compressor efficiency is 0.908 kW/ton, and the efficiency was assumed to improve by a 1.5% per degree Fahrenheit reduction in condensing temperature compared to the baseline. The resulting proposed efficiency of the compressors is 0.710 kW/ton for outdoor air temperatures of 55ºF and below, and the efficiency linearly resets up to 0.958 kW/ton at 80.6ºF outdoor air temperature. The savings for the decreased head pressure were then calculated in the same manner as for the production periods using the operating hours, efficiencies, and cooling loads in each bin, and the resulting savings during cleanup periods is 1,056 MWh. The increase in condenser fan energy use was determined to be 64 MWh, so the net cleanup period savings is 992 MWh.

Finally, this savings calculation was repeated again for weekend operation. During weekend operation, the proposed condensing temperature is 72ºF for all outdoor temperature bins up to 55ºF, and then resets linearly to 90.2ºF at an outdoor temperature of 91.4ºF. The baseline condensing temperature during weekend operation is 96ºF, for which the compressor efficiency is 0.985 kW/ton, and the efficiency is assumed to improve by a 1.5% per degree Fahrenheit reduction in condensing temperature compared to the baseline. The resulting proposed efficiency of the compressors is 0.678 kW/ton for outdoor air temperatures of 55ºF and below, and the efficiency linearly resets up to 0.946 kW/ton at 91.4ºF outdoor air temperature. The savings for the decreased head pressure were then calculated in the same manner as for the production periods using the operating hours, efficiencies, and cooling loads in each bin, and the resulting savings during weekend operation is 1,012 MWh. The increase in condenser fan energy use was determined to be 114 MWh, so the net weekend operation savings is 898 MWh.

No information could be found about how the savings for utilizing the side port of the compressors was determined. The reported savings for this across all operation of the compressors is 277,131 kWh.

The liquid recirculation pumps involved in this project consist of one unit rated at 30 HP and one unit rated at 40 HP. These pumps are assumed to operate continuously at full speed, with a load factor of 70% prior to the completion of the project. The calculations specify that the recirculation pumps can both operate at 71.8% speed and meet the required demand, but the source of this speed value is unclear. The demand of the pumps at this speed was calculated using an affinity exponent of 2.7, which shows that the electrical demand of the pumps is expected to be 41% of the baseline demand. This results in savings of 81,124 kWh for the 30 HP pump and 108,166 kWh for the 40 HP pump.

The ex ante electric savings for this project are summarized below in Table 25.

Table 25. Ex Ante Savings (MWh)

Improvement	Production	Cleanup	Weekend	Total
Fan Speed Reduction	584	356	409	1,348
Raise Suction Temp & Sequence	1,942	731	853	3,526
Decrease Head Pressure	4,290	992	898	6,180
Utilize Compressor Side Port	168	10	99	277
Liquid Recirculation Pumps	189			189
Grand Total				**11,521**

The gas savings for this project were determined in four steps – skid feed water savings, hot water dumping savings, boiler blowdown heat recovery, and skid condensate recovery.

The skid feed water flow rate was measured to be 48.9 GPM, and during the baseline the incoming water is specified to be 138.2ºF, with a leaving water temperature of 214.4ºF (76.2ºF temperature rise). Using a boiler and steam system efficiency of 78%, the baseline natural gas use to heat the feed water is 20,940 MMBtu. The post-implementation incoming water temperature is 151.5ºF, a 13.3 degree increase from the baseline. The annual natural gas use required to heat this water to the leaving water temperature is calculated to be 17,266 MMBtu, which is a reduction of 3,674 MMBtu compared to the baseline. Multiplying by 10 to convert from MMBtu to therms, the resulting savings is 36,739 therms.

To determine the hot water dumping savings, the baseline average rate of water being dumped was calculated to be 75.21 GPM, and the water being dumped has a temperature of 138.2ºF. The makeup water temperature is 78ºF, so the makeup water temperature needs to be raised 60.2ºF. The annual gas use required to raise this flow rate of water by 60.2ºF with the facility's 78% efficient boilers is calculated to be 25,411 MMBtu. The amount of dumping after the completion of the project is specified to be 48.71 GPM, a reduction of 35.2%. This results in an equivalent reduction in natural gas use required to heat makeup water, and the resulting natural gas savings is 8,955 MMBtu. Converting to therms yields 89,546 therms of annual gas savings from reducing hot water dumping.

To determine the amount of energy recovered from the boiler blowdown, trended data of the temperature differential of the makeup water was used. The flow rate of makeup water is specified to be 41.29 GPM, and the average temperature differential of the makeup water is 18.65ºF. This yields average heat recovery of 0.610 MMBtu per hour, or 5,343.7 MMBtu per year. This translates to 53,437 therms per year.

To calculate the natural gas for skid condensate recovery, bucket tests were used to measure the amount of condensate water being lost. These bucket tests show a loss rate of 1 gallon every 25.2 seconds at one location, and one gallon every 29 seconds at a second location. The temperature difference between the condensate water and the makeup water at the first location was measured to be 116.4ºF, and 53.9ºF at the second location. The amount of natural gas required to heat up the water loss on an annual basis was calculated to be 15,163 therms for the first location, and 6,099 therms for the second location, for a total of 21,263 therms.

The natural gas savings for this project are summarized below in Table 26.

Table 26. Ex Ante Gas Savings (Therms)

	Gas Savings
Skid Feed Water Savings	36,739
Hot Water Dumping Savings	89,546
Boiler Blowdown Heat Recovery	53,437
Skid Condensate Recovery	21,263
Total	**200,985**

Description of Verification

A site visit was completed on October 19, 2017. To verify the installation and operation of the evaporator fan VFDs, during the site visit the customer explained that the new evaporator fan VFDs operate based on sensors such that it will operate at full speed when there is a hog carcass in front of the evaporator, and will automatically turn down to 20Hz (33% speed) when there is no hog carcass in front of the evaporator. The quantity of VFD-driven evaporator fans was confirmed to be 82, and the VFDs were inspected to verify their installation and operation. The customer confirmed that prior to the completion of the project the fans did not have any speed controls, and that all of the fan motors are 5 HP each.

