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Ameren Illinois Company 2018 Business Program Impact Evaluation Report

Appendix D – Custom Initiative Site Visit Reports

Final

April 30, 2019

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Opinion Dynamics

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Appendix D. Custom Initiative Site Visit Reports

In this section, we present detailed project-level desk review and on-site M&V reports for 15 Custom Initiative projects evaluated as part of the 2018 Business Program impact evaluation.

Project 900883

Project ID#:	900883
Measure:	Compressed Air Study and System Improvements
Savings:	121.34 kW, 1,060,067 kWh
Facility Type:	Industrial
End Use:	Compressed Air

Measure Description

This project consisted of multiple compressed air system improvements at a large industrial facility. The improvements were based on an initial compressed air audit where the system baseline energy was measured and the system evaluated for process improvements. Based on a review of project documentation, the primary measures for this project included remanufacturing one of the large compressors to increase displacement and maximize efficiency; replacing an aftercooler; and modifying system piping to ensure the proper delivery of compressed air at the specific pressure needed.

Replacing the aftercooler eliminated a flow restriction that made the compressors work harder. The design intention was to reduce the differential pressure across the cooler to 1 psig. The additional system piping was intended to provide a specific high pressure operation with an adequate amount of air and allow the rest of the facility to run at reduced pressure. Based on project documentation the original system pressure was 94 psig. With the proposed modifications the system pressure was reduced to 85 psig without impacting pressure sensitive processes at the facility.

Other measures that may have been included in the project were changing out a specific process from using compressed air to a blower. This recommendation was included in the compressed air study, but it is not clear from the documentation if this measure was implemented.

Based on the project documentation it appears there was a separate project at this facility to address compressed air leaks in the facility. Energy savings from the air leak project are estimated and excluded from the savings estimates associated with this project.

Summary of the Ex Ante Calculations

A summary of the compressors included in the baseline study are shown in Table 1.

Table 1. Compressor Summary

Description	Manufacturer	Model	Type	ACFM	Nameplate HP	Rated Pressure
1 - "#9"	Ingersoll-Rand	2C35M4	Centrifugal	3048	800	106
2 - "#10"	Ingersoll-Rand	2C35M4	Centrifugal	2764	800	106
3 - "11"	Ingersoll-Rand	2C35M4	Centrifugal	2764	900	106
Recip	Ingersoll-Rand	PRE-2	Reciprocating	2564	600	100

Description	Manufacturer	Model	Type	ACFM	Nameplate HP	Rated Pressure
1 Floor	Sullair	20-100L	Rotary	474	100	100

The ex ante savings estimates are based on metered data. The baseline estimate is based on 10 days of logging. The data collected included motor amps based on 5-second averages. Using assumptions on loaded power factor (PF), unloaded PF, voltage, and unloaded amps; compressor performance demand (kW) and flow (scfm) for each interval were calculated. The values for the 5 compressors were totaled to provide total system demand and flow at each interval.

This data was then analyzed using a bin calculation using 36 bins based on 250 cfm flow increments. The flow ranged from 0 cfm to 9,000 cfm. This analysis provided a weighted average demand and flow for each bin. Energy for each bin was calculated using the percent time at that load, average demand, and multiplying by 8,760 hours per year.

The energy values for each bin were totaled for the estimated annual baseline energy use of 9,522,237 kWh. The value was reduced by the energy saved by a separate air leakage study, which had a claimed savings of 1,356,075 kWh. This reduced the baseline energy usage to 8,166,162 kWh. The baseline demand value was calculated by dividing the annual energy usage by 8,736 hours. There was not an explanation of why the annual hours were reduced from 8,760 hours to 8,736 hours. This resulted in a baseline condition of 934.77 kW in demand.

The post-retrofit estimate is based on calculations on the original metered data. The expected flow was adjusted based on a reduced pressure of 85 psig. This flow was then allocated to the four large compressors (see Table 1). The calculation was based on the largest compressor as the base and the other three providing trim capacity. The energy value for each bin were totaled for the estimated annual post-retrofit energy use of 7,106,095 kWh. The demand value was calculated by dividing the annual energy usage by 8,736 hours. For the post-retrofit condition the demand was 813.43 kW. In addition to the calculated post retrofit estimate of energy use, metered data was collected after the compressor retrofit was completed. The compressors were metered for 9 days after the retrofit was completed.

A summary of these estimates are provided in Table 2.

Table 2. Summary of Energy and Demand

	kW	kWh
Baseline	934.77	8,166,162
Post-Retrofit	813.43	7,106,095

The ex ante savings for this project are presented below in Table 3.

Table 3. Ex Ante Savings

	Demand Savings (kW)	Annual Energy Savings (kWh)	Gas Savings (therms)
Compressed Air Study and System Improvements	121.34	1,060,067	0

Measurement and Verification Plan

Since four of the five compressors in this project are supplied by 4,160 volts, no on-site logging will be completed due to safety concerns. If available, trends of compressor operation will be collected from the compressed air controller. However, based on the project documentation we do not expect trends to be available.

For the evaluation of this project, a site visit will be completed to inspect the equipment and verify the operation. Specifically, the equipment inspection will include verifying that the compressors and system layout are consistent with the supplied documentation. The replaced equipment will be specifically inspected.

