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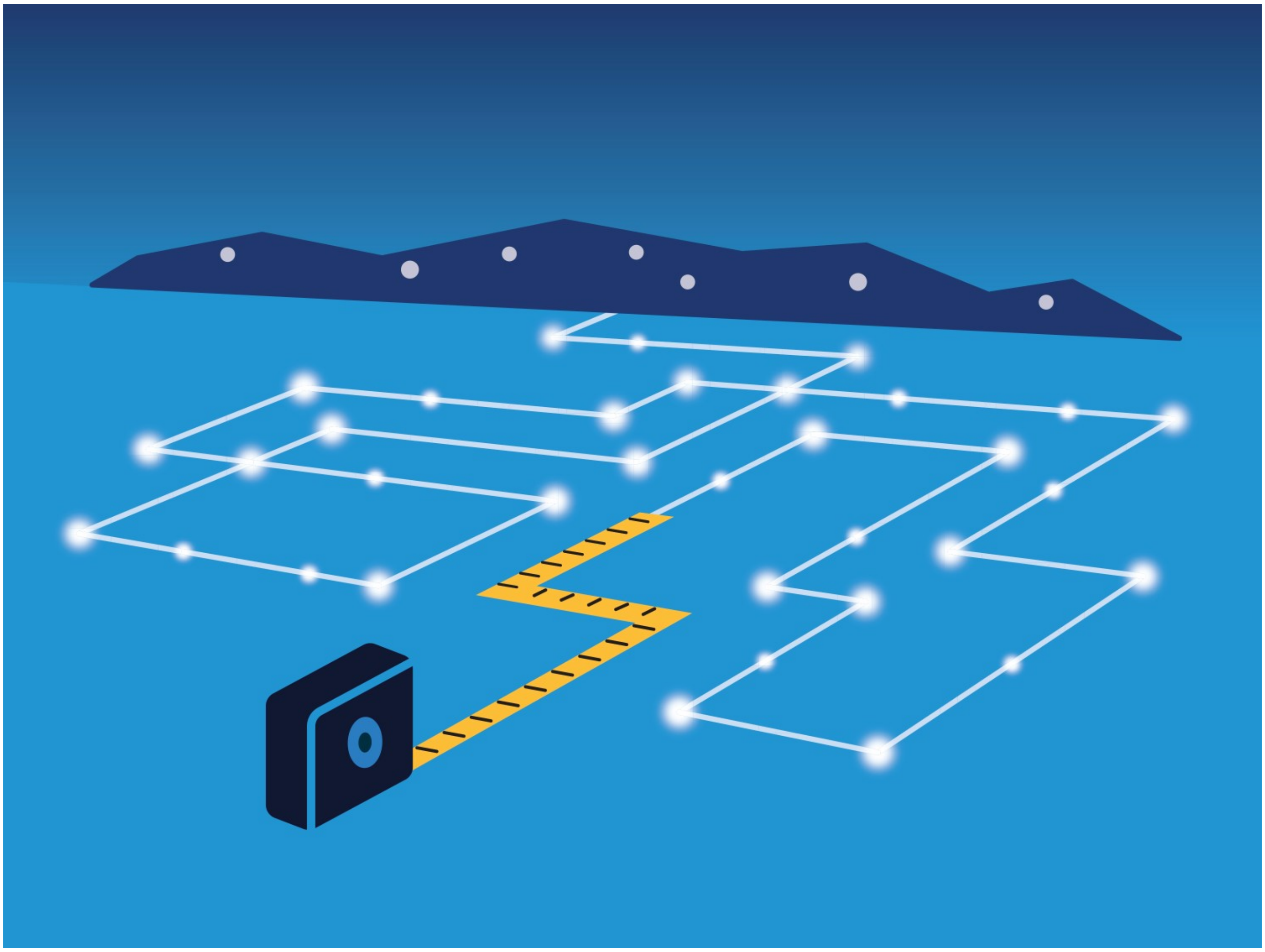

Ameren Illinois Company 2019 Business Program Evaluation Report

Appendix D – Custom Initiative Site Visit Reports

Final
April 29, 2020

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Appendix A. Custom Initiative Site Visit Reports

In this section, we present detailed project-level desk review and on-site M&V reports for 16 Custom Initiative projects evaluated as part of the 2019 Business Program impact evaluation. Four projects occurred at a single site, so the evaluation team combined these projects into one site visit report. Similarly, another three projects occurred at a different site, and the team wrote up the findings from this site visit into one report as well.

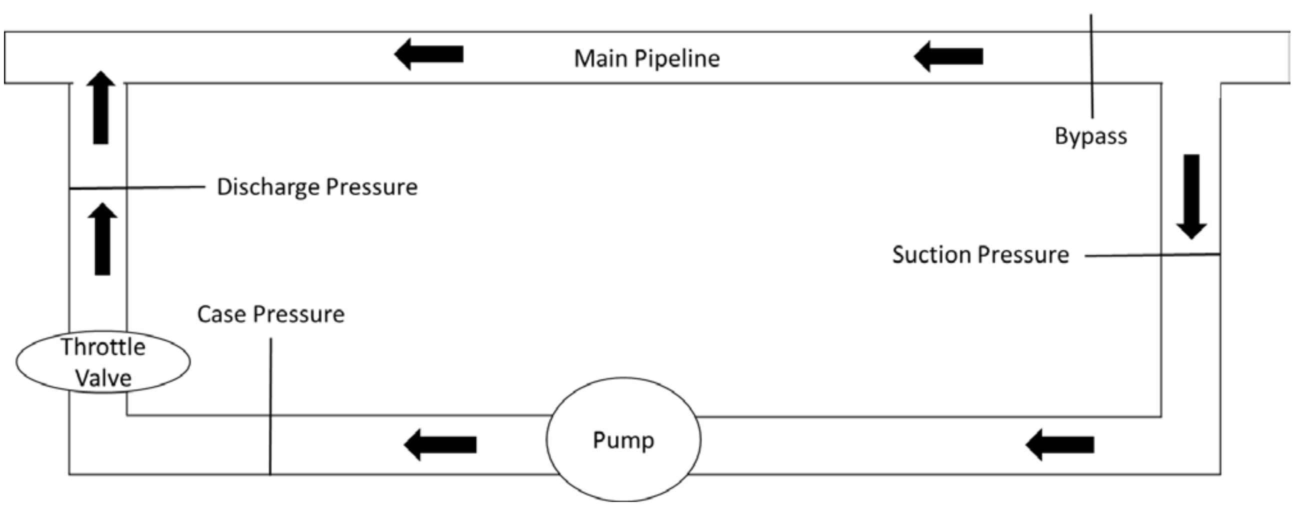
Project 1800506

Project ID#	1800506
Measure:	De-Stage Pump
Savings:	1,117,549 kWh; 337.22 kW
Facility Type:	Fuel Supply
Enduse:	Pumping

This project covers de-staging of an existing pump from seven to five stages. The pump is part of a booster station along a liquid petroleum pipeline. The pump is a 3,000 horsepower (HP) centrifugal pump. The operator altered the pump by removing two of the seven impeller stages. Reducing two of the stages reduced differential head pressure in the pump. The reduced head pressure will minimize the need to throttle the system pressure with a control valve to maintain system pressure at the desired setpoint.

The pump provides a boost of pressure to the pipeline when necessary. Figure 1 below shows a diagram of the pump and the relevant pressure readings on the system. The pump provides additional system pressure for the pipeline via a bypass valve when the difference between the case pressure and the suction pressure is greater than 1,000 pounds per square inch (psi).

Figure 1. Pump Flow Diagram



Summary of the Ex Ante Calculations

Baseline energy consumption for this measure were calculated using a full year of SCADA trended data for:

- the flow rate through the pump to be modified,
- pressure at the station upstream of the pump,
- the station suction pressure,
- the station case pressure, and
- the station discharge pressure.

The trend data is provided at one hour intervals for one year. We used the pump curve of the original pump before the de-staging to calculate the pump's efficiency at each hour. The pump that has been de-staged as part of this project is assumed to operate when the station case pressure at the upstream station is greater than 1,000 psig and the discharge pressure at the upstream station is greater than 50 psig. The differential pressure seen by the pump is the difference between the upstream station case pressure and the upstream discharge pressure.

When the pump is running, the baseline kW is calculated using the following equation:

Equation 1. Pump Power Equation

$$pump\ power\ (kW) = \frac{0.746 * \ flow\ rate\ (bph) * differential\ pressure\ (psig)}{2405 * pump\ efficiency\ (\%)} * 100$$

The hours that the pump is run is simply the count of the hours that the pump is running in the calculation. For the year, the number of hours that the pump runs is 3,314. Baseline energy consumption is then simply the sum of the pump power (kW) for each hour that it runs.

The hourly calculated pump power for the baseline is scaled by 5/7 to determine the power use of the pump after the pump is de-staged. The energy consumption after the project is similarly calculated as the sum of the pump power (kW) for each hour that it runs. The ex ante energy savings are the difference between the two energy consumption values.

A summary of these estimates are provided in Table 1.

Table 1. Pump Energy and Demand Under Baseline and De-Staged Conditions

Booster Pump	kW	kWh
Baseline	1,180.27	3,911,422
De-Staged	843.05	2,793,873

Table 2 presents the ex ante savings for this project.

Table 2. Ex Ante Savings for De-Staged Booster Pump Project

	Demand Savings (kW)	Annual Energy Savings (kWh)	Annual Gas Savings (therms)
De-Staged Booster Pump	337.22	1,117,549	N/A

Measurement and Verification Plan

The team plans to evaluate this project through a site visit. The team will observe the de-staged booster pump and will interview the site contact to collect additional information on the pump station operation. The pressures and flow rates used in the ex ante analysis are trended data collected and monitored by the facility. The team will request a sample of the same trended data points for the pump after the de-staging project.

Specific questions for this project include:

- When was the project completed?
- Since the de-staging of the pump, does the pump provide sufficient booster pressure to the pipeline?
- Have there been any changes in the pipeline operation since the project's completion that would influence the power usage of the pump?

Description of Verification

The team completed a site visit on September 11, 2019, during which time the team interviewed the site contact and verified the installed pumping equipment and pressure gauges. The facility provided one month of trend data from the pumping station, including reconfigured pump flow rate, suction pressure, case pressure, and discharge pressure readings.

Calculation Description

The trended data provided by the facility was used to determine the average power use of the pump over the provided time period of one month. The power use of the pump and conditions when the pump is running were calculated using the same formulae used in the ex ante calculation. The average ex post average power use of the pump was higher than the value estimated by the ex ante calculation which assumed the power would scale by 5/7 with the de-staging of the pump. The ex ante analysis predicted an average power use of 843.1 kW compared to the ex post average power use of 928.5 kW from the trended data. This results in a demand reduction realization rate of 75%.

The ex ante operating hours were of 3,314 hours per year (38% of the year) while the ex post data show the pump operating 44% of the time, which extrapolates out to 3,874 hours per year. The ex post hours of use were multiplied by the average ex post pump power to calculate energy consumption of the pump after de-staging. To account for any differences in production or other variables that could lead to the increased hours of usage after de-staging, the baseline energy consumption was increased by a value of 3,374/3,314. Subtracting the two energy usage values results in ex post energy savings of 975,455 kWh/year and a realization rate of 87%.

Table 3 presents the ex ante and verified savings, along with the realization rates for both demand and electric savings from the project.

Table 3. Summary of Verified Project Savings

De-Staged Booster Pump	kW	kWh
Ex Ante	337.22	1,117,549
Verified	251.81	975,455
Realization Rate	75%	87%

Projects 1800589, 1901040, and 1900485

Project ID#	1800589, 1900485, and 1901040
Measure:	1800589: Building Controls

Project ID#	1800589, 1900485, and 1901040
	1901040: Building Controls 1900485: Building Controls
Savings:	1800589: 1,202,630 kWh; 27.46 kW; 80,893 therms 1901040: 1,012,608 kWh; 46.24 kW; 60,415 therms 1900485: 10,196 therms
Facility Type:	Education
Enduse:	HVAC

Summary

This report includes three projects that were all implemented on a community college campus that share common meters and central plant equipment. The evaluated measures include upgraded controls which implement advanced scheduling, sequencing, dynamic supply air temperature resets, dynamic static pressure setpoint resets, and upgraded control valves, among other measures. The evaluation team used a billing regression model to determine the savings for the three projects.

Measure Descriptions

1800589: Building Controls

This project covered the upgrade and tuning of existing HVAC controls in three buildings on an education campus completed at the end of December 2018. The buildings are labeled D, U, and T. The HVAC control system installed as part of this project replaces an existing HVAC control system. The existing control system operated independently for each building, while the new control system integrates all of the buildings on the campus into a single centralized building automation system (BAS).

1901040: Building Controls

This project covered the upgrade and tuning of existing HVAC controls in three buildings on an education campus completed at the end of December 2019. The buildings are labeled C, P, and U. The HVAC control system installed as part of this project replaces an existing HVAC control system. The existing control system was independent for each building, while the new control system integrates all of the buildings on the campus into a single centralized building automation system (BAS).

1900485: Building Controls

This project involved the replacement of hot water values in the air handling units (AHUs) in building D with advanced controllers. The project achieved savings by reducing hot water use during occupied periods through reduced leakage. The project claimed no electric savings.

Summary of the Ex Ante Calculations

1800589: Building Controls

The ex ante savings were modeled with whole building models using EnergyPlus for buildings D, U, and T. The total modeled savings equaled 1,202,630 kWh, 27.46 kW, and 80,893 therms.

1901040: Building Controls

The ex ante savings were modeled with whole building models using EnergyPlus for buildings C, P, and U. The total modeled savings where 1,012,608 kWh, 46.24 kW, and 60,415 therms.