The head pressure reset controls and suction pressure controls implemented for the refrigeration system were reviewed, and the customer explained that the Low and Low-Low suction pressures are kept at constant setpoints during all production periods, so there is no suction pressure reset during production periods, the low-low suction pressure being kept at -7 inches of mercury. The suction pressure resets at night when production is not operating, from approximately 1:30am to 6am Monday thru Friday and on weekends, which was not being done prior to the completion of the project. The low and low-low side both discharge to the high side, and the high side compressors now operate to maintain a head pressure of 120 PSI. The customer explained that prior to the completion of the project the high side compressors operated to maintain a head pressure of 140 PSI.

The condensate recovery measures completed in the rendering plant were reviewed, and the customer explained that nearly 100% of the hot water being lost previously was now being recovered, so the only makeup water that the system needs is to replace what is lost from boiler blowdown. The customer explained that the condensate recovery system was previously undersized, which is why so much was being lost. The use of a heat exchanger to preheat the incoming makeup water using the boiler blowdown water was confirmed by inspection, and the customer explained that the rate of boiler blowdown is automatically controlled via sensors that measure the conductivity of the boiler water.

The customer was asked if there have been any significant changes to production levels or anything such as facility expansions or renovations that would have a significant impact on the billed electric and gas use for the facility, and they explained that production numbers have remained constant, but earlier in the year a new process was added to the production line that required the installation of a new air compressor, additional conveyor motors, hydraulics, and lighting, which would contribute to increased energy use. Details of the added equipment was recorded so that the energy use of the new process can be taken into account if a billed regression is completed.

Summary of Ex Post Calculations

To determine the ex post savings for this project, the ex ante savings calculations were reviewed, and changes were made using the information collected during the site visit and the pre and post-implementation trends provided by the customer. Additionally, the algorithms used in the savings calculations were reviewed and updated to reflect industry standard practice.

The savings calculations for the evaporator fan VFDs were reviewed, and it was found that the speed reductions specified for the production, cleanup, and weekend periods were reasonable. The ex ante energy savings were determined using an affinity exponent of 3, but this was changed to 2.4 as this is more accurate of the actual relation between fan speed reduction and demand reduction. This modification to the savings calculations causes the savings for the evaporator fan VFDs to decrease by 148,670 kWh to 1,199 MWh.

Trended data of the refrigeration system loads was used to determine the average load during production, cleanup, and weekend operation, and the resulting average loads are provided below in Table 27, as well as the ex ante values.

Table 27. Average Refrigeration Loads

Period	Ex Ante			Ex Post		
	High	Low	Low-Low	High	Low	Low-Low
Production	5,537	497	1,595	3,718	496	1,584
Cleanup	3,826	451	789	2,730	455	898
Weekend	3,233	449	305	2,069	451	304

The most notable difference is significantly lower high side compressor loads during all time periods. The savings calculations were updated to include these refrigeration load values. The reduction in high side refrigeration loads causes the savings for this project to decrease for both the suction pressure and head pressure controls.

Trended data provided in the project documentation and provided by the customer were used to determine the actual pre and post-implementation suction pressures during the production, cleanup, and weekend periods. It should be noted that the post-implementation low temperature booster pressure trends shows two very distinct operating periods during the weekend, so the weekend operation was split up into two different operating profiles in the savings calculations. The suction pressures found during these time periods using the provided trended data are shown below in Table 28.

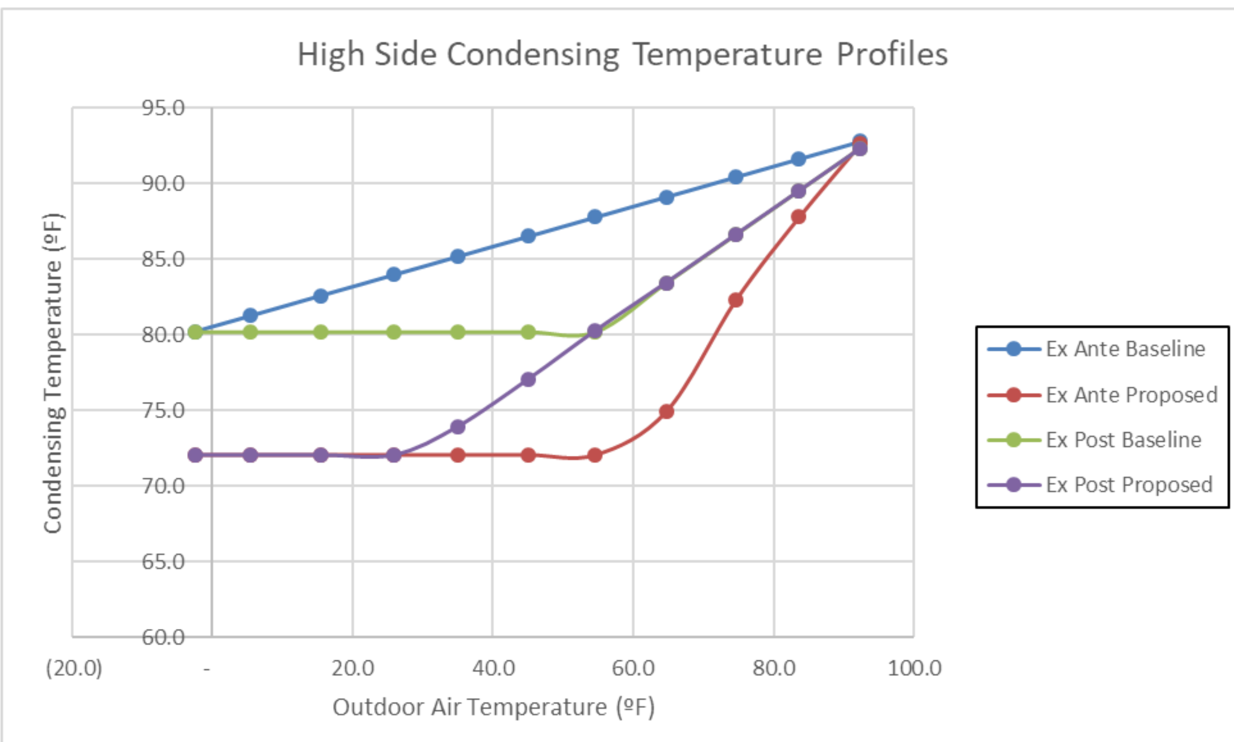
Table 28. Summary of Suction Pressures

Compressors	Production Pre	Production Post	Cleanup Pre	Cleanup Post	Weekend Period 1 Pre	Weekend Period 1 Post	Weekend Period 2 Pre	Weekend Period 2 Post
Low-Low	-3.0	-3.0	-4.2	-3.5	-5.0	-6.5	-4.4	31.0
Low	-1.0	-1.0	-1.3	-2.0	-1.3	-2.3	-1.3	-2.3
High	25.6	27.3	24.3	27.2	23.4	27.3	23.4	27.3