To verify the equipment operation, the customer will be interviewed to determine the typical operation of the compressors and which compressors are base-loaded or modulate. Additionally, the pressures at the compressors as well as the system pressure (downstream of the regulator) will be verified.

Specific questions for this project include:

- What are the general uses of compressed air in the facility?
- What is the level of compressed air usage for the equipment kept at 94 psig?
- What was the final scope of the project as compared to the study recommendations?
- Have there been any other changes made that would impact the amount of compressed air used by the facility (increases or decreases in production, equipment changes, etc.)?
- What pressure did the system run at prior to the project? What is the current system pressure?
- How was the reduction in system air pressure achieved? Was this done at the compressor or at a pressure control valve?
- Current operating hours indicate there is only one day of shut down per year, confirm this is accurate with actual operation. Are there any seasonal variations in production or other factors that would affect compressed air usage?

Description of Verification

A site visit was completed on November 13, 2018. The site contact was interviewed and the compressed air system improvements were verified. The project documentation described some system improvements which were not implemented. The facility did not replace the aftercooler to eliminate flow restrictions in the system and they did not decrease the system pressure from 94 psig to 85 psig. The facility determined it was cost prohibitive to modify the system to run at 85 psig. The facility rebuilt compressors #9 and #10 to improve their efficiency and operation.

Nameplates of the compressors were observed. The compressor nameplate information matched the project documentation. The site contact confirmed that the plant typically runs two of the 800 HP compressors (#9, #10, or #11) and the 600 HP compressor (Reciprocating Ingersoll-Rand). The Sullair (100 HP) compressor rarely operates. These operating conditions are consistent with the baseline metered operating data.

The site contact confirmed that the compressors have an outlet pressure of 110 psig and target a plant pressure of 94psig. The plant pressure is controlled by a pressure regulator. The compressors run 24 hours per day 6 days per week with some infrequent operation on Sundays. The compressors have no central control system and each compressors responds individually to changes in observed upstream pressure. There are no seasonal variations in the use of the compressed air. The site does not collect trend data on the compressor operation.

Calculation Description

As discussed in the verification plan, the medium voltage compressors could not be metered due to high voltage safety concerns. In the absence of metered data, savings for this project have been estimated by following the ex ante calculations methods combined with operating information collected at the site visit. The verified savings were determined using the estimated compressed air load from the baseline measurement period and the operating conditions observed at the site visit. The metered data from the post-retrofit metering period was also considered in the verified analysis.

The ex ante calculations determined the compressed air load after the fixing the identified leaks and used a bin calculation method to determine the energy usage of the 4 compressors. The calculation assumed that two of Ingersoll-Rand centrifugal compressors run to provide base load and trim capacity. The calculation also assumes additional trim capacity is provided by the reciprocating Ingersoll-Rand compressor. The site representative confirmed that this is the typical operating condition at the facility. In the ex ante calculation the demand was further decreased by assuming the system pressure would be decreased from 94 psi to 85 psi.

The metered data from the post-retrofit period was collected with the plant pressure setpoint at the original 94 psi. The post-retrofit metered data shows that the savings are at least as significant as those estimated by the ex ante calculation. Differences between the ex ante calculation and the metered data are likely due to typical flow demand fluctuations observed in large industrial facilities. The verified calculated savings are at most a conservative estimate of the project savings and they have not been changed, such that the realization rate for this project is 100%.

Table 4. Summary of Project Savings

Compressed Air System Improvements	kW	kWh
Ex Ante	121.34	1,060,067
Verified	121.34	1,060,067
Realization Rate	100%	100%

Project 900966

Project ID#:	900966
Ex Ante Measure:	Motors
Ex Ante Savings	52.20 kW; 373,834 kWh
Facility Type	Industrial
End Use:	Wood Chip Processing

Project Description

This project is replacement of a wood grinder at a manufacturing facility. The existing grinder is replaced with a new grinder that has decreased run time resulting from higher throughput capacity. In addition to replacing the grinder, the retrofit project includes reconfiguring the flow of saw dust from the grinder to reduce the number of times saw dust is handled. Reconfiguring of the process flow eliminates an existing choke point in the process (the bag house) and speeds up the overall process so that the motor run time is reduced.

The analysis considers three different measures that contribute to the overall energy savings of the project: (1) upgrading the grinder from one with a 85 HP motor to one with a 180 HP motor, (2) reduction in operation time of the regeneration fan, and (3) reduced operation of the silo and auger.

Summary of the Ex Ante Calculations

The baseline kW and kWh are determined from the equipment horsepower rating as follows:

$$kW = HP * 0.7457$$

$$\frac{kWh}{year} = 2548 * kW$$

In the baseline case the grinder runs 2,548 hours per year. This is based on running 9 hours per day, 5 days per week and 4 hours on Saturday for 52 weeks per year. The savings estimate assumes the new grinder will only run 1.5 hours per day, 5 days per week. This is equivalent to 390 hours per year.