1900485: Active Flow Control Valves

The ex ante savings were determined based on an assumed reduction in hot water use in the AHUs in building D. The savings are achieved by reducing the hot water use during occupied periods through reduced leakage. No electric savings were claimed for this project. The baseline condition assumed that the existing units leaked a total of 5% of flow, or 12 gallons per minute (gpm), for 3,706 hours per year. The baseline condition also assumed that the existing units used a total of 10% of flow, or 24 gpm for 1,292 hours per year. The total hours of system leakage and control valve loss is 4,368 hours, which is based on building D's occupancy schedule. The change in temperature of the water that leads through the coils was 30°F. The total ex ante savings for this project equaled 10,196 therms.

Table 4 presents the ex ante savings for these projects.

Table 4. Ex Ante Savings for HVAC Building Controls Projects

Project	Demand Savings (kW)	Annual Energy Savings (kWh)	Gas Savings (therms)
1800589	27.46	1,202,630	80,893
1901040	46.24	1,012,608	60,415
1900485	0	0	10,196

Measurement and Verification Plan

1800589: Building Controls

The team will evaluate this project through a site visit, where we will observe and verify control system setpoints. We will complete the final evaluation of energy savings using a billed data regression. Specific issues to discuss during the site visit include:

- When was the project completed?
- How long did it take to implement the project? What were the specific start and end dates?
- What controls were in place previously? What was the age and condition? Were they functional?
- How were the buildings scheduled before the project? Did building D equipment run 24/7 without scheduled setbacks?
- How are the buildings and spaces in them currently scheduled (times and temperatures)? Have there been any changes to the schedule since installation?
- Do you have flow or BTU meters on buildings D and U for chilled water usage? If so, could we receive the data?
- What efficiency functions did you add with the new system?
- Can you confirm that all three buildings share an electric meter and D and U share a gas meter? Are there any sub-meters for the buildings?
- Does building T have supplemental gas heat for the heat pump system (yes, hot water boiler – gas powered)? If so, is it used often? How often?

- Do building occupants, e.g. teachers, have any local control? Is there a control override for off-schedule occupancy?
- Has the site completed any other projects, such as those listed in the project documentation (geothermal distribution pumps, compressed air system, lighting system upgrades, heat pump temperature control strategies, chilled water plant control upgrade, reduction of ventilation fan speeds, computer power management, and building energy metering) since the controls upgrade that significantly impact the building energy use?
- Is any trend data available? Specifically, for Building D, can you provide any trending data for the four AHUs, e.g. hot water (HW) flow or valve position, supply air and mixed air temperatures, and HW temperatures? Similarly, can you provide trending info for the boiler(s)?
- Is trending available with the new system? If so, is trending a new capability that you didn't have with previous controls system?

1901040: Building Controls and 1900485: Building Controls

We evaluated these projects through desk reviews because the team sampled these projects in later waves. However, the site visit provided information about this project as part of the baseline description of the campus controls. We based the final savings on a billed data regression.

Description of Verification

The evaluation team completed a site visit to the community college on October 15, 2019. Each of the projects was completed on different systems in different campus buildings. The site contact confirmed that the project 1800589 started at the beginning of October 2018 and was completed in December of 2018. A follow-up e-mail from the site contact confirmed that project 1901040 started in October and finished in December 2019. The site completed project 190485 between July and August 2019. Sub-meter data was not available or feasible for assessing the savings for these projects. Overall, the projects were installed and operated as expected.

The campus also had four additional small out-of-scope projects that occurred sometime throughout 2019. These projects were primarily lighting projects, and the aggregate ex ante savings from them was 674,739 kWh and 37 kW. We removed the savings for these projects from the billing analysis results to avoid double counting the savings.

Calculation Description

Projects 1800589 and 1900485

The evaluation team used a billed data regression to estimate verified savings. Because central plant equipment serves multiple buildings, the evaluation team could not analyze the projects individually. However, the team completed separate billing regressions for electric and gas savings. Overall, the campus experienced significant energy savings between 2018 and January 2020. First, the evaluation team completed a weather normalized billing regression using a baseline period spanning from September 2017 to September 2018 and a post-installation period from January 2019 to November 2019. Projects 1800589 and 1900485, as well as the four small projects outside the scope of this review, drove the savings over this time frame. The total weather normalized savings from the billing regression equaled 1,742,804 kWh, 198.95 kW, and 95,962 therms. After subtracting the savings from the out-of-scope projects, the savings for this set of projects is 1,068,065 kWh, 44.48 kW, and 95,962 therms. This resulted in realization rates equal to 89%, 162%, and

105% for energy, demand, and gas savings, respectively. Figure 2 and Figure 3 present the weather normalized savings for these projects.

Figure 2. Weather Normalized Modeled Electric Savings

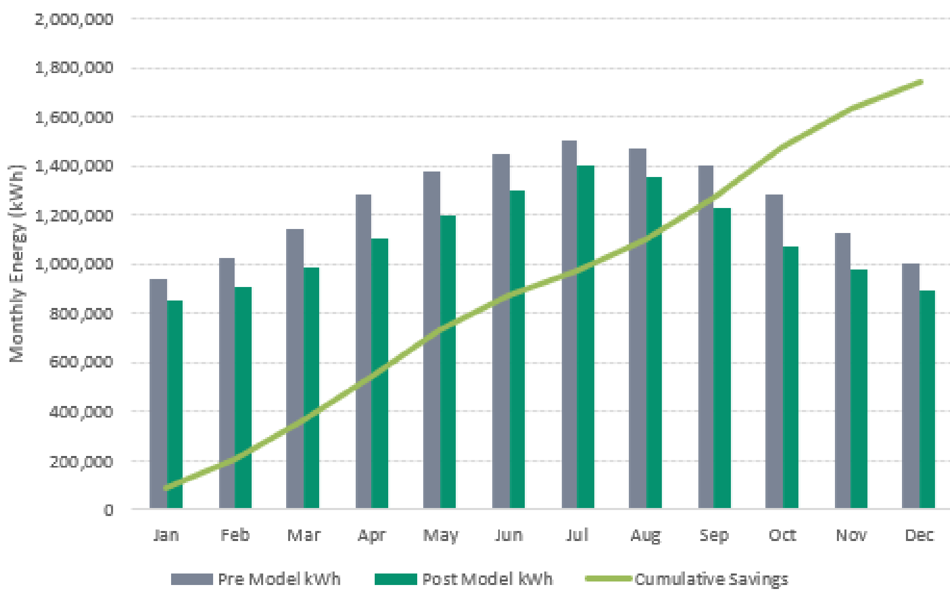
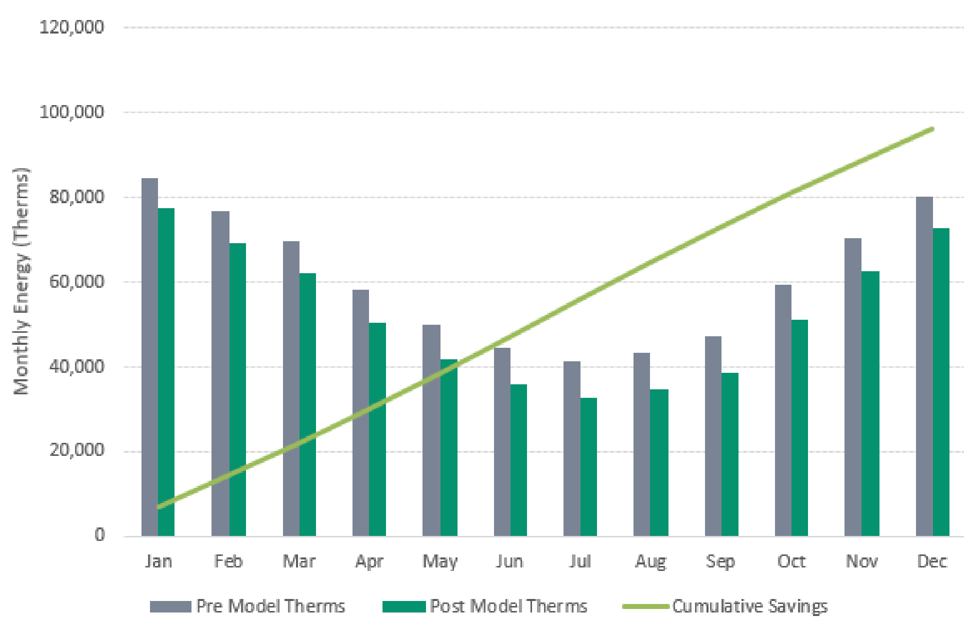


Figure 3. Weather Normalized Modeled Gas Savings



Finally, project 1901040 is similar in scope to project 1800589. We extrapolated the electric savings using the modeled post-installation data from project 1800589 against the actual campus consumption for the billed post-implementation billed period. Because of the limited post-implementation timeframe for project 1901040, the team could not create an independent model. Using this extrapolation is reasonable since we expect similar seasonal savings load shapes for the two projects. Using this method, we estimated verified savings equal to 1,261,575. kWh, 57.6 kW, and 100,581 therms. This yielded realization rates of 125% for energy and demand, and 166% for gas. Table 5 and Table 6 show the extrapolated savings estimate for electric and gas.

Table 5. Extrapolated Electric Savings for Project 1901040

Months	Project 1800589 and Project 1900485 Savings				Project 1901040 Savings		
	Pre Model kWh	Post Model kWh	Savings	% of Total Savings	Modeled Post	Actual Post	Savings
Jan	937,061	848,578	88,483	5%	905,429	802,933	102,496
Feb	1,023,104	904,769	118,335	7%			
Mar	1,142,139	982,906	159,233	9%			
Apr	1,285,561	1,106,865	178,696	10%			
May	1,378,415	1,193,215	185,200	11%			
Jun	1,444,780	1,300,807	143,973	8%			
Jul	1,502,453	1,400,750	101,702	6%			
Aug	1,474,289	1,351,935	122,355	7%			
Sep	1,403,715	1,229,608	174,107	10%			
Oct	1,280,831	1,075,530	205,301	12%			
Nov	1,130,183	974,698	155,485	9%	955,212	893,681	61,531
Dec	998,887	888,954	109,933	6%	944,212	792,845	151,367
Totals	**15,001,418**	**13,258,613**	**1,742,804**	**100%**	**2,804,853**	**2,489,459**	**1,261,575**

Table 6. Extrapolated Gas Savings for Project 1901040

Months	Project 1800589 and Project 1900485 TMY Savings				Project 1901040 Savings (2019-2020)		
	Pre Model kWh	Post Model kWh	Savings	% of Total Savings	Modeled Post	Actual Post	Savings
Jan	84,425	77,358	7,067	7%	70,431	59,330	11,101
Feb	76,723	69,357	7,366	8%			
Mar	69,698	62,060	7,638	8%			
Apr	58,367	50,291	8,077	8%			
May	50,026	41,626	8,400	9%			
Jun	44,394	35,777	8,618	9%			
Jul	41,386	32,651	8,734	9%			
Aug	43,194	34,529	8,664	9%			
Sep	47,175	38,665	8,510	9%			
Oct	59,359	51,321	8,038	8%			
Nov	70,290	62,675	7,615	8%	64,293	60,310	3,983
Dec	80,081	72,846	7,236	8%	66,096	57,190	8,906
Totals	**725,118**	**629,156**	**95,962**	**100%**	**200,820**	**176,830**	**100,581**

Table 7 through Table 9 show the complete project summary for this set of projects. Overall, this set of projects saved more than was initially anticipated in the ex ante savings estimates, with aggregate realization rates of 139%, 105%, 130% for energy, demand, and gas, respectively.

Table 7. Summary of Ex Ante Savings by Project

Building Controls Projects	Demand Savings (kW)	Annual Energy Savings (kWh)	Gas Savings (Therms)
1800589	27.46	1,202,630	80,893
1901040	46.24	1,012,608	60,415
1900485	N/A	N/A	10,196
Total	**73.7**	**2,215,238**	**151,504**

Table 8. Summary of Verified Savings by Project

Building Controls Projects	Demand Savings (kW)	Annual Energy Savings (kWh)	Gas Savings (Therms)
1800589	44.48	1,068,065	85,221
1901040	57.60	1,261,575	100,581
1900485	N/A	N/A	10,741
Total	**102.08**	**2,329,640**	**196,543**

Table 9. Summary of Realization Rates by Project

Building Controls Project	Demand Savings (kW)	Annual Energy Savings (kWh)	Gas Savings (Therms)
1800589	162%	89%	105%
1901040	125%	125%	166%
1900485	N/A	N/A	105%
Total	**139%**	**105%**	**130%**

Project 1800623

Project ID#	1800623
Measure:	HVAC Controls
Savings:	26,085 therms
Facility Type:	Academic Building
Enduse:	HVAC

Measure Description

This project includes control and setpoint upgrades to 23 air handling units (AHUs) in an education building built in the 1960s. The systems date back to the building's original construction and are energy-intensive by nature. System types include dual duct and constant volume reheat systems, both of which are prone to excessive simultaneous heating and cooling.

The control upgrades include occupancy scheduling with setback temperature setpoints, discharge air temperature (DAT) reset, hot deck and cold deck reset based on outside air temperature (OAT) and increasing the economizer setpoint. The educational institution also installed carbon dioxide (CO2) sensors for demand-controlled ventilation (DCV). Reset measures can have dramatic effects on heating and cooling energy consumption for these types of systems.

The educational institution completed this project in March of 2019. Table 10 shows the proposed new schedules and setpoints. Table 11 presents the proposed DAT reset parameters. Table 12 shows the proposed OAT reset parameters for the hot and cold decks. The existing and proposed economizer setpoints are shown in Table 13. The evaluation team received these tables in project documentation files.