The suction pressures were found to increase less than what is specified in the ex ante savings calculations, and in some cases the suction pressures actually decreased and caused negative savings. The compressor performance curves used in the ex ante savings calculations to determine the efficiency improvement of the compressors due to the changes in suction pressure were used in the ex post savings calculations as they were deemed reasonable. The resulting savings for the suction pressure controls is 1,040 MWh, compared to the ex ante savings of 3,526 MWh.

To determine the savings for the head pressure controls, the ex ante savings were reviewed, and multiple changes were deemed necessary to the savings calculations. Industrial refrigeration systems will maintain a constant condensing temperature as outdoor air increases until it is no longer able to maintain a constant condensing temperature. The ex ante savings show that in the baseline there is a linear increase in condensing temperature between the coldest and warmest temperature bins, which is contradictory to how industrial refrigeration systems typically operate. The baseline minimum condensing temperature of 80.2ºF is reasonable and the post-case temperature of 72ºF is consistent with what was observed during the site visit. The baseline system should maintain the minimum condensing temperature until the outdoor air temperature reaches approximately 60ºF, after which the condensing temperature should linearly increase, and in both the pre and post case, the condensing temperatures above this outdoor air temperature should be identical. The savings calculations were updated to reflect this operation. A graph showing the ex ante and ex post condensing temperatures for the production periods is provided below in Figure 9.

Figure 9. High Side Condensing Temperature Profiles



Upon review of the algorithms used in the determination of savings for the head pressure controls, it was found that a rule of thumb of 1.5% efficiency improvement per degree Fahrenheit change in condensing temperature was used, and that 1.5% was simply multiplied by the difference in temperature between the condensing temperature and a reference temperature (which is 92ºF for the production periods). This rule of thumb is an acceptable approach to calculating efficiency improvements if the change in temperature is small (less than 5 degrees), but in this case a temperature difference of 20 degrees results for some outdoor air temperature bins. To provide a better estimate of the resulting efficiency change, the calculation was updated to use an exponential calculation, such that for each degree of temperature change the incremental efficiency improvement is 1.5%. All of the changes made for the head pressure controls result in a net savings of 778,047 kWh, compared to the ex ante savings of 6,192,117 kWh.

The ex ante savings for utilizing the side port of the compressors and the installation of variable speed drives on the liquid recirculation pumps were reviewed and deemed reasonable. No changes were made to the savings for utilizing the side ports of the compressors or the liquid recirculation pump VFDs.

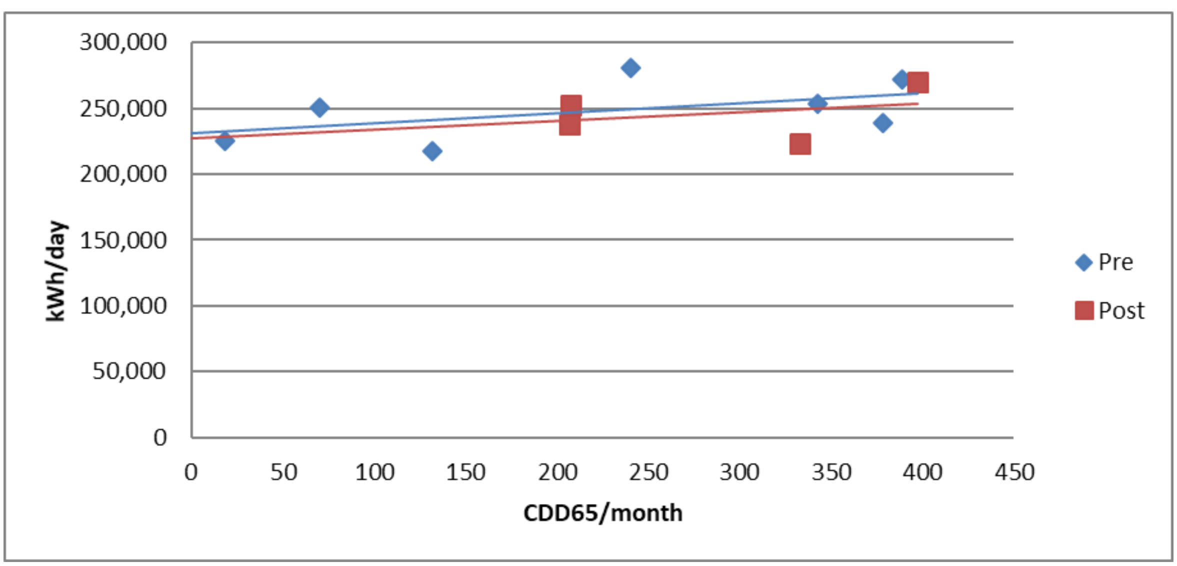
The total ex ante and ex post electric savings for this project are summarized below in Table 29.

Table 29. Summary of Electric Savings (MWh)

Measure	Ex Ante	Ex Post
Fan VFDs	1,348,230	1,199,530
Suction Pressure	3,526,255	1,040,394
Head Pressure	6,180,402	778,047
Side Port	277,131	277,131
Recirculation Pump	189,290	189,290
Total	**11,521,308**	**3,484,393**

The billed electric use for the facility was obtained and used to check that the ex post savings are consistent with what is shown in the billed use history. During the site visit the customer explained that since the completion of this project an additional process was added to the production system that caused an increase in electric consumption for the facility, and the equipment for that additional process was estimated to consume between 1.5 and 2.5 million kWh per year. A weather-normalized billed use regression was completed, and the resulting regressions are shown below in Figure 10.