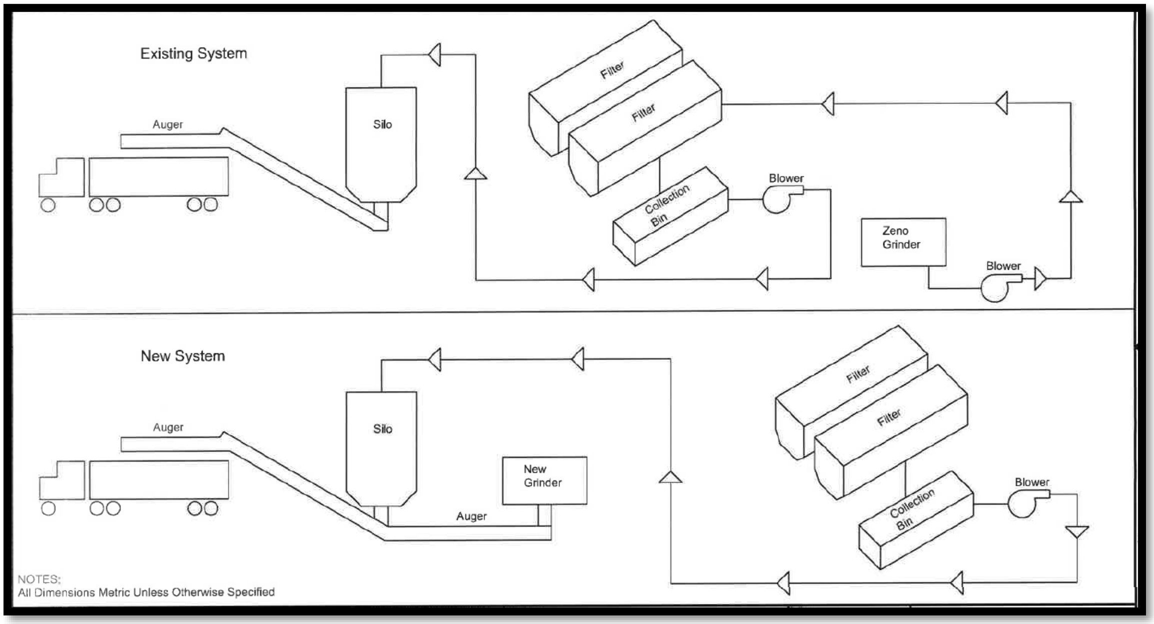
Table 5 shows the energy use for the baseline case and proposed case with the estimated savings.

Table 5. Energy Use in Baseline and Update Cases

<table>
<tr><th colspan="4">Baseline</th><th colspan="3">Proposed</th><th colspan="2">Savings</th></tr>
<tr><th>Equipment</th><th>Motor HP</th><th>kW</th><th>kWh/yr</th><th>Motor HP</th><th>kW</th><th>kWh/year</th><th>kW</th><th>kWh/year</th></tr>
<tr><td colspan="9">Measure 1- Zeno Grinder (2548 hrs/yr in the baseline, 390 hrs/year in proposed)</td></tr>
<tr><td>Grinder Motor</td><td>85</td><td>63.38</td><td>161,503.71</td><td>180</td><td>134.23</td><td>52,348</td><td>70.85</td><td>109,155.71</td></tr>
<tr><td>Hydraulics</td><td>8.6</td><td>8.58</td><td>21,850.50</td><td>11.5</td><td>8.6</td><td>3,344.46</td><td>-0.02</td><td>18,506.04</td></tr>
<tr><td>Shaker Tray</td><td>2.2</td><td>2.24</td><td>5,700.13</td><td>3</td><td>2.20</td><td>872.47</td><td>0.04</td><td>4,827.66</td></tr>
<tr><td>Belt Feeder</td><td>0.7</td><td>0.75</td><td>1,900.04</td><td>1</td><td>0.70</td><td>290.82</td><td>0.05</td><td>1,609.22</td></tr>
<tr><td>Blower Motor</td><td>18.70</td><td>18.64</td><td>47,501.09</td><td colspan="3">Equipment Eliminated</td><td>18.64</td><td>47,501.09</td></tr>
<tr><td colspan="7">Total</td><td>52.19</td><td>181,599.58</td></tr>
<tr><td colspan="9">Measure 2- Regen Fans equipment runs 520 hrs/yr</td></tr>
<tr><td>Regen Fans</td><td>1.2</td><td>1.119</td><td>581.65</td><td>1.2</td><td>1.119</td><td>290.82</td><td>0.0</td><td>290.82</td></tr>
<tr><td colspan="7">Total</td><td>0.0</td><td>290.82</td></tr>
<tr><td colspan="9">Measure 3—Surge Bin- Trans- Silo equipment runs 6,240 hrs/year</td></tr>
<tr><td>Air Lock</td><td>1.4</td><td>1.12</td><td rowspan="3">Total for Measure 3: 255,924.24</td><td>1.4</td><td>1.12</td><td rowspan="3">Total for Measure 3: 63,981.06</td><td>0.0</td><td rowspan="3">191,943.18</td></tr>
<tr><td>Auger Motors</td><td>2.5</td><td>2.61</td><td>2.5</td><td>2.61</td><td>0.0</td></tr>
<tr><td>Transport Pump Motor</td><td>40.36</td><td>37.29</td><td>40.36</td><td>37.29</td><td>0.0</td></tr>
<tr><td colspan="6">Total</td><td>0.0</td><td colspan="2">191,943.18</td></tr>
<tr><td colspan="6">Overall Savings</td><td>-52.19</td><td colspan="2">373,834</td></tr>
</table>

Figure 1 shows a flow diagram of the equipment in the baseline system and the proposed system. The proposed system flow diagram shows that the new grinder output bypasses the filter and bag house.