Table 10. Proposed New Schedules and Setpoints for Each AHU Included in the Project

Air Handing Unit (AHU)	Proposed Schedule/Setpoints (Hours Include Time Needed for Warm Up / Cool Down)								
	Monday - Friday		Saturday		Sunday		Unoccupied Space Setpoints		
	Start	Stop	Start	Stop	Start	Stop	Cooling (°F)	Heating (°F)	Humidity High Limit (%RH)
C	6:00am	11:00pm	6:00am	11:00pm	6:00am	11:00pm	80	60	
D	6:00am	11:00pm	6:00am	11:00pm	6:00am	11:00pm	80	60	
E	6:30am	3:00pm	6:30am	3:00pm	6:30am	3:00pm	80	60	
F	6:30am	3:00pm	6:30am	3:00pm	6:30am	3:00pm	80	60	
G	6:00am	11:00pm	6:00am	11:00pm	6:00am	11:00pm	80	60	
J	7:00am	6:00pm	7:00am	6:00pm	7:00am	6:00pm	80	60	
K	6:00am	11:00pm	6:00am	11:00pm	6:00am	11:00pm	80	60	60%
L	6:00am	11:00pm	6:00am	11:00pm	6:00am	11:00pm	80	60	
M	6:00am	11:00pm	6:00am	11:00pm	6:00am	11:00pm	80	60	
N	6:00am	11:00pm	6:00am	11:00pm	6:00am	11:00pm	80	60	
O	6:00am	11:00pm	9:00am	11:00pm	1:00pm	10:00pm	80	60	
P	7:00am	4:30pm	Closed	Closed	Closed	Closed	80	60	
Q	6:00am	11:00pm	6:00am	11:00pm	6:00am	11:00pm	80	60	
R	6:00am	11:00pm	6:00am	11:00pm	6:00am	11:00pm	80	60	
T	9:00am	10:00pm	9:00am	10:00pm	9:00am	10:00pm	80	60	60%
U	6:30am	3:00pm	6:30am	3:00pm	6:30am	3:00pm	80	60	60%
V	6:00am	11:00pm	6:00am	11:00pm	6:00am	11:00pm	80	60	60%
W	7:00am	4:30pm	7:00am	4:30pm	7:00am	4:30pm	80	60	60%
X	6:00am	11:00pm	6:00am	11:00pm	6:00am	11:00pm	80	60	60%
Y	7:00am	4:30pm	7:00am	4:30pm	7:00am	4:30pm	80	60	60%
Z	6:00am	11:00pm	6:00am	11:00pm	6:00am	11:00pm	80	60	
AA	6:00am	11:00pm	6:00am	11:00pm	6:00am	11:00pm	80	60	
BB	6:00am	11:00pm	6:00am	11:00pm	6:00am	11:00pm	80	60	

Table 11. Existing and Proposed Discharge Air Temperature Setpoints and Reset Strategies

AHU Tag	Existing			Proposed Setpoint		
	System Type	DAT Setpoint	Reset Strategy	DAT Range	OAT Range	Reset Strategy
D	CVRH	55	None	55-65	30-70	Based on OADB
L	CVRH	55	None	55-65	30-70	Based on OADB
M	CVRH	55	None	55-65	30-70	Based on OADB
N	CVRH	55	None	55-65	30-70	Based on OADB
D	CVRH	55	None	55-65	30-70	Based on OADB

Table 12. Existing and Proposed Setpoints and Reset Strategies for Dual Duct (DD) and Make-up Air (MX) Units

AHU Tag	System Type	Existing				Proposed			
		Cold Deck		Hot Deck		Cold Deck		Hot Deck	
		Setpoint	Reset Strategy	Setpoint	Reset Strategy	Setpoint	Reset Strategy	Setpoint	Reset Strategy
C	CVMZ	55	None	75-105	OAT	55-58	OAT	75-105	OAT
E	CVDD	55	None	75-105	OAT	55-58	OAT	75-105	OAT
G	CVDD	55	None	75-105	OAT	55-58	OAT	75-105	OAT
J	CVMZ	55	None	75-105	OAT	55-58	OAT	75-105	OAT
O	CVDD	55	None	75-105	OAT	55-58	OAT	75-105	OAT
P	CVDD	55	None	75-105	OAT	55-58	OAT	75-105	OAT
Q	CVMZ	55	None	75-105	OAT	55-58	OAT	75-105	OAT
R	CVDD	55	None	75-105	OAT	55-58	OAT	75-105	OAT
V	CVDD	55	None	75-105	OAT	55-58	OAT	75-105	OAT
W	CVDD	55	None	75-105	OAT	55-58	OAT	75-105	OAT
X	CVDD	55	None	75-105	OAT	55-58	OAT	75-105	OAT
Y	CVDD	55	None	75-105	OAT	55-58	OAT	75-105	OAT
Z	CVDD	55	None	75-105	OAT	55-58	OAT	75-105	OAT
AA	CVDD	55	None	75-105	OAT	55-58	OAT	75-105	OAT
BB	CVDD	55	None	75-105	OAT	55-58	OAT	75-105	OAT

Table 13. Existing and Proposed Economizer Setpoints and Control Strategies

AHU Tag	System Type	Existing		Proposed	
		Setpoint	Controlled by OADB or Enthalpy	Setpoint	Controlled by OADB or Enthalpy
C	CVMZ	55	OADB	60	OADB
D	CVRH	55	OADB	60	OADB
G	CVDD	55	OADB	60	OADB
J	CVMZ	55	OADB	60	OADB
K	CVSZ	55	OADB	60	OADB
M	CVRH	55	OADB	60	OADB
O	CVDD	55	OADB	60	OADB
P	CVDD	55	OADB	60	OADB

AHU Tag	System Type	Existing		Proposed	
		Setpoint	Controlled by OADB or Enthalpy	Setpoint	Controlled by OADB or Enthalpy
Q	CVMZ	55	OADB	60	OADB
R	CVDD	55	OADB	60	OADB
T	CVSZ	55	OADB	60	OADB
V	CVDD	55	OADB	60	OADB
W	CVDD	55	OADB	60	OADB
X	CVDD	55	OADB	60	OADB
Y	CVDD	55	OADB	60	OADB

Summary of the Ex Ante Calculations

Analysis for this project is very complex as heating and cooling are delivered by district plants. Steam from a steam plant is used for space heating. Cooling is delivered by two chilled water plants that collectively run two 3,500 ton steam-turbine-driven chillers and one 1,250 ton electric chiller. Furthermore, steam is used with a backpressure turbine to produce electricity. The customer estimates 80% of its chilled water is produced by steam-driven chillers using natural gas, while 20% is produced by the electric chiller. The customer provided billing data for steam and chilled water use for the building in question.

It appears a consultant developed the original calculations, and then the program implementer modified them. The calculations use a bin analysis for each AHU, which is reasonable for this project type. The calculations for each AHU account for outside air temperature, relative humidity, and the prescribed setpoints to determine system energy use before and after the project. The calculations appeared reasonable, but they were not reviewed in great detail because there is no way to determine pre-existing conditions in this assessment. Instead, the program implementer used a metering analysis to verify and modify the consultant's energy savings estimate. To this end, the customer provided billing data for the building's use of chilled water and steam, the estimated central plant natural gas used for cooling, and billing data for the building's other gas consumption (non-HVAC).

The program implementer used the customer provided billing data to estimate natural gas consumption by enduse, including cooling, heating, cooking/other, and domestic hot water. The implementer allocated the share of gas consumption to each enduse based on benchmark data from AIC's website.[1] As mentioned previously, natural gas generated 80% of the chilled water consumed. The steam consumed by the building was estimated to provide 60% of its energy to heating, 30% to domestic hot water, and 10% to cooking/other. It appears as if the program implementer estimated the steam percentages by changing the percentages until the enduse profile matched the one from the benchmark data on AIC's website.

The program implementer then compared its calculated baseline gas consumption for the building's heating and cooling to the baseline calculated from the bin analysis. The baseline from the bin analysis was 37% higher than the baseline calculated in the metering analysis, thus leading the program implementer to de-rate the estimated savings by 37%. This is a sizable adjustment for this building type. The program implementer's enduse profile for the building shows domestic hot water fuel consumption equal to 50% of the space heating consumption, which appears excessive to the evaluation team. The program implementer's estimated gas use for cooking/other was about 22% of the estimated space heating consumption. This too appears excessive, particularly when the building has a dedicated gas meter for these loads, which could not be traced to all gas-

[1] Note that the evaluation team was unable to find this information to verify the building type and data validity.

consuming equipment in the building. Table 14 shows the ex ante baseline and post-retrofit gas consumption for the project.

Table 14. Summary of Annual Gas Consumption Under Baseline and Post-Retrofit Conditions

HVAC Controls	Therms
Baseline	265,746
Post-Retrofit	239,661

Table 15 presents the ex ante estimated savings for this project.

Table 15. Ex Ante Estimated Savings for HVAC Controls

	Gas Savings (Therms)
HVAC Controls	26,085

Measurement and Verification Plan

The evaluation team plans to evaluate this project through a site visit, where we will observe the control system setpoints and compare them to the setpoints prescribed in the energy model. We plan to discuss the following questions with the system operator:

- When was the project completed?
- Was the project completed for one building or multiple buildings?
- What are the primary consumers of natural gas in the building?
- Is the building on a single dedicated natural gas meter?
- How was the heating system scheduled before and after the project? What were the space temperature setpoints before and after?
- What was the condition of the control system before the project was completed?
- Have there been any changes to the gas-consuming equipment since the project was completed?
- Were there any CO_2 sensors in place before the project, and if so, were they functional?

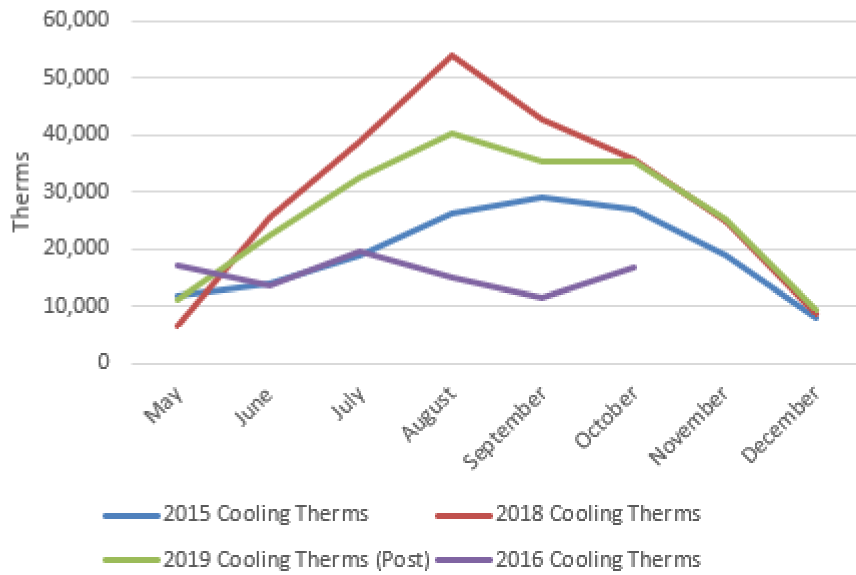
Description of Verification

The evaluation team completed a site visit on September 12, 2019. During the visit, the team interviewed the site contact and verified the building control system schedules and setpoints. The schedules and temperature setpoints that were used in the ex ante calculation were consistent with the actual building operation except for the unoccupied space cooling setpoint; it is set to 85°F instead of 80°F. We also noted that the occupied setpoint is 70°F. The site contact confirmed that natural gas generates about 80% of the chilled water. While the building has a dedicated meter for gas, the HVAC equipment uses none of that gas. All the HVAC energy is provided by the central steam and chilled water plants.

Calculation Description

The evaluation team could not conduct a regression analysis to estimate savings because the central plants provide all the energy for the HVAC equipment in the building. The evaluation team, therefore, requested more recent steam and chilled water usage information for the building to evaluate this project. Due to the high level of uncertainty associated with the savings from this project, the evaluation team first plotted reported natural gas consumption for cooling and steam in the building using customer provided billing data. Figure 4 shows the natural gas consumption for cooling.

Figure 4. Gas Usage for Building Cooling Over Time

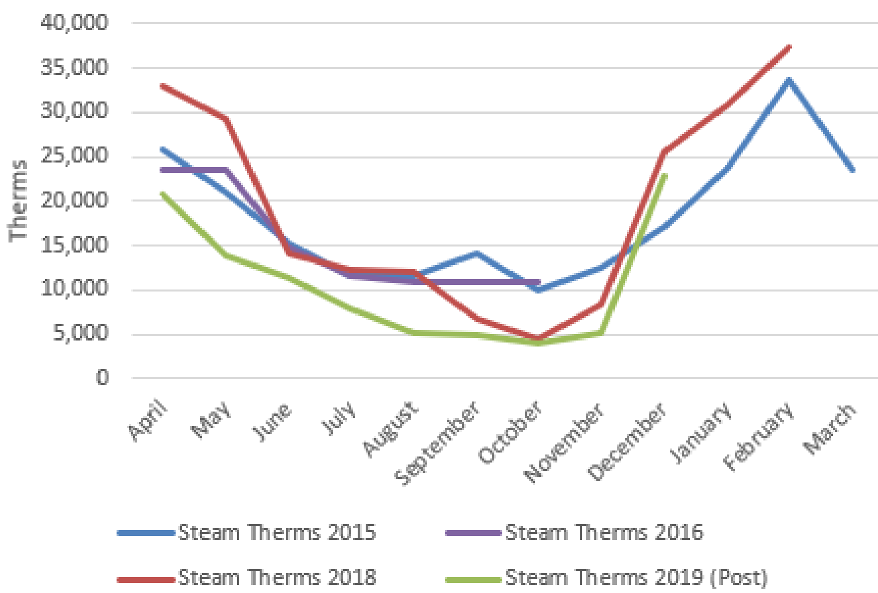


We made two significant findings related to cooling gas consumption:

1. There is little seasonal variance in estimated gas consumption for cooling in earlier years and more seasonal variance in later years, with the variance becoming greater over time.
2. Gas consumption for cooling in 2019 (after project implementation) is less than for 2018, before implementation.