Figure 10. Electric Billed Regressions



The electric billed regression shows almost no visible reduction in the electric energy consumption of the facility despite the completion of the project and no changes to production levels. The added energy use of the new production equipment largely offsets the ex post savings for this project, indicating that the ex post savings are consistent with the billed use of the facility.

During the site visit the customer explained that all of the condensate was now being recovered from the rendering plant, and the boiler blowdown heat recovery was confirmed to be operational. To determine the natural gas savings for this project the ex ante savings calculations were updated to reflect the site findings, and the algorithms used in the calculations were reviewed. The post-case condensate loss was changed in the savings calculations from 75.42 GPM (average) to zero, which causes the savings for the condensate recovery to increase. Additionally, upon review of the savings calculations for the boiler blowdown heat recovery it was found that the calculations do not take into account the efficiency of the boilers. Adding the boiler efficiency to the savings algorithms increases the natural gas savings for the boiler blowdown heat recovery. The resulting natural gas savings for this project is 409,349 therms. A summary of the ex ante and ex post gas savings is provided below in Table 30.

Table 30. Summary of Gas Savings

Measure	Ex Ante	Ex Post
Skid Feed Water	36,739	65,471
Hot Water Dumping	89,546	254,106
Boiler Blowdown Heat Recovery	53,437	68,509
Skid Condensate Recovery	21,263	21,263
Total	**200,985**	**409,349**

The total ex ante and ex post savings for this project are summarized below in Table 31.

Table 31. Summary of Ex Ante and Ex Post Savings

	Demand (kW)	Energy (MWh)	Natural Gas (therms)
Ex Ante	1,315.2	11,521	200,985
Ex Post	397.8	3,485	409,349
Realization Rate	30.2%	30.2%	203.7%

Project 900093

Project Details	
Ex Ante Measure:	Upgrade Boiler Burner
Facility Type:	Industrial
End Use:	Process

Measure Description

This project includes the installation of a new burner on a 1,200 BHP steam boiler. The new burner is also equipped with O2 trim controls. The new burner maintains a 3% O2 concentration across the burner firing range. The lower burner turndown reduces the cycling losses of the boiler, while the O2 controls improve the combustion efficiency.

Summary of the Ex Ante Calculations

The project documentation includes the calculation used to determine the annual energy savings. The gas savings for the new burner were calculated in two steps. The first was to account for the reduction in cycling due to the new burner's higher turndown. The ex ante calculations assumed a 1% energy savings based on the customer's indication that the baseline boiler cycled once per hour. The 1% savings estimate was multiplied by the total baseline boiler consumption to arrive at 21,111 therms of natural gas savings due to cycling.

The second portion was the savings due to increasing the combustion efficiency of the new burner. Combustion test results of the new burner showed a combustion efficiency of 85.3% at medium fire for the new boiler. This is higher than the baseline measured combustion efficiency at medium fire of 81.5%. Improving the combustion efficiency resulted in a 3.8% improvement in boiler efficiency. The improved efficiency yielded an additional 91,679 therms of natural gas savings.

The new boiler burner was also equipped with a variable frequency drive blower fan. Additionally, the blower fan size was reduced from 60 HP to 35 HP. The baseline burner fan was assumed to operate at 50% load factor, with inlet damper controls. Following the inlet damper control profile found in the Illinois TRM, this suggests a baseline fan power of 53%. The new burner blower was also assumed to operate at 50% load factor. Using the VFD load factors from the Illinois TRM estimates a VFD fan power of 30%. These calculations showed a baseline fan demand of 13.3 kW compared to an efficiency case demand of 6.7 kW.

The ex ante savings for this project are summarized below in Table 17.

Table 32. Summary of Project Savings

	Demand Savings (kW)	Annual Energy Savings (kWh)	Gas Savings (therms)
Upgraded Boiler Burner	6.6	56,616	112,790

Measurement & Verification Plan

IPMVP Option A, Partially Measured Retrofit Isolation, will be used to establish savings for this project. Depending on the availability of metered data, IPMVP Option C, Whole Building Analysis, could be used as an alternative, or supplemental, evaluation methodology.

A site visit will be performed during which the new burner will be visually verified to be installed and operating. The customer will be interviewed regarding the final installation date, and the performance of the new burner since its installation. The boiler O2 and stack temperature trends will be reviewed. The boiler test reports will be discussed. Boiler load profiles will be discussed and information about boiler downtime obtained. The customer will also be interviewed regarding the condition and operation of the baseline burner prior to its replacement.

The installed boiler burner will be metered with the customers permission. Nameplate data on the burner fan will be recorded. Either amperage loggers, or DENT real power meters will be installed for a period of at least two weeks to monitor the energy usage of the new burner fan. The burner fan kW will be used to develop a loading profile for the new burner. The load profile will be applied to the baseline burner control scheme (inlet guide vanes) to determine the overall electric energy savings. The burner loading will also be used to verify the average loading assumptions used in the ex ante analysis.

The gas bills for this customer will also be obtained. According to the project documentation, the boiler constitutes approximately 97.5% of the gas usage for this meter (or account). The building square footage will be obtained and information on how the building is heated. A weather and production normalized regression will be completed to confirm the metered data results.

Description of Verification

A site visit was completed on July 20, 2017. The plant engineer was interviewed and the new burner installation physically verified. At the time of the site visit the burner fan was running at 2,846 rpm or 80% of full speed rpms of 3,560 rpm. The motor nameplate showed the horsepower rating was 25.5 HP. The burner nameplate showed the burner had a maximum firing rate of 37,543 MBTUH. The boiler nameplate showed the boiler was rated at 1,000 HP with a max firing rate of 40,300 MBTUH. A summary of boiler efficiencies from the project documentation is shown in Table 33. The baseline values are based on a combustion analysis completed prior to the retrofit. The proposed values are based on the boiler firing at 3% O2 content.