Figure 1. Flow Diagram – Existing and New System



Measurement and Verification Plan

During the site visit, the following items should be evaluated:

- Discuss new configuration with facility contact. Discuss changes in capacity and loads on motors with the removal of the choke point.
- Observe the new system and compare with provided flow diagram.
- Confirm motor nameplate horsepower ratings.
- The analysis estimates that the grinder and associated equipment will only need to run for 1.5 hr/day. Confirm that this is consistent with the actual operating time observed.
- Confirm daily run time of the regeneration fan with the new grinder.
- Calculations of kW for the motors do not include power factor or motor efficiency. Obtain motor efficiencies and estimate motor load factors.
- Ask the facility operator about the silo/auger calculations used to determine kW and kWh. Have these estimates been consistent with actual operation since installation?
- The calculation indicates that the blower motor does not run in the new system but it is still shown in in the flow diagram, confirm that the blower motor does not operate in the new system.
- Are there seasonal fluctuations in production loads and working hours?

Description of Verification

A site visit was conducted on October 9, 2019. The site contact was interviewed and the installed equipment was verified. The facility confirmed that since the motor was upgraded the facility rarely works overtime or on Saturdays. There are no yearly fluctuations in production, the facility operates at a steady rate throughout the year. Production at the plant increased 30% in 2018, despite the increase in production the motor run time has not increased from the submitted estimate of 390 hours per year. Based on observations at the site visit, we expect that the run hours for the motors are higher than claimed in the ex ante calculation. We could not obtain sufficient evidence to support a change to the run hours so they have not been changed in the verified calculation.

The facility confirmed that kW for the motors was not measured. The kW for the baseline and new conditions are estimated based on motor HP. We expect that the motors do not run at full power regularly. The verified demand calculations have been updated to include an estimated power factor for each motor.

Calculation Description

The savings for this project were recalculated in the verified analysis using the ex ante methods and observations from the site visit. The ex ante calculation assumed a load factor of 100% on all of the motors. The verified calculation was performed assuming a load factor of 80% for all motors, except for the grinder, in the baseline and post project conditions. For the grinder motor, a load factor of 25% was used in the baseline and a load factor of 80% was used in the post project case.

The ex ante calculation assumed a motor efficiency of 100% for all the motors, this efficiency was changed to 90% for all motors in the verified calculation. Table 6 shows the energy use for the baseline case and proposed case with the estimated savings.

Table 6. Energy Use Verified

<table>
<tr><th colspan="2">Baseline</th><th colspan="3">Update</th><th colspan="2">Savings</th></tr>
<tr><td>kW</td><td>kWh/yr</td><td>Motor HP</td><td>Kw</td><td>kWh/yr</td><td>kW</td><td>kWh/yr</td></tr>
<tr><td colspan="7">Measure 1 - Zeno Grinder (2548 hrs/yr in the baseline, 390 hrs/year in update</td></tr>
<tr><td>17.6</td><td>44,862</td><td>180</td><td>119</td><td>46,531</td><td>-101.7</td><td>-1,669</td></tr>
<tr><td>7.6</td><td>19,422</td><td>11.5</td><td>7.6</td><td>2,972</td><td>0</td><td>16,450</td></tr>
<tr><td>2.0</td><td>5,066</td><td>3</td><td>2.0</td><td>775</td><td>0</td><td>4,291</td></tr>
<tr><td>0.7</td><td>1,688</td><td>1</td><td>.66</td><td>258</td><td>.04</td><td>1,430</td></tr>
<tr><td>16.57</td><td>42,223</td><td colspan="3">Equipment Eliminated</td><td>16.57</td><td>42,223</td></tr>
<tr><td colspan="5">Total</td><td>-85.1</td><td>62,725</td></tr>
<tr><td colspan="7">Measure 2 - Regen Fans - equipment runs 520 hrs/yr</td></tr>
<tr><td>.99</td><td>517</td><td>1.2</td><td>.99</td><td>517</td><td>0.0</td><td>0.0</td></tr>
<tr><td colspan="5">Total</td><td>0.0</td><td>0.0</td></tr>
<tr><td colspan="7">Measure 3 - Surge Bin - Trans - Silo - equipment runs 6,240 hrs/yr</td></tr>
<tr><td>.99</td><td rowspan="3">Total for measure 227,488.21</td><td>1.4</td><td>99</td><td rowspan="3">Total for measure 227,488.21</td><td>0.0</td><td rowspan="3">0.0</td></tr>
<tr><td>2.32</td><td>2.5</td><td>2.32</td><td>0.0</td></tr>
<tr><td>33.14</td><td>40.36</td><td>33.14</td><td>0.0</td></tr>
<tr><td colspan="5">Total</td><td>0.0</td><td>0.0</td></tr>
<tr><td colspan="5">Overall Savings</td><td>-85.1</td><td>62,725</td></tr>
</table>

Updating the motor efficiency and reducing the load factors caused a significant decrease in expected savings. Table 7 shows the comparison of ex ante and verified savings along with the project realization rates.