Figure 5 shows the building's steam consumption converted to natural gas consumption.

Figure 5. Steam Usage Converted into Therms Over Time



The evaluation team found that gas consumption from the building's steam usage (the majority of which we estimate is used for space heating) is quite consistent for the three years before project implementation. There is a clear reduction in gas consumption through the cooling season after project implementation. This is reasonable given the deployment of temperature resets, which we expect to reduce reheat and simultaneous heating and cooling through the summer months. For the months shown, there is a 46,000 therm or 33% reduction in steam usage.

It is worth noting that the ex ante analysis of estimated consumption for domestic hot water and cooking equipment is irrelevant. We assume it is the same before and after implementation, and therefore, it falls out of the results in our analysis. Due to the high level of other uncertainties, we cannot reduce, and because much of the savings stems from reduced simultaneous heating and cooling, weather normalization is not necessary for this project.

The evaluation team's revised savings is 46,000 therms of calculated steam savings. This is conservative as it does not include savings for cooling. Based on the evaluation team's experience, this reasonable for a 300,000 square foot educational building. The customer's annual steam consumption at the central plant, translated to natural gas consumption, is about 260,000 therms. The evaluation team's savings estimate is less than 20% of annual steam consumption. This is not unreasonable for the system types and measures deployed.

Table 16 shows the ex ante and verified savings for this project. The realization rate is 176%.

Table 16. Summary of Project Savings

HVAC Controls	Therms
Ex Ante	26,085
Verified	46,000
Realization Rate	176%

Project 1801399

Project ID#	1801399
Measure:	New Induction Melting Power Supply with Controls
Savings:	298,980 kWh, 56.40 kW
Facility Type:	Industrial
Enduse:	Process Heat

Measure Description

This project covers the installation of a new induction melting power supply. The power supply saves energy by utilizing sensors and controls to provide optimized power to maintain the necessary molten metal temperature.

The ex ante savings for this project are based on rated efficiency and estimated operating hours. Table 17 shows the specifications for the existing and new power supply. The increased efficiency of the new unit allows for a decrease in operating hours while maintaining a consistent production rate.

Table 17. Specifications of New and Existing Power Supply

Power Supply	Rated Power Draw (kW)	Average Efficiency	Melt Rate (lbs/hr of red brass to 2150 °F)	Hours of Operation (hrs/yr)
Existing	400	83%	2,400	2,321
New	400	94%	2,800	1,926

Savings for this measure were calculated using the rated power use and efficiency of the baseline equipment combined with expected operating conditions. The power use savings are based on a comparison of the rated power draw and efficiency of the baseline and new power supply. The melt rate of the baseline and new equipment is used to determine the reduction in operating hours for an assumed constant production rate. The baseline hours are determined assuming the equipment operates for 10.5 hours per day for five days per week, with a utilization factor of 0.85. The new power source has a capacity rate increase of 17% over the baseline equipment, thus leading to a 17% decrease in expected operating hours. Savings for this measure are calculated using Equation 2 with the input values from Table 17 for the existing (baseline) and new power supply.

Equation 2. Energy Use of Melting Power Supply

$$Energy\ (kWh) = \left(\frac{Rated\ Power\ Draw}{Avg\ Eff}\right) * annual\ hrs\ of\ operation$$

Table 18 provides a summary of the estimated energy and demand usage of the melting power supply under baseline and retrofitted conditions.

Table 18. Summary of Energy and Demand Usage Under Baseline and Post-Retrofit Conditions

Melting Power Supply	kW	kWh
Baseline	482	1,118,554
Post-Retrofit	426	819,575

Table 19 presents the ex ante savings for this project.

Table 19. Ex Ante Savings for New Induction Melting Power Supply

	Demand Savings (kW)	Annual Energy Savings (kWh)	Annual Gas Savings (therms)
New Induction Melting Power Supply with Controls	56.40	298,980	0

Measurement and Verification Plan

The team will evaluate this project through a site visit. The team will verify the installation of the new equipment and will interview the site contact about the melting process and the use of the power source. As part of the site visit, the team will also confirm the baseline and post-project operating hours. If melt records or trended data are available, the team will request it from the site contact. If the data are not available, the team will install an amp meter that will remain in place for three to four weeks to collect on and off operating hours of the new power supply. The manufacturer specifies a power factor for the unit of 95.5%, which the team will spot check during the site visit.

Specific questions for the site contact include:

- When was the project completed?
- Were any new controls installed with the new power source?
- Has production remained constant since the new equipment was installed?
- Has the product type remained constant? (brass and/or red brass)
- Are the operating hours tracked by the equipment or by a facility operator? If those records are available, they will be collected for the evaluation.
- What is the voltage supply of the new and existing power source?
- How has productions varied since the project was completed? How does production vary annually?

Description of Verification

The evaluation team completed a site visit on October 15, 2019, at which time the team verified the installed equipment and discussed the melt process with the site contact. The installed equipment is a power supply for an induction melting furnace. The power supply converts 460 volt (V) three-phase power into higher voltage single-phase AC power. The supply voltage provided by the power supply exceeded 1000 V. Therefore the evaluation staff could not meter it safely. Metering the 460 V supply voltage would not provide the necessary information on the variance of the equipment’s power consumption. The project evaluation will rely on operating conditions provided by the site contact and observations made at the site visit.

The site contact explained that the solid metal is melted for the first hour of operation, during which time the furnace runs at full power of 400 kW. Once the metal is melted, the furnace maintains the molten metal temperature for one to four hours while the metal is poured into molds. During this period, while the metal is maintained as a molten liquid, the furnace power fluctuates between 50 kW and 100 kW. The site contact confirmed the estimated operating hours and noted that production rates vary significantly over the year.

Calculation Description

As discussed in the description of verification, the team could not verify the equipment due to the dangerously high operating voltage. The ex ante calculation assumed that the power source operates at full power during the entire operation period. Based on discussion with the site contact about the process, however, the equipment actually runs at 400 kW about one hour of each production cycle. It runs on average at 75 kW for about two and a half hours of the production cycle. The equipment has a screen that displays an instantaneous readout of the equipment power supply. The site contact used this information to provide us with the power estimates above. Given this information, we calculated the average power during a production cycle is 168 kW. The team used the rated efficiency to determine the average operating power (kW) for the baseline and new equipment.

The ex ante calculation based the operating hours on capacity and efficiency of the baseline and new power supply. These hours estimates are reasonable and were confirmed by the facility. We determined energy savings (kWh) by multiplying the assumed operating hours by the calculated power use of the baseline and new power supply and taking the difference.

Table 20 shows the ex ante and verified demand and electric savings, along with realization rates. The realization rates for this project are only 42% for both demand and electric savings because the ex ante analysis incorrectly assumed that the equipment would run at maximum power for the entire production cycle. In the verified analysis, we corrected the average power assumption to include the maximum power portion of the production cycle and the lower power idle period. The power draw is the same for both pre and post installations. The new equipment achieves a higher efficiency by maintaining better temperature control of the molten metal.

Table 20. Summary of Savings from Melting Power Supply with Controls

Melting Power Supply	kW	kWh
Ex Ante	56.40	298,980
Verified	24.00	125,465
Realization Rate	42%	42%

Project 1802041

Project ID#	1802041
Measure:	Compressed Air Dryer Replacement and Pressure Reducing Valve
Savings:	45.32 kW, 396,849 kWh
Facility Type:	Industrial
Enduse:	Compressed Air

Measure Description

This project covers the installation of a new 2,400 standard cubic feet per minute (scfm) cycling refrigerant dryer and a pressure reducing valve (PRV). The customer installed the new dryer in parallel with an existing desiccant dryer. The dryer is estimated to operate 8,756 hours per year before and after the project. Project documentation notes that the customer plans to use the dryer in non-winter months for energy savings compared to a heated blower purge desiccant air dryer. This operating condition is inconsistent with the assumed operating hours, so the evaluation team plans to verify this condition at the site visit.

In addition to the dryer, the customer installed a pressure reducing valve to lower the system operating pressure to 80 pounds per square inch in gauge (psig). Prior to the project, the system pressure was about 102 psig.

The new dryer and PRV were identified as potential energy savings projects during an RCx study that was completed on the compressed air system at the facility. In addition to the new dryer and the PRV, the RCx study also motivated a leak detection and repair project, and installation of a new 150 HP fixed speed compressor. Figure 6 shows the original system configuration, and Figure 7 shows the placement of the new dryer in parallel with the existing dryer.

Figure 6. Original System Diagram

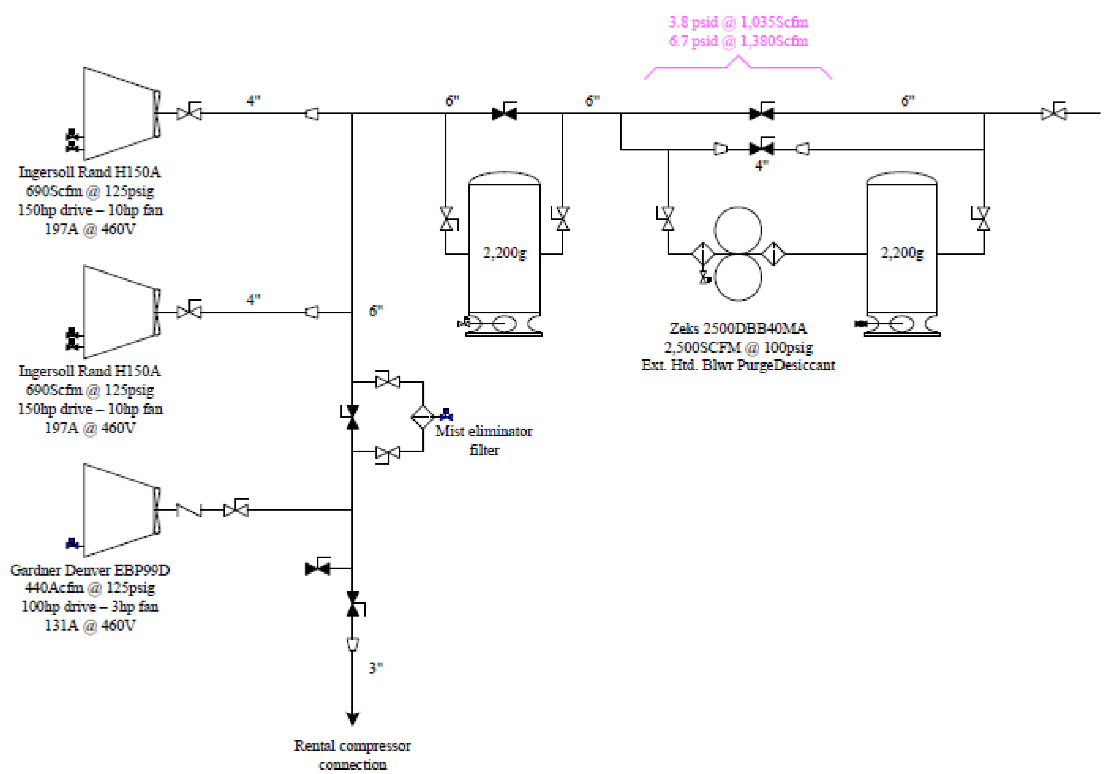
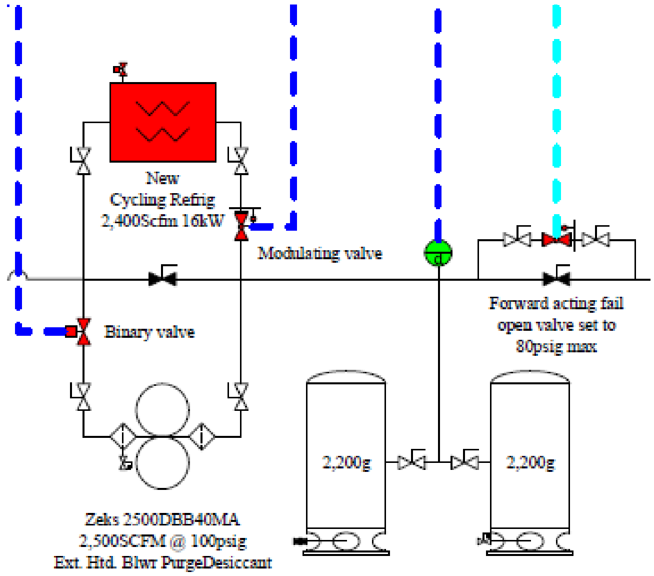


Figure 7. System Diagram with New Dryer in Parallel with Existing Dryer



Summary of the Ex Ante Calculations

A third-party contractor calculated savings for this project as part of the RCx study discussed earlier. The contractor did not provide the calculations of the savings; however, the evaluation team will request these files. The savings estimates appear to include metered energy use data of the compressed air system and trended system pressure. The baseline for this project is the measured/calculated baseline energy use minus the energy savings associated with the repaired compressed air leaks, which are 1,910,332 kWh per year. Few details were included in the project documentation regarding how the post-implementation energy use was determined, from which the savings were calculated.

Table 21 presents the ex ante savings for this project.

Table 21. Ex Ante Savings from Compressed Air Dryer and Pressure Reducing Valve Project

	Demand Savings (kW)	Annual Energy Savings (kWh)
Compressed Air Dryer and PRV	45.32	396,849

Measurement and Verification Plan

The team will evaluate this project through a site visit, where we will verify the installation of the equipment. We will also verify and discuss the operation of the compressed air system, including verification of the operating hours of the compressed air system and dryer. Additionally, we will verify the system pressure set point during the site visit. Specific questions for the site contact include:

- When was the project completed?
- Was a new 150 HP fixed speed compressor installed?
- Does the new compressor run year-round or only during summer months?