Table 33. Boiler Efficiencies

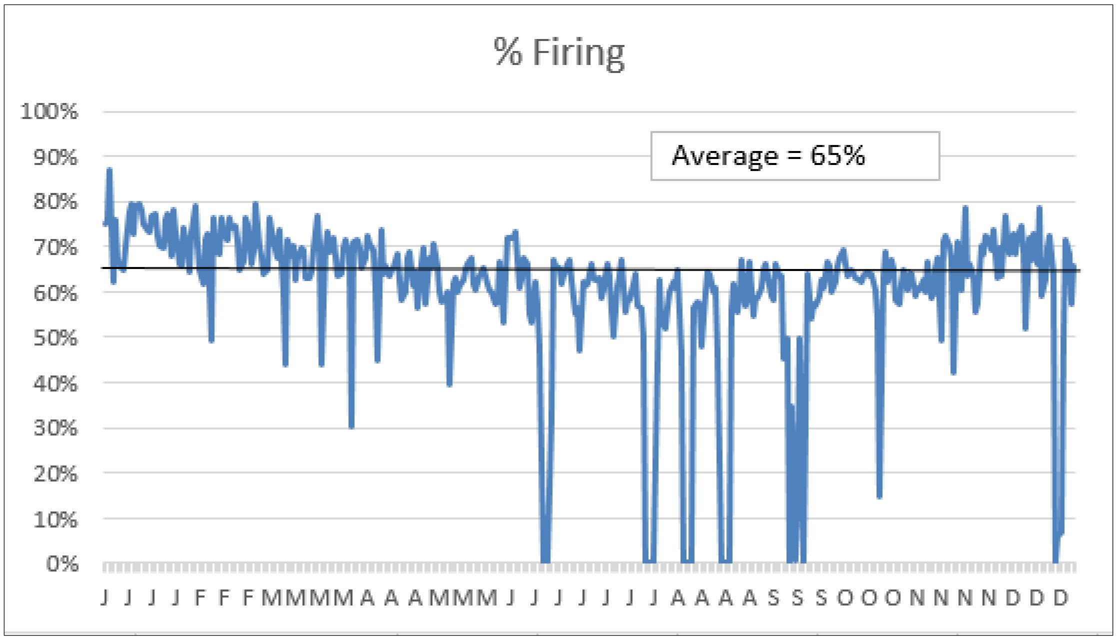
	High Fire – 70%	Med Fire – 30%	Low Fire – 0%
Baseline	83.07%	81.52%	83.86%
Proposed	84.78%	85.26%	87.18%

The boiler was shut down on June 13th, 2016 for annual maintenance work and installation of the new burner. The boiler was started up on June 17th, 2016. This shutdown was part of the annual shutdown that occurs every June for approximately one week. The boiler is also shut down monthly for approximately 8 hours for cleaning and inspection.

This is the only boiler at the facility and it primarily feed the plant processes. The boiler feeds only (3) steam unit heaters while the rest of the facility is heated by natural gas direct-fired makeup air units. The site contact confirmed that the boiler load is relatively stable with an average load of 75% and typically ranging from 58% to 80%. Typically steam flow of 16,000 lb/hr with boiler outlet steam pressure at 63 psig. This supplies approximately 55 psig to the plant process. The boiler load is stable because the plant usually has a backlog of orders.

The site contact also provided daily gas data for the boiler so the load profile could be evaluated. For the three years of data provided, the average load was 66%, 65%, and 64%. The daily load profile from 2016 is shown in Figure 11.

Figure 11. Daily Load Profile (2016)



Per the site contact, the new burner has performed very well overall. The average O2 level has dropped from approximately 4% to 2.7%. In the June 2017 outage the O2 setpoint was further reduced to 1.6%. The second adjustment was made because the boiler has been stable at the higher O2 levels and further gas savings were desired. The site contact shared that he felt the O2 trim was providing the most savings. Since the boiler provides a steady load there is less savings due to reduced cycling.

Calculation Description

Update utility data was obtained. This data showed a baseline production usage in the summer so the winter heating load could be estimated. Overall the heating usage is 8.4% of annual gas usage. Part of this gas usage is for natural gas direct-fired makeup air units, which was assumed to be 2.5% of annual gas usage. The remaining was to supply steam to unit heaters.

A regression analysis using updated billed usage for the facility was used to help inform the ex post savings. The analysis used 11 months of pre retrofit data and 12 months of post retrofit data. The analysis showed 137,247 annual therms savings, which is 6% of annual usage. This percentage is less than the ideal of at least 10% of annual gas usage for a regression analysis. The coefficient of variation for the baseline period was 5.2 % and for the proposed period was 5.2%. These are both well within the desired level of less than 20%. However this methodology was not appropriate based on data obtained during the site visit. The boiler load is not weather dependent so a regression based on CDD and HHD is not an appropriate methodology for savings analysis.

For the actual savings analysis the boiler operation was modeled in a spreadsheet. The model assumed that the majority of boiler load was for the manufacturing process. This is a steady load and requires the boiler to be fired in the high firing range of 65%. The model assumed that approximately 6% of boiler usage was for building heating. In the baseline condition the boiler had a 3:1 turndown rate and efficiency at high fire was 82.86%. In the proposed condition the boiler had a 10:1 turndown ratio and an efficiency at high was 84.78%. The results from the model showed the boiler should achieve 66,396 therms savings per year.

The savings from the new burner fan motor were based on the ex ante calculations. The load profile was updated based on the daily gas usage provided by the customer. The new fan horsepower was updated from the ex ante estimate of 35 HP to the burner nameplate value of 25.5 HP. The ex post calculation showed an energy savings of 72,066 kWh and a demand savings of 8.4 kW.

The results from the modeling and realization rate are shown in the table below. The gas savings was reduced because the boiler efficiency of 81.5% in the ex ante calculation was lower than the 82.86% used in the ex post case. The boiler model did not calculate savings from cycling. Based on the site visit there was no information to support the assumption that the boiler cycled once per hour. The boiler appears to run steady with very little cycling. For the new fan, greater savings was achieved because the new fan was smaller than assumed in the ex ante calculations.

Table 34. Summary of Project Savings

	Demand Savings (kW)	Annual Energy Savings (kWh)	Gas Savings (Therms)
Ex Ante	6.6	56,616	112,790
Ex Post	8.4	72,066	66,396
Realization Rate	127%	127%	55%

Project 901012

Project Details	
Ex Ante Measure:	Upgrade Boiler Burners
Facility Type:	Hospital
End Use:	HVAC

Measure Description

This project includes the installation of four new burners and associated 30 HP VFD controlled blower fans on steam boilers at the facility. The existing burners had 60 HP constant volume blower fans. The new burners are also equipped with O2 trim and linkage-less controls. The new burner maintains a 3% O2 concentration across the burner firing range.