Table 7. Project Realization Rates

New DDC Controls	kW	kWh
Ex Ante	-52.19	373,834
Verified	-85.1	62,725
Realization Rate	N/A	16.7%

Project 1000030

Project ID#:	1000030
Ex Ante Measure:	Heat Recovery from Chiller
Savings	-44.91 kW, -392,365 kWh, 182,098 Therms
Facility Type:	Hospital
End Use:	Chiller

Measure Description

This project includes replacement of an existing 250-ton heat recovery chiller with a new 100-ton heat recovery chiller. Based on the project documentation, the original chiller was out of service for two months at the beginning of 2017. With the maintenance costs increasing, the customer was looking to replace the chiller.

With the opportunity to purchase a new chiller, the customer also made a choice to reduce the size of the chiller. By reducing the size of the chiller, it would run fully loaded all year and be the most cost effective in achieving energy savings. The new chiller became operational in early March 2018.

Summary of the Ex Ante Calculations

The savings for this project were calculated using an energy model. The model outputs were provided with the project documentation, but the actual model files have not been obtained. The summary report indicates that the baseline was chosen as a chiller with no heat recovery. This is equivalent to a new construction baseline.

The savings were based on the model outputs for the baseline and post-retrofit conditions. A summary of the model outputs showing total energy consumption for the facility is shown in Table 8. Since a heat recovery chiller has additional electrical loads, the demand and energy usage increases in the post-retrofit case.

Table 8. Model Outputs

	kW	kWh	Therms
Baseline	970.90	8,505,044	511,900
Post-Retrofit	1,015.81	8,898,487	329,302

The only adjustment to these values was that the outputs were reduced for annual operating hours of 8,736 hours per year. The reduction from 8,760 hours is likely to capture maintenance downtime. As stated in the measure description, the chiller was sized to meet year round cooling loads so it should be running year round. This adjustment does not affect demand but only energy consumption.

Table 9. Model Output Adjusted for 8,736 Hours per Year

	kW	kWh	Therms
Baseline	970.90	8,481,743	510,497
Post-Retrofit	1,015.81	8,874,107	328,399

The ex ante savings were estimated by subtracting post-retrofit usage from baseline usage. The savings for this project are summarized below in Table 10.

Table 10. Summary of Project Savings

	Demand Savings (kW)	Annual Energy Savings (kWh)	Gas Savings (therms)
Heat Recovery Chiller	-44.91	-392,365	182,098

Measurement & Verification Plan

IPMVP Option A, Partially Measured Retrofit Isolation, will likely be used to establish savings for this measure. A site visit will be performed during which the installation of new heat recovery chiller will be verified.

During the site visit the following information will be collected and/or verified:

- The customer will also be asked for a copy of the model files unless they are obtained prior to the site visit
- Verify type of chiller in place before project was completed
- Verify make and model of the new chiller
- Verify operation of the chillers and free cooling temperature set points

The following set points and inputs will be verified:

- Hot water temperature when in heating mode
- Hot water temperature reheat schedule (140 F @ 0 F outside to 100 F @ 100 F outside)
- Hot water pump size that serves the heat exchanger
- Chiller efficiency in cooling mode
- Chiller efficiency in heating mode
- Boiler efficiency (high)
- Boiler efficiency (low)
- Annual operating hours

Operating data from the facility EMS pertaining to the chillers will be requested, including:

- Chiller power or amps
- Chiller tons of output

The EMS data collected will be analyzed to determine the cooling demand of the facility at various conditions. Winter operation will be analyzed to assess the effect of free cooling. The data requested should include operation during which the outside air wet bulb (WB) temperature is low enough to provide free cooling to confirm its operation.

If chiller EMS data is not available, data loggers will be installed to monitor the current draw or energy use. The loggers will record data at 15-minute intervals and be left in place for a minimum of two weeks. Instantaneous measurements of voltage, amps, power, and power factor will be taken at the time of deployment or removal to calibrate logged data.

The energy savings calculations for this project will use a bin approach (or hourly) using collected data to determine post-retrofit chiller load and power kW for annual operating conditions. Baseline chiller operation will use vendor data to calculate baseline chiller power kW for typical facility cooling loads.

To determine the summer peak demand savings for this project, the average operation of the installed chillers will be found for periods from 1-5 PM Monday thru Friday during the summer months. The verified demand savings calculations can be summarized with the following equation:

$$Demand\ savings\ (kW) = Baseline\ Peak\ Demand\ kW - Proposed\ \ Peak\ Demand\ k\mathrm{W}$$

Description of Verification

A desk review was completed on February 26th, 2019. The project consultant was interviewed. The consultant confirmed the project was completed in March of 2018. This project is a recommendation from a recommissioning study conducted over the years 2013 to 2015. The intent of the heat recovery chiller was to use the rejected heat for the hot water system in the facility. The load is relatively steady and predictable.