- How were the compressors sequenced/controlled before the project, how are they sequenced/controlled now?
- What are the uses of compressed air at the site? What drives flow demand?
- Have there been any changes in production or processes since the project that influence flow demand?
- Does the system have compressed air storage?
- What is the system pressure setpoint?

Description of Verification

The team completed a site visit completed on February 12, 2020. During the site visit, we confirmed by inspection the installation of the cycling refrigerated dryer. We also confirmed that the existing compressed air dryer was a heated blower purge dryer with a rated capacity of 2,500 cubic feet per minute (cfm). The compressors use air from inside the facility rather than pulling air from outside, and at the time of the site visit the compressors operated at 102 pounds per square inch (psi).

We also confirmed the installation of the PRV by inspection. During the site visit, we found the pressure setpoint set at 99 psi on the controller module, which is higher than the 80 psi setpoint specified in the project documentation.

The customer confirmed that there had been no other significant changes at the facility that would have an impact on the compressed air use. The two dryers are piped in parallel. The customer explained that the facility uses the cycling refrigerated dryer from late March to early November, as the compressed air study that was completed back in 2018 indicated that the refrigerated dryer is more efficient than the heated blower purge dryer when outside air temperatures are above 50ºF.

Calculation Description

The evaluation team obtained the specification sheets for the existing heated blower purge dryer and the new cycling refrigerated dryer. The existing heated blower purge dryer has moisture controls. It has a demand of approximately 51.7 kW when operating. The blower fan motor has a demand of 13.8 kW. From the compressed air study report, we determined that the average compressed air system flow was 890 cfm. Using this information, we determined that the average electrical demand of the heated blower purge dryer is 23.32 kW.

Heated blower purge dryers use compressed air at the end of each purge cycle, which typically equates to 3% of the rated capacity of the dryer. For this dryer, that amounts to 75 cfm. The specific efficiency of the compressors at the facility is 0.156 kW per cfm, so the purged air results in a compressor demand of 11.72 kW. The average total demand for the heated blower purge dryer (heater, blower, and compressed air) is 35.05 kW.

The new cycling refrigerated dryer operates for approximately 5,475 hours per year, during which the heated blower purge dryer is turned off. The installed refrigerated dryer has a rated capacity of 2,400 cfm and a full-load electrical demand of 15.8 kW. The average compressed air load is 37% of the rated capacity of the dryer, and the full-load demand multiplied by the percent load results in an average demand of 5.85 kW. The refrigerated dryer uses no compressed air during the drying process.

The demand of the cycling refrigerated dryer provides an average savings of 29.20 kW compared to the heated blower purge dryer. Multiplying this by the annual hours where the load is switched from the heated blower purge dryer to the refrigerated dryer yields annual savings of 159,982 kWh.

To calculate the savings from the installation of the pressure reducing valve (PRV), we needed to determine the amount of compressed air leaks in the system. The project documentation indicates that 132 cfm of leaks were identified during the 2018 system audit, and prior to the start of this project a total of 71 cfm of leaks were fixed. The remaining leaks, therefore, equate to 61 cfm. With the reduction of pressure from 102 psi to 99 psi, the flow rate of the leaks is reduced to 59.4 cfm. Using the specific demand of the compressors (0.156 kW per cfm), this yields a demand reduction of 0.25 kW, and an annual energy savings of 2,147 kWh.

The resulting total savings for this project (dryer and PRV) is 162,129 kWh, which is significantly less than the ex ante savings. We do not know the reason for the large discrepancy between ex ante and verified savings because the project documentation did not include the calculations to determine the ex ante savings. One contributing factor to the savings reduction is that the PRV is reducing the system pressure less than what was originally intended (3 psi reduction rather than 22 psi). Another factor that may contribute to the savings reduction is the moisture controls of the existing heated blower purge dryer – the compressed air study from 2018 indicated that the moisture controls were disabled. During the study, the moisture controls were enabled, tested to ensure proper operation, and were left on in order to reduce the energy consumption of the dryer. It is possible that the ex ante savings include the savings from enabling the moisture controls. However, the scope of work for this project does not include the enabling of the dryer's moisture controls, so it was not included in the verified savings analysis. Table 22 presents a summary of the savings for this project.

Table 22. Summary of Savings from Compressed Air Dryer and Pressure Reducing Valve Project

Compressed Air Dryer and PRV	kW	kWh
Ex Ante	45.32	396,849
Verified	18.51	162,129
Realization Rate	41%	41%

Project 1900133

Project ID#	1900133
Measure:	Process Heating and Cooling Improvements
Savings:	930,010 kWh; 0.0 kW
Facility Type:	Manufacturing/Industrial
Enduse:	Process Heating and Cooling

Measure Description

This project covers the installation of two new skid-mounted systems for supplying water for process temperature control. This system, a temperature control unit (TCU), includes chilled water and steam-to-hot water heat exchangers, distribution pumps with VSDs, and automatic controls. The new system is expected to operate more efficiently than the old system while reducing product run times. This project replaced a 130-ton chiller plus 482 HP of pumps.

Summary of the Ex Ante Calculations

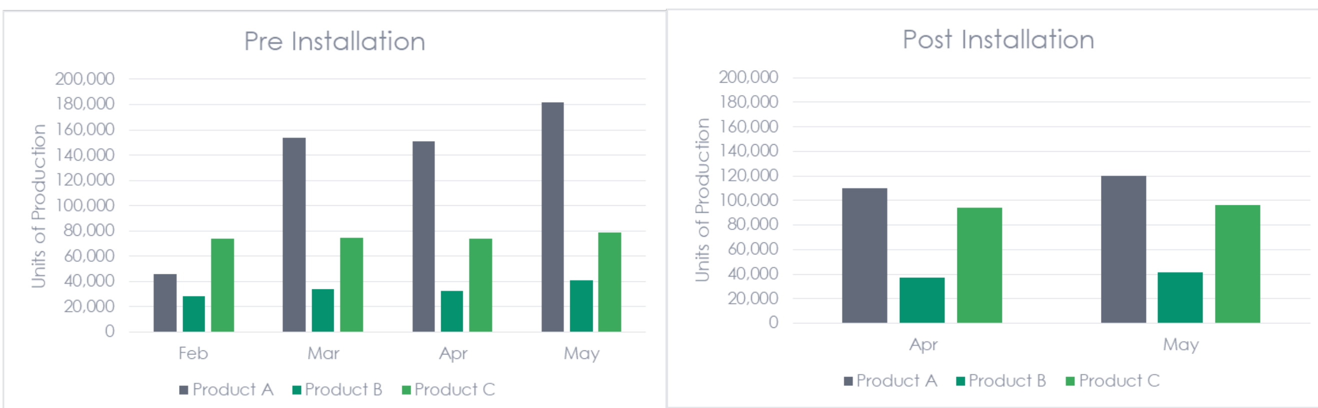
The evaluation team calculated the savings for this measure by comparing the pre- and post-case production energy intensity, as expressed in utility-meter kWh per unit of production. Production and metered data were collected for a four-month period from February through May 2018. Pre-replacement energy intensity was 2.22 kWh per unit of production. Average post-replacement energy intensity for the two months from April through May 2019 measured 1.90 kWh per unit.

Pre- and post-replacement energy usage was normalized to pre-case production levels, so the average observed monthly energy usage for the four-month pre-implementation case period was extrapolated to 12 months to establish baseline energy consumption. The average monthly production for the pre-case period was multiplied by the post-case energy intensity to establish proposed energy use.

The documentation did not include the spreadsheets covering the calculation of total energy used in the analysis. Also, no rationale was provided for the selection of the four months used in the pre-case energy intensity (i.e., it is unclear whether that period is representative of the entire year).

Figure 8 shows production by product before and after the project's installation. Monthly production levels of Product B and C are quite flat, while production levels of Product A are more volatile. Total production was significantly lower than average for February for Product A. If that month is eliminated from the analysis, the pre-case energy intensity is 1.89 kWh per unit, which would result in negative savings for this project. The lower energy intensity is a result of having substantial fixed loads in the plant, and therefore when production is higher, the per-unit intensity is lower, all else equal. The evaluation team will inquire about the production levels of Product A, why they are volatile, and what the site contact expects production will be going forward.

Figure 8. Pre- and Post-Installation Production by Product



Measurement and Verification Plan

The team will evaluate this project through a site visit and will determine verified savings based on the most recent production and energy usage data. The team will normalize baseline and as-built energy usage to representative production levels based on current and expected production in the near future.

During the site visit, the evaluation team plans to ask the site contact the following questions:

- What was the design, lineup, and control of the existing system – i.e., how did it work?
- What happened to the existing equipment?
- Are system schematics available? (pre and post-project implementation)
- What are the water temperature set points and schedules?
- Is any free cooling available?
- How much heating is used for the process? Were any gas savings realized?
- Has production changed since installation of the new equipment? Since implementer verification?

- Is production expected to increase in the foreseeable future?
- Is any trend or other operating data available?
- What utility meters are associated with the production equipment? Is the pertinent utility usage available?
- The pre-case calculation used February 2018 production in the calculations. Production for that month was significantly lower for Product A. What was the cause of this low production? What was the production in February 2019?

We might not directly use the information collected during the on-site verification to establish savings. However, we may use it to provide a reality check of the results or to understand possible discrepancies between the ex ante and verified results.

Description of Verification

The team completed a site visit on December 12, 2019. During the visit, we interviewed the site contact and verified the installation of the TCU.

The TCU is used to maintain the temperature in a rubber-curing process that consists of three rollers. Required temperatures range from 20°C to 155°C. A central boiler provides steam to a heat exchanger in the TCU, and three chillers provide cooling via a separate heat exchanger. There is no free cooling available from the system. The TCU will pump warm or cool water to the process as needed to maintain the required temperatures. The old TCU was in poor condition and was removed for disposal. The new TCU is expected to save energy by providing more accurate process temperatures, thereby reducing the product scrap rate, which will allow for less runtime and, therefore, less energy usage. There was no consideration of gas savings.

We asked the site contact about low production during February 2018, but he did not provide us with a specific reason. He assumed it was due to a temporary overstock of a line of products. Production at the plant is relatively steady, with no significant recent or planned changes in production. Production did drop to similarly low levels again in February 2019, as well as December 2018, so it may be a seasonal pattern.

The facility also completed several other energy efficiency projects. Other projects included the installation of three air-cooled chillers and combining two chilled water systems. Additionally, new pumps with VSDs were installed, and piping was modified. The customer received an incentive for this project, for which 249,432 kWh savings were claimed.

Another project completed with incentives was the installation of variable speed air compressors for which 82,934 kWh savings were claimed.

Calculation Description

The evaluation team used a regression analysis to determine savings as this most closely resembles the ex ante calculation approach. The regression did not produce the strongest fit, but this is, in part, due to the lack of granular production data provided. The production data we received was a “drum-based” production number. This is a customer provided number, but it is unclear whether this is an input (feedstock) or an output number. The facility produces three styles of belts, and production data indicates that the number of belts per drum varies significantly. Better production data may produce better confidence in the savings.

While conducting the regression analysis, the evaluation team noticed a large swing in consumption data that did not correlate with any production data for February and March 2019’s usage data. Because this data is likely a meter reading error (corrected the following month), the implementation period was extended to avoid having these months impact the post-case regression.

Another complicating factor was that there were the two additional projects completed several months after the initial project was completed, as shown in Figure 2. It is unclear when the installation of these projects began. However, the post-period model fits the data very well after those measures were completed, so the evaluation team assumes that the model properly accounts for the savings associated with these two projects.

Figure 9. Modeled Data and Project Milestones

Based on the regression model, the total savings for all three projects is approximately 759 MWh. The three projects in aggregate were expected to save 1,262 MWh in the ex ante calculations. Therefore, a blended realization rate (60%) for all three projects was applied to this project to determine the verified savings, as shown in Table 23.

Table 23. Appropriation of Ex Ante and Verified Savings for Process Heating and Cooling Project

Project	Ex Ante Savings	Verified Savings
This Project	930,010	559,828
Project 2	249,432	150,148
Project 3	82,934	49,923
Total Savings	**1,262,376**	**759,898**
Realization Rate		60%

There are no claimed kW savings, and due to the fact that a majority of the energy savings for this are expected to occur due to minimized run hours, which should happen during off-peak periods. No adjustments were made to this assumption. Table 24 presents a summary of the ex ante and verified savings, along with the associated realization rate.

Table 24. Summary of Process Heating and Cooling Project Savings

Process Improvement	kW	kWh
Ex Ante	0	930,010
Verified	0	559,828
Realization Rate	N/A	60%

Project 1900325

Project ID#	1900325
Measure:	Air compressors with cycling air dryer
Savings:	37.38 kW; 83,437 kWh
Facility Type:	Manufacturing
Enduse:	Compressed Air

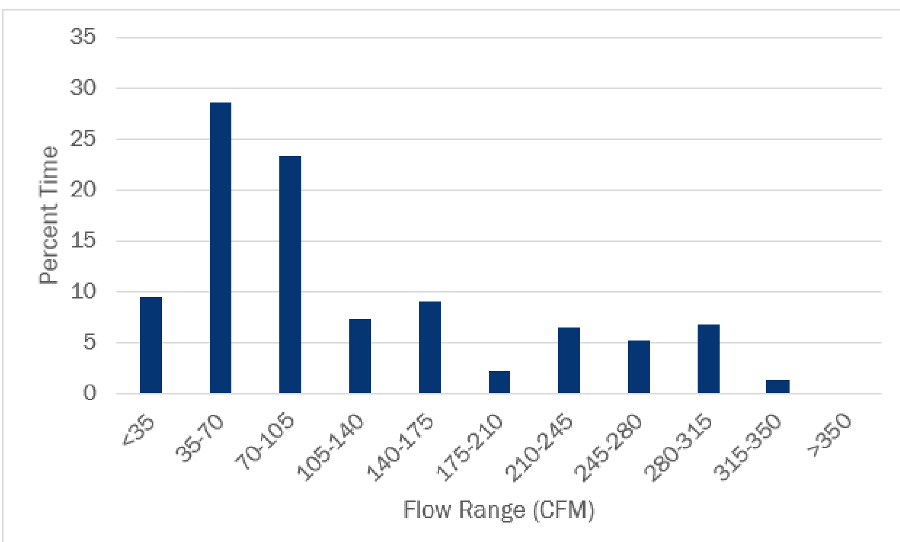
Measure Description

This project includes the installation of two air compressors and one cycling refrigerated air dryer at a manufacturing facility to replace a 150 HP single-speed, lubricated, rotary screw air compressor and a non-cycling refrigerated dryer. The new compressors consist of two new 50 HP lubricated, rotary screw compressors plus a new cycling refrigerated air dryer. One of the new compressors is equipped with a variable speed drive (VSD), and the other is a fixed speed compressor with load/unload controls. The new air dryer is sized for the combined full capacity of the new compressors.