Summary of the Ex Ante Calculations

The project documentation notes that only two boilers operate at any time. Therefore, savings were only calculated for two boilers.

Gas savings were calculated using a combination of pre/post combustion efficiency test, rated capacities, and annual operating hours. Measured combustion efficiency at medium fire for the existing equipment was 81.7% for boiler 2 and 81.99% for boiler 3. Combustion test results of the new burners showed a combustion efficiency of 86.2% at medium fire after the new burners and controls were installed; a 4.5% and 4.23% improvement in boiler efficiency for boilers 2 and 3, respectively. The improved efficiency yielded 126,678 therms of natural gas savings. The project documentation does not specify why boilers 2 and 3 were chosen when calculating energy savings. Pre-case combustion tests for boilers 1 and 4 do not appear to be included in the project documentation.

In addition to reducing the blower fan horsepower (HP), the new burner blowers were equipped with variable frequency drive (VFD) controls. The existing and proposed energy usage for the blower fans were calculated using Toshiba modeling software. The electric savings for the VFDs were noted to be capped at 67% of the baseline usage. An uncertainty factor of 75% was also applied to the energy savings for the VFD blowers, which further reduced the electric energy savings. The total electric energy savings for the blower fans for boilers 2 and 3 were calculated to be 281,125 kWh and 32.09 kW.

The ex ante savings for this project are summarized below in Table 17.

Table 35. Summary of Project Savings

	Demand Savings (kW)	Annual Energy Savings (kWh)	Gas Savings (therms)
Upgraded Boiler Burners	32.09	281,125	126,678

Measurement & Verification Plan

IPMVP Option A, Partially Measured Retrofit Isolation, will be used to establish savings for this project. Depending on the availability of trended data, IPMVP Option C, Whole Building Analysis, could be used as a supplemental analysis.

A site visit will be performed, during which the new burners will be visually verified to be installed and operating. The customer will be interviewed regarding the final installation date, and the performance of the new burners since their installation. The boiler O2 and stack temperature trends will be reviewed and the boiler test reports will be discussed. Boiler load profiles will be discussed and information about boiler downtime obtained. The customer will also be interviewed regarding the condition and operation of the baseline burners prior to their replacement.

The installed boiler burners will be metered (with the customer's permission). Nameplate data on the burner fans will be recorded. Either amperage loggers or DENT real power meters will be installed for a period of at least two weeks to monitor the energy usage of the new burner fans. The burner fan kW will be used to develop a load profile for the new burners. The load profile will then be applied to the baseline burner control scheme (outlet dampers) to determine the overall electric energy savings. The burner loading will also be used to verify the average loading assumptions used in the ex ante analysis.

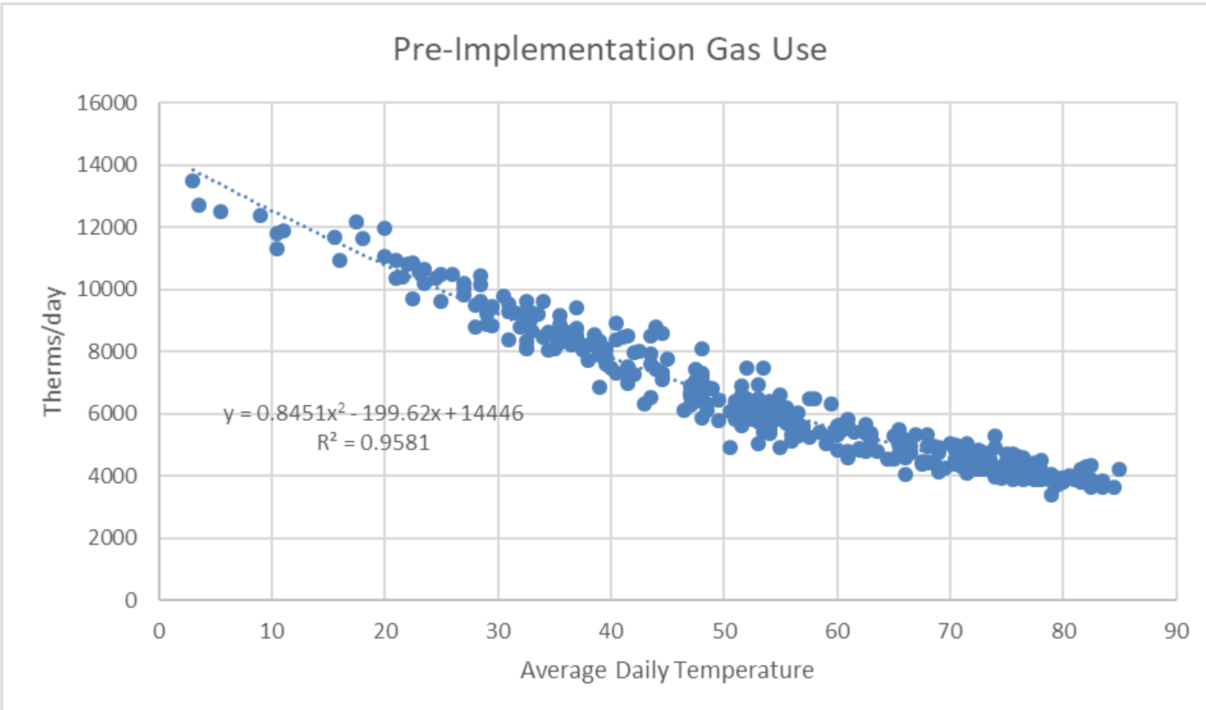
Description of Verification

A site visit was completed on October 20, 2017. During the site visit the customer explained that prior to the completion of the project the boilers had 60HP single-speed fans, and that the airflow was controlled by manually adjusted dampers. Combustion tests were on file from before the completion of the project, and the customer had daily gas use information that was collected as well. With the installation of the new burners with VFD-driven fans and oxygen trim controls, a constant flue gas oxygen concentration of 3% is maintained. New burners, fans, and oxygen sensors were confirmed to be installed on all four boilers in the central plant, but the plant has full redundancy so only two boilers are needed at any given time. The boilers operate year-round to meet the steam needs of the hospital, and are manually turned on and off. If only one boiler is operating, when the load on the boiler exceeds 60% of its rated capacity a second boiler will be started and the load will be shared evenly between the boilers. Three of the four boilers are water tube units that each have a capacity of 38,760 MBH, and the fourth boiler is a fire tube unit of which the rated capacity could not be found during the site visit. The boilers operate to maintain a constant steam pressure of 100 PSI all the time.