The consultant explained that the original 250-ton heat recovery chiller was installed in 2006. When it failed in March of 2017, it was repaired but with increasing costs of repairs the unit had essentially reached the end of its useful life. The facility did have enough cooling and heating capacity with the remaining boilers and chillers. The installation of this chiller provided more chiller capacity than was needed but with the added benefit of heat recovery.

The customer provided a copy of the model files and they were reviewed at a high level. The calculations were completed using an Excel spreadsheet. The consultant explained that since the intended use of the heat recovery chiller was to heat water, the typical modeling program (such as Trane Trace or eQuest) was not an appropriate methodology for analysis.

Updated utility bills were obtained and compared to the model outputs for the baseline and post-retrofit conditions. Table 11 provides a comparison of the model output to actual utility bills the 12 months after the chiller started up. The billed usage matches the predicted usage from the Excel spreadsheet analysis which indicates the post-case usage was estimated accurately.

Table 11. Post-Retrofit Model Outputs and Utility Bills

	kWh	Therms
Post-Retrofit	8,898,487	329,302
Utility Bills - March 2018 through February 2019	8,757,104	301,140

The consultant provided set points and equipment efficiency ratings which are summarized in Table 12. The consultant was not able to provide trends of chiller power or tons of output.

Table 12. System Operating Set Points and Efficiencies

Parameter	Value
Hot water temperature in heating mode	Temperature varies between 100 F and 130 F
Hot water temperature reheat schedule	130 F at OAT < 0 F and 100 F at OAT > 65 F with linear reset
Hot water pumps size	10 HP Heat Recovery Chiller Condenser Water Pump 5 HP Evaporator Water Pump
Chiller efficiency in cooling mode	15.0 EER
Chiller efficiency in heating mode	5.39 COP
Boiler Efficiency	Steam Boiler with Annual Efficiency of 65%

Calculation Description

The operating data obtained on the facility confirmed the facility is operating close to what the model predicted. The information obtained during the verification indicated the heat recovery chiller is operating well. The ex ante savings were not changed. The ex ante and verified savings and project realization rate are shown in Table 13.

Table 13. Summary of Project Savings

Heat Recovery from Chiller	Demand Savings (kW)	Annual Energy Savings (kWh)	Gas Savings (therms)
Ex Ante	-44.91	-392,365	182,098
Verified	-44.91	-392,365	182,098
Realization Rate	100%	100%	100%

Project 1000034

Project ID#:	1000034
Project:	New Resin Drying Equipment
Savings:	86.86 kW, 721,275 kWh
Facility Type:	Industrial
End Use:	Process

Project Description

This project involves replacing the existing resin drying system at a plastics processing plant. Prior to the completion of the project the resin drying process included eight individual dryers with constant speed fans and a constant drying temperature.

The new drying system includes a centralized system consisting of two larger and one smaller dryers. The new system uses variable speed drives on the blowers to adjust air flow to the amount of material being dried, air temperature, dew point, and desired drying time. The system can also adjust the drying temperature at the bin to match process conditions.

Summary of the Ex Ante Calculations

The ex ante savings for this project were based on metered data. The drying process was metered for 13 days prior to the retrofit to establish the average kW load for the process. This included measuring system voltage, amps and kW for one of the eight blowers. The points were averaged over an eight-hour shift. The equipment monitored were described as “regen” and “process” which appear to be the blowers. The other equipment monitored was described as “control” which appears to be the heater.

The average kW load was calculated using the following equation. Since the data represented only one of the eight dryers, the calculated value was multiplied by eight to get total kW load.

$$Avg\ kW_{8\ blowers} = Sum\left(Amp_{regen}, Amp_{process}, Amp_{control}\right) * Volts * 1.73 * PF \div 1000 * \#\ dryers$$

Where:
Ampregen = Average amps for regen blower = 14.27
Ampprocess= Average amps for process blower = 15.31
Ampcontrol = Average amps for control heater = 8.02
1.73 = factor for 3-phase power calculations
Volts = Line voltage = 464.19
PF = power factor = 0.85 (assumed value)
# dryers = 8

This resulted in a baseline demand of 205.3 kW. Annual energy consumption was calculated by multiplying this kW load by 8,304 hours. This is based on a 24/7 operation with the plant shut down for 19 days per year. Using these values, baseline annual energy consumption was estimated at 1,705,121 kWh.

After the retrofit, the process was monitored again for 13 days. The average kW load post-retrofit was calculated using the following equation:

$$Avg\ kW_{8\ blowers} = Sum\left(Amp_{regen}, Amp_{process}, Amp_{control}\right) * Volts * 1.73 * PF \div 1000$$

= 118.48 kW

Where:
Ampregen = 67.5
Ampprocess= 77.6
Ampcontrol = 21.7
Volts = 483.0
PF = 0.85

This resulted in an estimated revised demand of 118.48 kW when the saving measure is implemented. Using the same hours of 8,304 annually, post-retrofit annual energy consumption was estimated at 983,846 kWh.

A summary of the baseline and post-retrofit usage is provided in Table 14.

Table 14. Summary of Energy and Demand

	kW	kWh
Baseline	205.34	1,705,121
Post-Retrofit	118.48	983,846

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

Table 15. Summary of Project Savings

	Demand Savings (kW)	Annual Energy Savings (kWh)
Total Savings	86.86	721,275

Measurement and Verification Plan

For the evaluation of this project, a site visit will be completed, trended data will be collected if available, the equipment will be inspected, and the site representative will be interviewed.