Summary of the Ex Ante Calculations

The ex ante savings were calculated using approximately one week of metered flow and amperage data from the existing 150 HP compressor. The compressor operates approximately ten hours per day, four days per week. Figure 10 shows the flow profile of the compressor during the one week metering period.

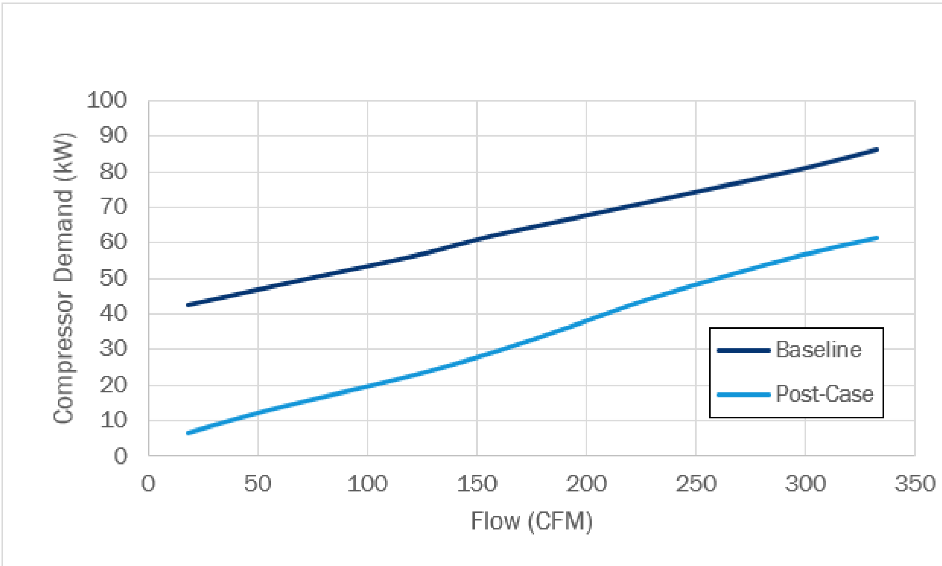
Figure 10. Compressor Baseline Flow Profile



The compressor's electrical demand was calculated for each flow bin shown in the graph above using information from the specification sheets of the existing compressor and a typical performance curve for a rotary screw compressor with load/no-load controls.

The system pressure is being reduced from 120 psi to 100 psi as part of this project, so the metered flow data was adjusted by a ratio of the pre-case absolute pressure to the post-case absolute pressure to determine the post-case flow rates. The electrical demand values of the new compressors to meet the post-case flow rates were determined using information from the specification sheets of the new compressors and a performance curve for the existing oil-injected variable speed rotary screw air compressor. Figure 11 provides a comparison of the baseline and post-case system electrical demand versus flow.

Figure 11. Comparison of Baseline and Post-Case Electric Demand Versus Flow



The average operating electrical demand of the existing compressor is 47.9 kW, and the average demand of the new compressors is 15.0 kW, thus leading to a reduction of 32.9 kW. The compressed air system operates 2,232 hours per year, and to determine the annual electric savings, the average demand reduction was multiplied by the annual operating hours. The resulting savings for the compressor replacement and system pressure reduction is 73,555 kWh.

To determine the ex ante savings for the replacement of the non-cycling refrigerated dryer with a cycling unit, we used information from the non-cycling and cycling unit specification sheets. The non-cycling unit has a continuous electrical demand of 5.199 kW while in operation. The new cycling dryer has a full-load electrical demand of 4.647 kW, and operates at an average load of 16.6%, as the average system flow is 83 cfm, and the dryer is rated for 500 cfm. The units operate 2,232 hours per year, yielding a baseline annual energy use of 11,604 kWh and a post-case annual energy use of 1,722 kWh. This represents ex ante savings of 9,882 kWh.

The compressor and dryer savings for this project total 83,437 kWh. Table 25 provides a summary of the savings for this project.

Table 25. Summary of Ex Ante Savings From Compressor and Dryer Replacement

	kW	kWh
Compressor Replacement	32.95	73,555
Dryer Replacement	4.43	9,882
Total	**37.38**	**83,437**

Measurement and Verification Plan

The team will evaluate this project through a site visit and will verify the installation of the new compressors, Gardner Denver L37 and L37RS, and new dryer, Gardner Denver GTRC-500A. We will ask the customer the following questions:

- What was the condition of the old compressor and dryer?
- What happened to the old compressor and dryer?
- Is a list of leaks repaired and disposition available?
- Does the plant have a regular leak detection/repair program?
- What are the hours of operation?
- What is the sequence of operation e.g., lead/lag? Is the variable speed compressor used as the trim compressor? Is it automatic?
- Have there been any changes in production since installation?
- Have there been any changes to the system or compressor pressure? Air demand?
- Is any trend data available?

Schedule and budget permitting, the team will install data loggers on the compressors and dryer for a minimum of 2 weeks.

Description of Verification

The team conducted a site visit on January 16, 2020, at which time we interviewed the maintenance manager and inspected the compressed air equipment.

The team verified that the installed compressors and cycling dryer matched the application documentation. The VSD compressor was operating at the time of the visit, and the single-speed compressor was in standby mode. The customer reported that the VSD compressor is the primary source of compressed air, and the single-speed unit only runs occasionally for backup purposes. We confirmed this by examining the total run hours on the two compressors – the VSD compressor had 1,951 hours on it while the single-speed unit had only 154 hours of runtime. The single-speed compressor is manually started if needed.

The old compressor was a 150 HP LeRoi water-cooled, rotary screw compressor. The site contact noted that the compressor was old and that they were having difficulty getting replacement parts. The old compressor and dryer were removed and are no longer in service. A 1,000-gallon storage tank was left in place. The site contact reported that the system pressure was unchanged with the new compressors. The VSD setpoint pressure was 105 psig at the time of the visit.

The customer reported that 15 leaks were repaired as part of the project. The customer reported that they check for leaks and repair them every two months.

The plant is in production four days per week, 10 hours per day, and the compressors are shut off during non-production hours. The plant has six production lines, but typically only three lines are in production at any given time. Three lines were running at the time of the site visit, and the VSD compressor was running at about 70% capacity. The cycling dryer setpoint was 33°F.

Calculation Description

To determine the verified savings for this project, we used the metered data from the ex ante savings calculations along with the pre- and post-case compressor performance data. We carried out the calculations in a similar manner as the ex ante calculations. Instead of conducting a bin analysis, however, we determined the pre- and post-case energy use of the compressors for each five-minute increment during the metering period. Additionally, we did not adjust reduced flow (due to changes in system pressure) in the verified calculations, as the project documentation indicates that leak fixes were just recently completed (so leak losses should be minimal), and the compressed air use of production equipment typically does not decrease as a result of system pressure reductions. This causes the compressor energy savings to decrease compared to the ex ante savings.

The average flow calculated in the verified analysis is 75 cfm, compared to the ex ante average of 83 cfm. This reduction causes the savings for the cycling dryer to increase.

Table 26 presents the verified savings for this project.

Table 26. Summary of Verified Demand and Electric Savings for Compressed Air System Project

	Coincident Peak kW	kWh
Compressor Replacement	19.88	71,413
Dryer Replacement	3.56	10,220
Total	**23.44**	**81,633**

Table 27 presents the ex ante and verified savings for this project.

Table 27. Summary of Ex Ante and Verified Project Savings for Compressed Air System Project

Compressed Air System Improvements	Coincident Peak kW	kWh
Ex Ante	37.38	83,437
Verified	23.44	81,633
Realization Rate	63%	98%

Projects 1900345, 1900350, 1900351, and 1900352

Project ID#	1900345, 1900350, 1900351, and 1900352
Measure:	1900345: Regenerative Thermal Oxidizer 1900350: Steam System Pressure Reduction 1900351: Flash Steam and Condensate Recovery 1900352: Flash Steam and Condensate Recovery
Savings:	1900345: 212,520 therms 1900350: 115,263 therms 1900351: 257,544 therms 1900352: 260,913 therms
Facility Type:	Industrial
Enduse:	Process

Summary

This report includes four projects as they were all implemented at the same site and have the potential to interact with each other. The measures included are a regenerative thermal oxidizer, steam pressure reduction, and two flash steam and condensate recovery projects. These projects were evaluated together, but savings are apportioned to each one. The facility is a tire manufacturer.

Measure Descriptions

1900345: Regenerative Thermal Oxidizer

This project consists of the replacement of bed material in a regenerative thermal oxidizer (RTO). The existing bed material was random pack-saddles, while the new material is honeycomb, or monolith, material. The new material provides higher heat exchange per volume and lower pressure drop.

1900350: Steam System Pressure Reduction

This project consists of the replacement of steam system piping, fittings, traps, tanks, and other parts in one area of the plant to allow for lowering system pressure from 135 psi to 15 psi, while still meeting the heating loads of the equipment served by the steam system. Steam pressure is reduced through a pressure reducing valve that results in zero loss of steam energy. This measure saves energy by reducing the flash steam downstream of the traps in the condensate system.

1900351 and 1900352: Flash Steam and Condensate Recovery

These projects consist of making improvements to two different flash steam and condensate return systems in the manufacturing facility. Steam is used in the production process, and the existing condensate systems result in significant condensate and flash steam losses that these projects aim to minimize.

Summary of the Ex Ante Calculations

1900345: Regenerative Thermal Oxidizer (RTO)

The ex ante savings were established based on gas usage data collected from a meter dedicated to the RTO. Pre-implementation data was collected for three months from March 26 through June 28, 2019. The average pre-implementation gas flow rate equaled 7.07 mmBtu/hour. The RTO operated continuously. A change in media occurred during a plant shutdown from July 1 to July 6, 2019. Post-implementation data was collected for a 17-day period from July 7 through July 23, 2019. The average post-implementation gas flow rate was 4.13 mmBtu/hour.

Hourly savings were calculated as the difference in pre- and post-implementation flow rates, or 29.4 therms per hour. The RTO is expected to operate for 8,400 hours per year, yielding a total savings of 246,960 therms per year.

1900350: Steam System Pressure Reduction

The ex ante savings were determined based on the reduction in the amount of flash steam produced. Prior to the completion of the project the condensate system was producing 14.6% flash steam, and after the completion of the project this was reduced to just 3.9%. The area of the plant affected by this project uses an average of 11,000 pounds (lbs) of steam per hour. Using the thermophysical properties of water, the energy lost to flash steam was determined to go from 1,558,700 Btu/hr to 420,131 Btu/hr. Assuming 8,200 hours per year of operation and a boiler efficiency of 81%, the annual gas savings resulting from this project equaled 115,263 therms.

1900351: Flash Steam and Condensate Recovery

The ex ante savings were determined based on the reduction in the amount of flash steam and condensate lost prior to the completion of the project, which is now being captured.

The system produces 14.3% flash steam as determined by saturated steam properties upstream and downstream of the condensate receiver. The total condensate flow of 32,300 lbs per hour (lbs/hr) from the affected line, produces 4,619 pounds per hour of flash steam as pressure is reduced from 175 psi to the condensate system's 15 psi. The rate of flash steam recovery was measured as 2,079 lbs/hr. The amount of energy required to heat this amount of water from the makeup water temperature of 60ºF to flash steam at 15 psi was calculated and multiplied by 8,568 hours per year of operation and divided by the steam boiler efficiency of 81%, yielding annual gas savings of 249,743 therms.

In addition to the flash steam recovery, energy is saved by the hot condensate returning to the boiler rather than having to make it up with relatively cold 60ºF makeup water. This adds about 7,800 therms savings per year.

The total savings for the flash steam recovery and condensate recovery improvements are 257,544 therms.

1900352: Flash Steam and Condensate Recovery

Project 1900352 was parallel to project 1900351 with the same savings strategies and ex ante calculation methods applied to a very similar production line. Flash steam recovery resulted in 256,788 therms savings and condensate recovery resulted in 4,125 therms savings for a total savings of 260,913.

Table 28 presents the ex ante savings for the four projects.

Table 28. Ex Ante Savings for Four Projects

	Gas Savings (therms)
1900345: Regenerative Thermal Oxidizer	212,520
1900350: Steam System Pressure Reductions	115,263
1900351: Flash Steam and Condensate Recovery	257,544
1900352: Flash Steam and Condensate Recovery	260,913

Measurement and Verification Plan

1900345: Regenerative Thermal Oxidizer

The team will evaluate the project through a site visit, during which time we will verify the installation and operation of the RTO. The questions we plan to ask the site contact include:

- What is the age and condition of this RTO?
- What are the normal hours of operation?
- Is the RTO shut off other than for plant shutdowns?
- How many shutdowns per year are there, and how long do they last?