Calculation Description

To determine the ex post gas savings for this project the daily gas use records received from the customer were used along with local historical weather data to determine how the gas use of the central plant correlates to outdoor air temperature. The correlation found between the daily gas use and the daily average temperature is shown graphically in Figure 12.

Figure 12. Pre-Implementation Daily Gas Use Correlation



The correlation between daily gas use and average daily temperature was used along with TMY3 weather data to determine the gas use each day during a "typical" meteorological year. The rated capacities of the boilers and the boiler sequencing specified by the customer was used to determine if one or two boilers needed to operate during each day of the year, and the loading of the boilers was calculated using the expected daily gas use, the number of boilers expected to operate, and the rated capacities of the boilers. The pre-implementation combustion tests that were taken were used to determine the pre-implementation operating efficiency of the boilers for each day and the steam load met by the boilers.

The customer was able to provide trends of the flue gas temperature and oxygen concentration for one of the boilers, the trends covering 3 days of operation. The trended data was used calculate the operating efficiency of the boiler with the new VFD fans and oxygen trim controls, and the average operating efficiency was found to be 83.28%. The daily post-implementation gas use was determined by multiplying the baseline gas use by the baseline efficiency and then dividing by the post-implementation efficiency. The difference between the total TMY3 gas use for the baseline and post-implementation boiler operation is the ex post savings for this project. The annual gas use of the boilers is expected to go from 2,513,086 therms to 2,455,416 therms, a reduction of 57,670 therms. This represents a 2.3% savings.

The ex post gas savings for this project are less than the ex ante savings because the flue gas temperatures shown in the trended data provided by the customer and observed during the site visit are significantly higher than the flue gas temperatures specified in the post-implementation combustion tests used in the ex ante savings calculations. Higher flue gas temperatures result in lower thermal efficiencies, so the post-implementation efficiency was found to be lower than what is used in the ex ante calculations.

Details about the energy use of the baseline fan motors was not available during the site visit, but based on the reduction in fan motor size and the installation of variable speed drives to control the new fan motors, the ex ante electric savings for this project were deemed reasonable. There are no changes to the electric savings for this project.

The ex ante and ex post savings for this project are summarized below in Table 36.

Table 36. Summary of Project Savings

	Demand Savings (kW)	Annual Energy Savings (kWh)	Gas Savings (Therms)
Ex Ante	32.09	281,125	126,678
Ex Post	32.09	281,125	57,670
Realization Rate	100%	100%	46%

Project 901381

Project Details	
Measure:	Baghouse Fan VFDs
Facility Type:	Industrial
End Use:	Process

Measure Description

This project includes removing dampers and installing VFDs on four 1,250 HP baghouse fans. The VFDs will control the fans based on mill operation. The fans will now be able to reduce speed and turn on when the mill is not in operation.

Summary of the Ex Ante Calculations

The ex ante calculations were provided in the project documentation. The savings for this project were calculated based on one day (24 hours) of pre- and post-case metered data. A summary of the pre-case and post-case metered data is summarized in Table 37.

Table 37. Summary of Metered Data

Pre-Case		Post-Case	
Power (kW)	Time (hrs)	Power (kW)	Time (hrs)
1,640	11.75	530	15.75
860	7.00	530	1.50
1,640	5.25	0	6.75

The average pre- and post-case power was calculated using a weighted average based on the operating hours during the metering period. The average pre-case power was calculated to be 1,412.5 kW (two fans) while the average post-case power was calculated to be 380.9 kW (two fans). The average power was multiplied by the annual operating hours, 4,992, and multiplied by two to account from the two fans that weren't metered. This resulted in pre-case usage of 14,105,400 kWh and post-case usage of 3,803,280 kWh and yields 10,299,120 kWh in annual savings, or a 73% reduction in energy usage. The demand savings were calculated to be 2,063 kW.

The ex ante savings for this measure are presented in Table 38.

Table 38. Ex Ante Savings

	Demand Savings (kW)	Annual Energy Savings (MWh)
Baghouse Fans VFDs	2,063	10,299

Measurement and Verification Plan

IPMVP Option A, Partially Measured Retrofit Isolation, will be used to establish savings for this project. No logging will be performed due to the equipment being medium voltage (4160V).

During the site visit, the equipment will be inspected and if possible, make and model information for the fans and motors will be collected. The VFD screens will be inspected to record the fan operating power and the percent speed during the time of the site visit.

The site representative will be interviewed about the typical operation of the fans and the process they serve. The fans are now able to shut off during when not loaded. The customer will be asked why the pre-case fans not able to be shut off when the fans were not loaded. Data concerning the fan operating speeds, fan power, and monthly summary usage, similar to the ex ante provided data, will be requested if the facility is able to trend operating data. Finally, the site representative will be interviewed concerning the facility's expected operation over the course of the next year and concerning their previous year's operation.

Description of Verification

A site visit was conducted on October 17, 2017. The installation of variable speed drives for all four baghouse fans was confirmed by inspection, and at the time of the site visit all of the fans were found to be off because the facility was not in production mode. The fan motors were confirmed to be 1,250 HP each.

During the site visit the customer explained that prior to the completion of the project the baghouse fan motors ran continuously because they were afraid that starting and stopping the motors on a daily basis would over time cause damage to the motors. During periods that the fans were not needed, the outlet dampers would be closed, which would cause the current draw of the motors to go from 145 amps to approximately 90 amps. Even under normal operating conditions the outlet dampers would be partially closed, so the fans never ran at their full capacities. The facility currently operates 12 hours shifts 5 days per week during utility off-peak hours (nights), and the fans are left to operate at capacity for an additional hour after shifts end to ensure that the exhaust stack is clear of unwanted particulates.