Blower and regeneration air heater specification information will be collected for both the pre and post-case blowers. The customer will be asked to provide make and model numbers for all pre and post-case blowers and heaters. All blowers and heaters that are part of the dryers located at the facility will be inspected and nameplate information will be collected.

Additional questions for the customer include but are not limited to:

- When was project construction started?
- When did the project go online?
- Was the load on all the individual eight dryers prior to the retrofit the same? How were these dryers loaded?
- Has there been any changes to the process that affects the load on the system?
- Was the power factor used in the baseline and the measure calculation a default or a measured value? We will confirm the power factor at the site visit.
- Confirm operating hours and production trends.

Description of Verification

A site visit was completed on November 14th, 2018 and the project was inspected. The new centralized drying system, consisting of two larger and one smaller dryers, was confirmed to have been installed.

During the site visit, the site representative was interviewed concerning the operation of the drying process. The site representative explained that the drying process reduces moisture content of the plastic pellets from their initial moisture content down to a moisture content of 0.03%. The moisture content is carefully monitored throughout the drying process to avoid over drying of the pellets. The initial moisture content of the pellets ranges from 0.06% on humid summer days down to 0.03% on drier days in the winter. The metered data for the pre-case was collected at the end of May and the metered data for the post-case was collected in April. Given that the metering occurred in the spring season, the metered data will be assumed to represent operation of the drier for an average initial moisture content. The metered baseline and new equipment energy use will not be adjusted to account for extreme moisture content values.

Interviews with the site staff confirmed that the pre-case the driers ran continuously with constant fan speed. The new system monitors the pellet moisture content and slows the fan speed when the pellets have reached the target moisture content of 0.03%. The new centralized drying system reduces energy use and decreases the risk of over drying the pellets. The site staff confirmed the yearly operating hours of 8,304 hours/year.

Calculation Description

The ex ante savings calculations and methodology was reviewed and found to be appropriate. Therefore, the ex ante analysis was used as the basis for the verified calculations. The ex ante calculation used a default power factor of 0.85 to determine the dryer system energy consumption. During the site visit, spot measurements were taken on the dryer while it was operating. The power factor spot measurements showed that the power factor default power factor of 0.85 was appropriate for the expected operating range of the dryer system.

The total ex ante and verified savings are shown in Table 16.

Table 16. Summary of Project Savings

	Demand Savings (kW)	Annual Energy Savings (kWh)
Ex Ante	86.86	721,275
Verified	86.86	721,275
Realization Rate	100%	100%

Project 1000191

Project ID#:	1000191
Measures:	HVAC Controls
Savings:	134,006 kW, 1,173,889.5 kWh
Facility Type:	High School
End Use:	HVAC

Measure Description

The project covers the replacement of the HVAC control system in a high school with a total facility size of 323,000 square feet. The baseline energy use and savings were determined using a Trane Trace whole building model. The project was completed in December 2018.

Summary of the Ex Ante Calculations

Energy use for the baseline and proposed conditions were calculated using a Trane Trace building energy model. The model input parameters were provided with the project documentation. The model files were not provided.

The baseline for this project is the existing control equipment with the existing system settings and operation modes. The baseline usage was calibrated based on actual utility bills. While the model predicted 36% energy savings, the savings were capped at 25% as a conservative estimate the facility should be able to achieve. Table 17 provides the predicted energy usage from the model and the capped savings used for the ex ante estimate. The demand was calculated by dividing the energy use by 8,760.

Table 17. Pre-Case and Post-Case Model Outputs and Capped Savings

	kW	kWh
Pre-Case Model	536.023	4,695,559
Post-Case Model	340.470	2,982,520
Post-Case Capped	402.017	3,521,669

The ex ante savings for this project are presented below in Table 18.

Table 18. Ex Ante Savings

	Demand Savings (kW)	Annual Energy Savings (kWh)
HVAC Controls Replacement	134.006	1,173,889.5

Measurement and Verification Plan

Since the controls were installed in December of 2018, there is only one month of actual operations with the new controls in place. Updated utility data will be reviewed to determine if claimed savings is showing up in the monthly bills.

A site visit will be performed during which the completed measures will be verified. The customer will be interviewed regarding the completion dates for each measure. Control set points both before and after the project was completed will also be obtained from the customer or the BAS if available. Screenshots of zone scheduling and temperature set points will be recorded. These will be confirmed against the measure level assumptions used in the building simulations. The customer will be asked about the operation of the replaced sensors and controls.

Nameplate data for all major HVAC will be obtained. This will include heating and cooling capacities, efficiency, motor horsepower ratings, and VAV minimum set points (if applicable). This may be done by taking screenshots of building mechanical schedules. Facility layout drawings showing how the various zones are utilized will also be recorded.

The customer will be interviewed in detail regarding the previous operation of the facilities systems and controls. The assumptions listed in the model files will be verified. These assumptions will be used to validate (and if necessary, update) the building simulations to validate the energy savings.