- Are there seasonal or other variations in production or RTO use?
- Does RTO gas use depend on product mix or hourly production?
- What is the typical temperature of incoming air? Does it vary significantly with season, product mix, or production?
- Can more gas usage data be provided? Is it sub-metered?
- How is oxidizer flow controlled? Did it increase or decrease with the new system?
- Are variable frequency drive speeds/power/etc. monitored or trended?
- Is there a difference in pressure drop through the RTO with the new fill?

We will calculate verified savings using a similar approach as that used for the ex ante savings. We will use post-implementation data to update the calculations.

1900350: Steam System Pressure Reduction

We will evaluate this project through a site visit. During the visit, we will verify by inspection the completion of the project, including verification that the system pressure is 15 psi. During the site visit, we will ask the following questions:

- When did the work on the steam system start and end?
- Have any other changes happened in the steam system that would have an impact on the amount of steam used, such as equipment additions or replacements?
- Are records of the steam use in the affected area of the plant available?
- Can you verify that the system is typically in operation approximately 8,200 hours per year?
- Prior to the completion of the project, was all of the flash steam lost to the atmosphere, or was it captured and used elsewhere in the steam system?
- What is the current operating efficiency of the boiler plant?
- Is the condensate return system a pressurized system?

We will calculate verified savings using a similar approach as that used for the ex ante savings. We will use post-implementation data to update the calculations.

1900351 and 1900352: Flash Steam and Condensate Recovery

We will evaluate these projects through a site visit. We will verify by inspection the completion of these projects and plan to ask the following questions during the visit:

- When did the work on the condensate systems start and end?
- Have any other changes happened in the steam systems that would have an impact on the amount of steam used, such as equipment additions or replacements?
- Are records of the steam use in the affected areas of the plant available?
- How much (if any) flash steam is lost with the new systems? How much condensate is lost?
- Can you verify that the systems are typically in operation approximately 8,568 hours per year?
- Are there any records of makeup water use available?

- What is the current operating efficiency of the boiler plant?
- Are the condensate return systems pressurized?

We will calculate verified savings using a similar approach as that used for the ex ante savings. We will use post-implementation data to update the calculations.

Description of Verification

The team completed a site visit on February 19, 2020. During the visit, we confirmed the completion of all four projects, and the customer provided the following details about each of them:

1900345: Regenerative Thermal Oxidizer

- The RTO project was completed in July 2019, and the bed medium became fouled in late August 2019. The RTO media was replaced once and fouled a second time. Because of this, the RTO is currently using natural gas at a rate similar to its gas consumption prior to the completion of the project.
- The RTO operates continuously, with the exception of an annual one-week shutdown that occurs in July.
- There are no significant seasonal variations in the operation of the facility.

1900350: Steam System Pressure Reduction and 1900351 and 1900352: Flash Steam and Condensate Recovery

- The steam system pressure reduction brought the system pressure down to 50 psi (not 15 psi, as indicated in the project documentation and the ex ante savings analysis), but the system pressure was raised back up to 135 psi in November due to some product quality issues that arose. Those problems have since been alleviated, and the customer is planning to lower the system pressure to 90 psi on March 1, 2020, and then to 50 psi on March 15, 2020.
- During the July 2019 shutdown when the work for these projects was completed, the site completed a significant number of steam trap replacements, which may also contribute to steam savings. The customer could not locate information about the steam trap replacements that showed their estimated savings.
- The system impacted by the steam pressure reduction has an unpressurized condensate system, and all-flash steam is lost to the atmosphere.
- The customer noted that the pressure reduction project savings do not account for reductions in leak losses, but the leak rate was never quantified as part of the project. It could not be quantified from the trended steam use data because of the steam trap replacements and other changes to the system that were made at the same time.
- The customer confirmed that the average operating efficiency of the boiler plant is about 81%.

Calculation Description

1900345: Regenerative Thermal Oxidizer

From the information collected during the site visit, the team determined that the RTO was operating as intended with the new bed medium for approximately 54 days before the medium became fouled. The savings calculations for this project were updated to include 54 days of savings, which equates to 38,102 therms. Changing the hours in the savings calculations is the only adjustment that the evaluation team made. Due to the problem with the bed medium fouling, this project has an effective useful life of one year.

1900350: Steam System Pressure Reduction

From the information collected during the site visit, we determined that during the year following the completion of the project, the system will operate at a pressure of 135 psi for approximately 2,680 hours, 90 psi for 336 hours, and 50 psi for 5,184 hours. In the savings calculations, we did not adjust to the baseline conditions, but the post-case was changed to reflect the first year pressure schedule collected during the site visit. The resulting first-year savings for this project is 47,830 therms.

1900351 and 1900352: Flash Steam and Condensate Recovery

We found the information collected during the site visit to be consistent with the details used in the ex ante savings analyses for these projects. We reviewed the ex ante savings calculations and found them reasonable. No adjustments to the savings were deemed necessary, so the verified savings are equal to the ex ante savings.

Table 29 provides a summary of the ex ante and verified savings for all four projects detailed above.

Table 29. Summary of Ex Ante and Verified Savings for Process Improvement Projects

Project Description	Ex Ante Gas Savings (therms)	Verified Gas Savings (therms)	Realization Rate
1900345: Regenerative Thermal Oxidizer	212,520	38,102	15%
1900350: Steam System Pressure Reductions	115,263	47,830	41%
1900351: Flash Steam and Condensate Recovery	257,544	257,544	100%
1900352: Flash Steam and Condensate Recovery	260,913	260,913	100%

Additional Comments

The flash steam recovery projects represent close to half the sampled savings, but they were at risk because the documentation was incomplete. Elimination of flash steam can occur in one place, but this does not mean it is saved. It has to be used somewhere. The flash steam projects were described as though a condensate pump issue were being remedied. The pumps lacked suction head and would cavitate and fail. Therefore, the receiver tank was pressurized with a pressure reduction valve downstream. This information was consistent with the invoice.

However, the project documentation did not mention the recovered steam being piped to the deaerator tank to be used there. The invoice did not include the cost for piping or any discussion of the piping (note that discussion of the piping design was included for the steam pressure reduction project 1900350). There was no documentation such as invoices or a proposal from the engineering company responsible for the design included piping costs, design, pressure drops, new traps, and so forth.

Fortunately, the evaluator personally knows the engineering company and the industry expert whose name was found on one of the documents. This relationship saved the project. The engineering expert from the company returned our call to confirm the addition of the piping and the load it served, meaning that the flash steam is being used, and therefore savings are occurring.

Project 1900455

Project ID#	1900455
Measure:	Air Compressor Replacements
Savings:	198.7 kW, 1,359,411 kWh
Facility Type:	Industrial
Enduse:	Compressed Air

Measure Description

This project includes the installation of two new air compressors – a 350 HP fixed speed water-cooled oil-free rotary screw air compressor and a 335 HP VSD water-cooled oil-free rotary screw air compressor. Project documentation reports the compressors operate 6,830 hours per year. Note that some of the project documentation also indicates that no savings were attributed to the new fixed speed compressor. Savings were only determined for the new VSD compressor.

Summary of the Ex Ante Calculations

The baseline energy use of the compressed air system was determined using metered data from a nine-day period prior to the completion of the project. This data shows that when the existing compressors were operating, the average electrical demand was 562.2 kW. The compressed air system operated 78% of the time during the metering period, which equates to 6,830 hours per year, and an annual energy use of 3,840,086 kWh. Metered data of the compressed air load and the performance specifications of the compressors that will be in place after the completion of the project were used to calculate the post-case electrical demand of the compressors. The compressors were calculated to operate with an average total demand of 363.52 kW for 6,824 hours per year, yielding an annual consumption of 2,480,674 kWh, a savings of 1,359,411 kWh.

Table 30 presents the ex ante savings for this project.

Table 30. Ex Ante Savings

	Demand Savings (kW)	Annual Energy Savings (kWh)	Gas Savings (therms)
Air Compressor Replacements	198.70	1,359,411	0

Measurement and Verification Plan

The evaluation team will evaluate this project through a site visit. The team will verify the installed equipment and will discuss the operation of the compressed air system with the site contact.

The evaluation team plans to ask the following questions during the site visit:

- What are the horsepower ratings and capacities of the compressors that were in place prior to the completion of the project?
- Which of the existing compressors were removed when the new compressors were installed?
- How were the compressors previously controlled/sequenced?

- Have any other changes been made to the compressed air system, such as significant leak repairs, compressed air storage added or removed, pressure regulators added or removed, or a significant change in system pressure?
- Has the demand for compressed air in the plant significantly increased or decreased since the completion of the project? This could be due to equipment being added, removed, or replaced with new equipment that requires more or less compressed air, increases or decreases in production levels, or changes in operating hours.
- How are the new compressors controlled/sequenced?
- What is the typical operating schedule for the compressors? (hours/day, days/week, etc.)

Description of Verification

The evaluation team completed a site visit on February 12, 2020. From discussions with the facility engineers, we determined that a total of seven compressors were in use prior to the completion of the project, which included three 200 HP units, three 150 HP units, and one 125 HP unit. The customer specified that all of the old compressors were oil-free single-speed rotary screw units made by Sullair. The new compressors consist of one 349 HP single speed compressor and one 335 HP VFD compressor. When the new compressors were installed, five of the existing compressors were removed, with only two 200 HP compressors left in place. The customer said that prior to the completion of the project, all of the compressors ran nearly all the time, with some of them turned off during Sunday shut-downs. No other significant changes have been made at the facility that would impact the compressed air demand, such as large changes in production levels.

During normal operation, one of the 200 HP compressors is turned on to provide a baseload; the VSD compressor is left on nearly all of the time to provide trim load; and most of the time, the new single-speed compressor is turned on as well. The customer said that the new single-speed compressor is manually turned off by the maintenance team during periods of lower demand.

The facility is in operation six days per week for nine months of the year. For the other three months of the year, the facility operates five days per week. Prior to the completion of the project, during off days, one 150 HP compressor and one 200 HP compressor were left on, and all of the other compressors were manually turned off. Now, only the new VFD compressor remains in operation on Sundays. At the time of the site visit, the system pressure was 101 psi, while the compressor control screens showed a target pressure of 100 psi. Prior to the completion of the project, the compressors could not maintain 100 psi, and the customer estimated that the average system pressure prior to the project was 86 psi.

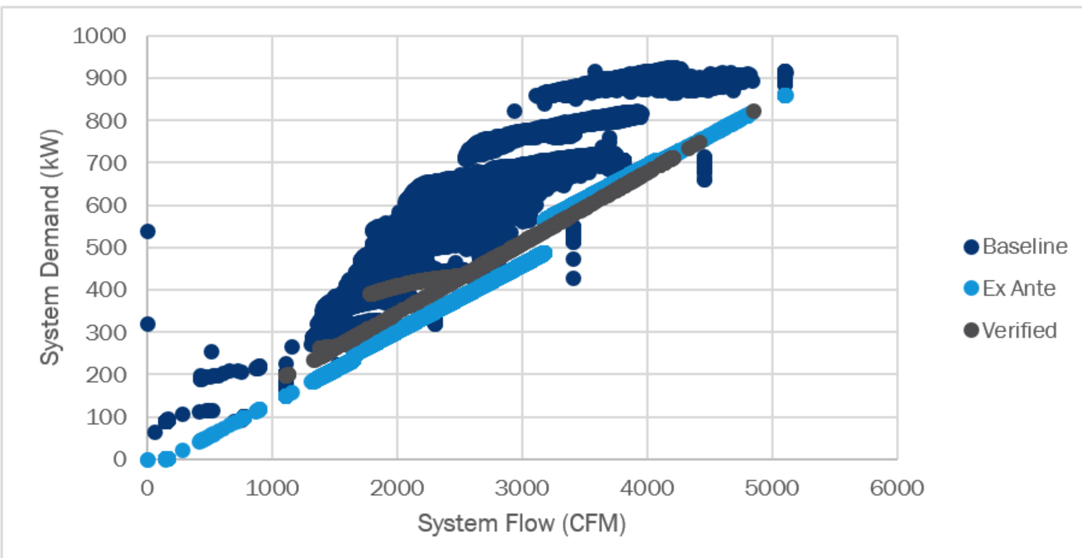
Calculation Description

The evaluation team used metered data of compressor electrical demand and compressed air flow from prior to the project's completion, along with the performance data of the current compressors to determine the energy required to meet the same compressed air demand. In the calculation, one of the 200 HP compressors that remained in place was specified to run Monday through Saturday. The customer stated that the new single-speed compressor is manually turned on and off based on the system load. To model this, the team estimated that the compressor was turned on whenever the compressed air load exceeded the capacity of the old 200 HP compressor by more than 768 cfm (which is 50% of the rated capacity of the new single-speed compressor). The VSD compressor automatically turns on and off and modulates as needed to maintain the system pressure setpoint.

There are several significant differences between the ex ante savings calculations and the verified calculations. The ex ante calculations assume the system pressure before and after the completion of the project will be the same. This is not accurate, as the system pressure increased substantially as a result of the project. The low-pressure issues of the past were likely the drivers for carrying out the project, at least in part.

The sequencing of the compressors is also different in the two calculations. The ex ante calculations use the new single-speed compressor as the first compressor in the sequence, running at full load during nearly all operating periods. This does not reflect the manual on/off control that the customer described during the site visit. During the site visit, we found that one of the old 200 HP compressors is on continuously from Monday through Saturday, but in the ex ante calculations, the first 200 HP compressor in the sequence is only on 12% of the time during system operation. The VSD compressor meets the trim load in both the ex ante and verified calculations, but the ex ante calculations reflect an ideal scenario for the post-implementation case, with all compressors perfectly sequenced such that the VSD compressor is always running to meet a load. Due to the absence of any sequencer at the facility, and the compressors only operating with pressure controls and manual on/off controls, this is unrealistic. Figure 12 shows the total system power as a function of flow for the baseline, ex ante, and verified demand.