With the installation of the VFDs, the fans are shut down outside of production hours (and still left on for ~1 hour after shifts end each day). The customer explained that the facility has recently switched from working 4 days per week to 5 days per week, so the fans operate more hours now compared to when the project was completed, and they expect to continue to operate 5 days per week in the future. The customer said that the demand of the fans during operation under VFD control is 145 amps, which is about the same as what the demand was during production periods prior to the completion of the project, thus all of the savings for this project come from the reduction in operation outside of production hours. The current provided to the fans is manually set via a controller module, which is set to 145 amps for each fan during all production times, so there is never any fluctuation in the energy use of the fans while operating.

Summary of Ex Post Calculations

The project documentation includes metered fan demand from prior to the completion of the project, which shows that the fans had an average demand of 820 kW during normal operation and 430 Amps when the outlet dampers were closed. These demand values were found to be consistent with the Amperage values specified by the customer during the site visit. The customer specified that the fans operate an average of 65 hours per week (13 hours per day, 5 days per week), and now consume no energy outside of normal operating hours. The baseline fans consumed 430 kW each during all hours outside of normal operation (103 hours/week), which is the source of the savings for this project. The ex post saving calculations for this project are summarized below in Table 39.

Table 39. Summary of Ex Post Calculations

Pre-Case		Post-Case	
Power (kW)	Time (hrs/week)	Power (kW)	Time (hrs/week)
3,280	65	3,280	65
1,720	103	0	103

The resulting baseline annual energy use for the baghouse fans is 20,354 MWh and the post-implementation annual energy use is 11,117 MWh. The resulting savings for this project is 9,238 MWh. The demand savings for this project is 1,720 kW, which is equal to the baseline energy use during non-production hours, as this demand was reduced to zero with the completion of this project, and the non-production time covers all peak periods.

The ex post savings for this project are less than the ex ante calculations due to several factors. Post-implementation demand readings included in the project documentation indicate an operating power of 530 kW for two fans (265 kW each), but that fan power is not consistent with the demand specified by the customer and the settings found in the controller module for the fans. The customer specified that the operating demand of the fans with the installed VFDs is about the same as what the operating demand was prior to the completion of the project. Increasing the post-implementation operating demand of the fans from 265 kW each to 820 kW each causes the savings for this project to decrease. The ex ante savings calculations specify a total of 4,992 hours per year that the operating data applies to, but this appears to only account for the operation for 4 days per week (consistent with prior 4 days/week work schedule), but does not account for the savings that occur during weekends, when the fans used to operate continuously with the dampers closed and now never run. Including the weekend savings causes the savings for this project to increase. Another factor that impacts the savings for this project is the number of hours that the fans are on and off. The ex ante savings specify that the fans are now off for 7 hours per day during weekdays, but according to the customer they are off 11 hours per day. Increasing the number of hours that the fans are now off also causes the savings for this project to increase. These factors combine to result in a net decrease in savings for this project.

The ex ante and ex post savings for this project are summarized below in Table 40.

Table 40. Summary of Ex Ante & Ex Post Savings

	Demand Savings (kW)	Annual Energy Savings (MWh)
Ex Ante	2,063	10,299
Ex Post	1,720	9,238
Realization Rate	83%	90%

Project 901989

Project Details	
Measure:	Strategic Energy Management

The customer completed seven measures as part of the SEM program. The measures include installing interlocks, turning off equipment when not needed, and removing excess light fixtures. The project documentation included assumptions, calculations, and descriptions for each of the measures. Four of the seven measures were noted to not have any installation or implementation cost. The remaining three measures were noted to each have a cost of less than $800 and result in a simple payback period less than 12 months.

The calculations and assumptions were reviewed and determined to be reasonable and appropriate based on the noted operating hours. Therefore, no changes were made to the ex ante analyses. Project savings are presented in Table 41.

Table 41. Summary of Project Savings

	Demand Savings (kW)	Energy Savings (kWh)	Gas Savings (Therms)
Ex Ante	1.0	739,223	-
Ex Post	-	739,223	-
Realization Rate	0%	100%	-

Based on the review, it is possible there are uncaptured demand savings for this project. The facility operates 10 hours per day during weekdays. Facilities with those hours typically have at least one hour of operation during Ameren's peak period of 4:00 pm to 7:00 pm. For example, if the facility schedule is consistently 7:00 am to 5:00 pm, there would be two hours of peak demand savings for shutting off the welders. Additional demand savings may be available for the quench pump, and dust collector measures depending on the specific equipment schedules. The ex post analysis did not include calculations for peak demand savings since time specific schedule information was not included in the project files. However, AIC should collect time specific schedules in order to properly account for demand savings which are occurring.

Project 901993

Project Details	
Measure:	Strategic Energy Management

The customer completed several energy reduction measures at the facility. The completed electric measures include replacing 28W and reducing the horsepower and speed of the cooling tower motors.

The supplied project documentation did not contain detailed descriptions for each of the claimed energy saving measures. Calculations for savings were also not available in the project documentation. Therefore, it is not possible to recreate the claimed energy savings for the T8 28W replacement bulbs. For instance, it is not clear what new fixtures are replacing the existing lamps.

No adjustments were able to be made to the ex ante savings based on a desk review of the project documentation. The savings appear reasonable based on the evaluation teams previous experience with these measures.

Similar to project 901989, each of the measures completed for this project may have eligible demand savings. Detailed time-of-day schedules were not available during the review. The evaluation team did not include ex post demand estimates.

The ex ante and ex post savings are presented in the table below.

Table 42. Summary of Project Savings

	Demand Savings (kW)	Energy Savings (kWh)	Gas Savings (Therms)
Ex Ante	10.3	596,383	-
Ex Post	-	596,383	-
Realization Rate	0%	100%	-

Project 901994

Project Details	
Measure:	Strategic Energy Management

The customer completed ten energy saving measures. The measures included VFDs, efficient light fixtures, and turning off process equipment when not in use. The project documentation included assumptions, calculations, and descriptions for each of the measures.

The calculations and assumptions were reviewed and determined to be reasonable and appropriate based on the noted operating hours. Demand savings were included for this project, and the estimates were found to be reasonable for the measures. No changes were made to the energy savings estimates for this project.

The ex ante and ex post savings are presented in the table below.

Table 43. Summary of Project Savings

	Demand Savings (kW)	Energy Savings (kWh)	Gas Savings (Therms)
Ex Ante	148.14	363,785	-
Ex Post	148.14	363,785	-
Realization Rate	100%	100%	-