Figure 12. Total System Power as a Function of Flow



As shown in the graph above, at lower compressed air loads the ex ante system electrical demand is lower than the verified demand, but the ex ante and verified demand values converge at higher flow rates.

Another significant difference between the ex ante and verified analyses is that in the ex ante case assumes the compressed air system is in operation for only 6,830 hours per year. From the information collected during the site visit it is understood that there is a demand for compressed air all the time, even during “off” days, when production is not running. Compressed air is used for cleaning and prep work that occurs between production runs.

The resulting verified savings for this project is 1,156,298 kWh, yielding a realization rate of 85% (shown in Table 31). We determined the verified demand savings for the coincident summer peak window (weekday afternoons from 1-5 pm from June through August).

Table 31. Summary of Ex Ante and Verified Savings

Air Compressor Replacements	kW	kWh
Ex Ante	198.70	1,359,411
Verified	159.38	1,156,298
Realization Rate	80%	85%

Project 1900538

Project ID#	1900538
Measure:	Chiller replacement
Savings:	1,482,933 kWh; 180.69 kW
Facility Type:	Manufacturing/Industrial – Food Processing
Enduse:	Process cooling

Measure Description

This project covers the installation of a new water-cooled centrifugal chiller with 800 tons of cooling capacity. The site installed the chiller to replace an existing 500 ton unit to meet increased demand due to increased production.

The new chiller has variable speed drive (VSD), with 0.6305 kW/ton full-load efficiency and 0.4913 kW/ton non-standard part-load efficiency (NPLV). The existing chiller was reported to be in good condition, but it did not have sufficient capacity to meet increased demand. Therefore, the team assumed the baseline chiller plant was the existing 500 ton chiller plus a new, standard efficiency, 300 ton capacity, single-speed chiller.

Summary of the Ex Ante Calculations

The team calculated savings for this measure using the chiller vendor's proprietary software. The software accounts for baseline and proposed chiller efficiencies plus local weather conditions.

The customer acquired two proposals by separate manufacturers for the chiller replacement. The vendor that was not selected for this project assumed that the existing chiller would be re-built, and a 300 ton chiller would satisfy the expanded production demand. The selected vendor used a new single-speed, standard efficiency, 800 ton chiller as the baseline. The implementing team calculated savings with:

- Baseline energy and demand calculated based off a two-chiller system (the existing 500 ton chiller plus a new, standard efficiency, 300 ton capacity, single-speed chiller). The existing chiller did not have known efficiency curves, so the implementing team used a similar York chiller to generate efficiency curves.
- Proposed energy usage and demand calculated based off the as-furnished chiller.

Table 32 provides a summary of these estimates.

Table 32. Summary of Energy and Demand Usage in Baseline and Post-Retrofit Conditions

Chiller Replacement Project	kW	kWh
Baseline	332.44	2,797,967
Post-Retrofit	151.75	1,315,033

Table 33 presents the ex ante savings for this project.

Table 33. Ex Ante Savings for Chiller Replacement

	Demand Savings (kW)	Annual Energy Savings (kWh)	Gas Savings (therms)
Chiller Replacement	180.69	1,482,933	N/A

Measurement and Verification Plan

The team evaluated this project through a site visit. During the visit, the team will observe and verify the chiller set points and schedules. The team will complete the final evaluation of energy savings with a billed data regression if possible. The claimed savings represent about 10% of energy use for 2018. If available, the team will conduct an alternative analysis through a review and analysis of trended data. If neither option is appropriate, the team will establish savings using information collected during the site visit to model the operation of the new chiller and baseline system.

Specific questions for the site contact, along with the answers the evaluation team received, are as follows:

- What happened to the existing chiller? Was it at the end of its useful life? Were there maintenance issues?
  - The existing chiller was removed from the site. It was at the end of its useful life, and it didn't have enough capacity for the chiller plant to meet peak loads.
- What are the hours of use for the new chiller?
  - The chiller is part of a system that includes two other 800 ton chillers and a 500 ton chiller, all operating based on the required capacity.
- Was the cooling tower or tower water pump modified to accommodate the new chiller?
  - No
- Has production changed since the installation of the new chiller?
  - No
- What are the cooling loads, and how do they vary by day, week, month, and year?
  - Much higher in the summer. The facility has airside economizing and waterside economizing to minimize cool-weather chiller operation, although chilled water is needed most times to meet the load that can't be met with economizers.
- Is production expected to increase (or decrease) in the foreseeable future?
  - No
- Is any trend or other operating data available?
  - No
- The documentation references the installation of a new distribution pump. Was a VSD installed to control its flow? Was it included in a separate incentive or included as a part of this project?
  - No changes to the pumps. The chilled water loop consists of primary pumps only, there is no secondary pump on the main loop.

This project is a candidate for independent metering of the chiller. The team plans to hold scheduled discussions with the customer to determine whether or not to install meters. If trend data is available, we will use it in lieu of temporary meters. Also, if we determine that collecting data during the coldest part of the year will not provide useful data, the team will not install metering equipment.

There are two other items of note that we will consider in our verified analysis:

- NPLV only applies to space conditioning loads, and not industrial loads, unless it is calculated per the industrial loading profile. We plan to take this into consideration in our analysis.
- There is a question about the appropriate baseline for this project. The age of the old chiller, available space, and other factors may play into the selection of an appropriate baseline. The team will review the suitability of the baseline used in the ex ante analysis and may adjust the verified baseline according to information collected during the evaluation process.

Description of Verification

The evaluation team performed a site visit to better understand the requirements and processes of the facility. The facility produces Portabella and Cremini mushrooms. The cooling loads for the building are primarily shell dominated, but mushroom production does generate some heat and moisture as well.

This facility now has three 800-ton chillers and one 500-ton chiller. Previously it had two of each. The additional capacity was not added because of additional loads that had been or were expected to be brought online. Rather, it was due to the plant being too close to capacity for owners' preferences when the 500-ton chiller reached the end of its useful life. In addition, in the evaluation team's opinion, there is no additional space available in the chiller plant for a new chiller. Therefore, adding a 300 ton chiller to the existing plant as used in the ex ante calculation was not an option.

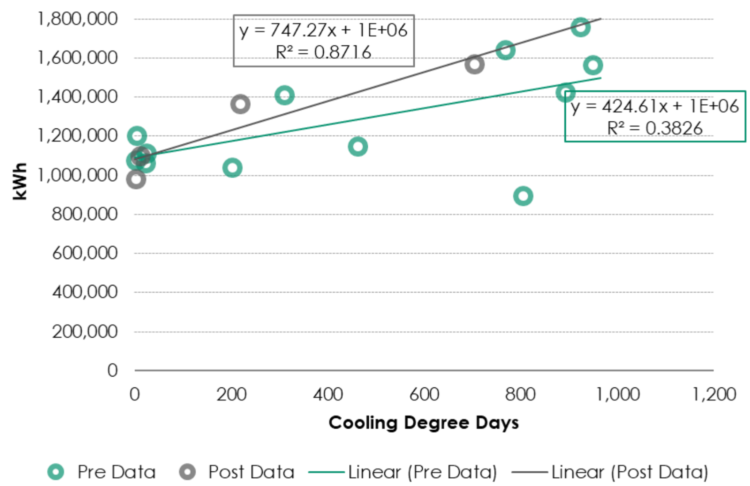
The new chiller was not operating during the time of the site visit (January 15th, 2020; 34.1°F outside air temperature). The entire load was being maintained by the existing 500-ton chiller. During cold periods, the facility is able to provide some, but not all, of its cooling needs with air-side economizers, However, the remaining 500-ton chiller was sufficient for that load while outside temperatures were in the mid-30s.

Calculation Description

The evaluation team attempted a billing regression analysis. However, the team only had five months of post-installation billing data (September 2019 – January 2020), which is not enough to generate a reasonable regression for the post case. Further, the baseline usage did not provide sufficiently accurate models. This may be due to varying production, for which the evaluation team does not have data.

With that said, the billed consumption data we do have does not strongly appear to support an ~10% annual energy reduction. The data shows no correlation with heating degree days (as expected), and the cooling degree day correlation does not appear to have noticeably decreased, as shown in Figure 13.

Figure 13. Monthly Site Energy Usage Cooling Correlation



Trend data was also not available at the site. The site visit occurred during a very cold period, therefore the chiller in question was not in operation. For this reason, no data from the chiller's operation was collected.

As a result, the evaluation team reviewed and adjusted the ex ante calculations. The ex ante calculation used a bin-based calculation for the base-case and a proprietary vendor-based calculation for the efficient case. The baseline calculations were rigorous and appear to have been well prepared.

There are two substantial factors in the adjustment:

1. Hours of use in the ex ante calculation were 8,666 hours/year. However, the evaluation team found that the chiller was not operating during cooler periods due to substantial air side economizing availability. The adjusted hours of operation were 4,076 per year because free cooling is typically capable of handling the load below 55°F outside air temperature. This accounts for a majority of the difference between ex ante and verified savings.
2. The adjusted baseline used was a single new 800-ton chiller rather than a new 300-ton chiller and a refurbished 500-ton chiller. This is primarily due to space considerations (a new 300-ton chiller would not have fit in the space). Additionally, R-11, an old refrigerant used in cooling and refrigeration systems, has not been in production since 1987, so it is unlikely that a chiller using it would have its lifespan extended.

Table 34 shows the verified savings and realization rates.

Table 34. Summary of De-Staged Booster Pump Project Savings

De-Staged Booster Pump	kW	kWh
Ex Ante	180.69	1,482,933
Verified	82.23	335,153
Realization Rate	46%	23%

Project 1900759

Project ID#	1900759
Measure:	Water Source Heat Pump System with High Efficiency Hot Water Boiler
Savings:	114,700 kWh; 67.90 kW; 16,572 therms
Facility Type:	School/College
Enduse:	HVAC

Measure Description

The customer replaced the heating and cooling systems serving an elementary school. The old system was at the end of its useful life, and a new two-pipe water source heat pump system was installed. Condensing boilers provide heating, and heat rejection for cooling is provided by an evaporative closed-loop cooling tower (not the fluid dry cooler described in the project documentation). The customer installed 29 unit ventilator style heat pumps plus 22 console-style heat pumps. The existing equipment was not used as the baseline for the new system.

The baseline is considered to be a two-pipe hot water/chilled water system. In this system, two hot water boilers and an air-cooled chiller operate as the building plants. Large central circulation pumps distribute hot water or cold water to unit ventilators or fan coil units throughout the facility. The unit ventilators are responsible for ventilating the space.

The proposed system is a water source heat pump system. This system utilizes two smaller hot water boilers and a cooling tower as the building plants. Circulation pumps distribute condensing water throughout the building. The individual heat pumps, depending on the position of the reversing valve, either reject heat to the room or to the loop. These heat pumps are responsible for ventilating the space.

Summary of the Ex Ante Calculations

Savings were determined by developing eQuest models that were used to compare the energy use of the building with only changes to the baseline and proposed systems considered. The ex ante temperature set points were 74°F and 72° F for cooling and heating, respectively, with 4°F setbacks. Customized occupancy schedules and control assumptions were used that are generally in line with the project documentation. It should be noted that the kW savings for this project were calculated using the demand over the course of the entire year. The peak demand for the baseline facility was in August, and the peak demand for the proposed facility occurred in December. The demand savings should be based on the demand reduction during the coincident peak demand period as defined in the Illinois technical reference manual. A summary of the baseline and post-implementation demand and energy consumption and ex ante savings are provided in Table 35.

Table 35. Summary of Ex Ante Estimated Energy and Demand and Savings

	kW	kWh	Therms
Baseline Consumption	669	584,820	57,241
Post-Implementation Consumption	602	470,120	40,669
Ex Ante Savings	67.90	114,700	16,572

Measurement and Verification Plan

The team evaluated this project through a site visit. We verified the installation of the water source heat pump system and discussed the following:

- Describe the old heating and cooling system, including age and condition.
- How is heating/cooling controlled? Is there a building energy management system (EMS)?
- Do the unit ventilators have economizing capability?
- What other gas-using equipment is used?
- Normal hours of occupancy?
- When does the school year start/stop?
- When does the school have summer school? Christmas break? Spring Break?
- Equipment scheduling and loop setpoints?
- What, if any, other EE measures installed in this building in the past two years?

The team will use information collected to update the ex ante eQuest model and calibrate the results with the most-recent billed gas and electrical usage information available.

Description of Verification

The team completed a site visit at this facility on December 19, 2019. At the time of the visit, we recorded the project installation and operational parameters. Of note, the in-session operating hours are 5:30am – 4:30pm, Monday – Friday, and on weekends as needed. The heating setpoint is 70.5°F and the cooling setpoint is 72°F with a 5°F setback during unoccupied periods for both heating and cooling, which are different than the assumed schedules and temperature setpoints. The installed equipment was consistent with the project documentation.

Calculation Description

The team modified the ex ante models to reflect the verified building setpoints and operating hours. In particular, we lowered the heating and cooling setpoints, and increased the setback temperature change from 4°F to 5°F. The resulting energy savings equaled 103,300 kWh, which gives a realization rate for the energy of 92% (see Table 36). We calculated the coincident peak demand savings using the summer energy reduction and by adjusting for occupancy. The ex ante demand was determined by just taking the maximum load in the baseline and proposed cases. The peak load in the proposed case occurs in winter. Overall, this increased the coincident peak demand savings associated with this project resulting in a realization rate of 120%. Finally, the gas savings increased as a result of the modified occupancy parameters, giving a realization rate of 140%.

Table 36. Summary of Ex Ante and Verified Savings

Water Source Heat Pump System with High-Efficiency Hot Water Boiler	Coincident Peak kW	kWh	Therms
Ex Ante	67.90	111,700	16,572
Verified	81.5	103.300	23,120
Realization Rate	120%	92%	140%

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