Specific questions to ask at the site visit:

- Are there any unique uses of gas and electricity in the school?
- How was the system controlled prior to the installation of the new controls, the documentation notes that dysfunctional controls and sensors were replaced, was this equipment working in any capacity or was the system operating without control?
- Was there a BAS system prior to the project?
- What are the schedules for the equipment? Does the HVAC equipment maintain temperature in the summer months?
- What was the commissioning process like for the new controls? Were staff trained? Were new settings and new monitors checked out?
- When did the project start, how long did it take to implement, when where the new controls fully functional?

- How is the school used during the summer months?

Description of Verification

A site visit was completed on Wednesday February 13th. The Energy Manager and Project Consultant were interviewed. The facility is a high school building.

The project documentation showed the project was completed in December of 2018. During the site visit the Project Consultant explained that 85% of the project was complete in August of 2018. Once school started it took longer to complete the project.

The project scope of work (as shown in Appendix A) lists a potential project where the steam boiler would be replaced. The Energy Manager explained that the school is heated by a mix of steam and hot water boilers. The steam boilers serves about 1/6 of the total square footage. These boilers were not replaced during this project. The only work on these boilers is the annual maintenance and tune-up work.

However, the hot water boilers were replaced. The boilers were physically verified and the nameplate data showed these boilers were rated 85% efficient. The scope of work also stated that VSDs would be installed on cooling tower fans and chilled water pumps. These were verified on the project control screens.

The schedules for the facility were reviewed. There are five areas in the building. Area A is scheduled 5 am to 4 pm Monday through Friday; Area B is scheduled 5:30 am to 4 pm Monday through Friday; Area C is scheduled 5 am to 5 pm; Area D scheduled 7 am to 7 pm; the pool area is scheduled 4:40 am to 9:30 pm seven days a week; Area E is scheduled 7 am to 6 pm Monday through Friday; and the wrestling room is scheduled 2 pm to 6 pm Monday through Friday.

Other equipment modifications include AHU control valve replacements, VAV/RH control valve replacements; and conversion of 3-way to 2-way valves for the hot water heating.

Screenshots were recorded showing temperature set points for cooling and heating and setbacks and set ups for unoccupied periods. The set points varied by space but were approximately 70 F. Occupants can override temperatures for up to 4 hours during unoccupied periods. Occupants can adjust temperatures to 76 F for heating and 68 F for cooling during occupied periods.

Calculation Description

The project savings were evaluated using a billed data regression analysis. The pre-case period included the 16 month from January 2017 through April 2018. The post-case included the 5 month period from August 2018 through December 2018. The results from the regression are shown in Table 19. The pre-case had a root mean square error (RMSE) of 25,452 and coefficient of variation (CV) of 7.2%. The post-case had a RMSE of 5,420 and CV of 1.9%.

Table 19. Summary of Regression Analysis

	kW	kWh
Pre-Case Regression	492.58	4,315,038
Post-Case Regression	387.51	3,394,626
Savings	**105.07**	**920,412**

The ex ante and verified savings for this project are summarized in Table 20. The regression analysis using the billed data showed that the savings achieved with this project are under the estimated savings described in the application. The lower saving may be due to the project being completed in August 2018 so a full year of billed data was not available for the regression analysis. If more operating data was available with the new controls the savings may have been higher.

The low savings rate may also be due to occupants overriding temperature set points. Compared to other schools observed, this facility had more leniency in allowing occupants to override temperature set points.

Table 20. Summary of Project Savings

HVAC Controls Replacement	kW	kWh
Ex Ante	134.01	1,173,890
Verified	105.07	920,412
Realization Rate	**78%**	**78%**

Project 1000415

Project ID#:	1000415
Measures:	New DDC Controls
Savings:	24.22 kW, 389,485 kWh, 28,420 therms
Facility Type:	Medical
End Use:	Heating/Cooling

Measure Description

The project was is completed in an outpatient medical facility with a building size of 93,500 square feet. The project includes upgrading the direct digital control (DDC) system to control the building's HVAC system. Once the system is installed, the building will implement some additional savings measures by optimizing operation of the HVAC system. The project appears to have been implemented in spring of 2018.

The project includes the following specific changes to reduce energy use

- Reduce VAV minimums
- Cycle units to match a given occupancy schedule
- Implement controls on roof top unit (RTU) 3 to allow for zoning and setbacks
- Install air flow measuring station in the ductwork for the air handler that serves the cleanroom
- Implement unit scheduling with nighttime setback where possible
- Supply air temperature reset

The building HVAC equipment is listed below. There are no changes to the operation of the CRAC, CUHs, and the air-cooled unitary that contribute to energy savings associated with this project.

- RTUs - 7 total (all variable volume reheat)
- Computer room air conditioning unit (CRAC)
- Cabinet unit heaters (CUH)
- Air-cooled unitary system (1.2 kW/ton)

- Air-cooled chiller (1.38 kW/ton)
- Hot water boiler (77% efficiency)

Summary of the Ex Ante Calculations

Energy use for the baseline and the energy savings were calculated using a Trace Trane energy model. The baseline for this project is the existing control equipment with the existing system settings and operation modes. Figure 2 and Figure 3 below show the model baseline, model proposed savings, and the actual energy usage from a two-year average of billed data.

Figure 2. Annual Energy Use, kWh

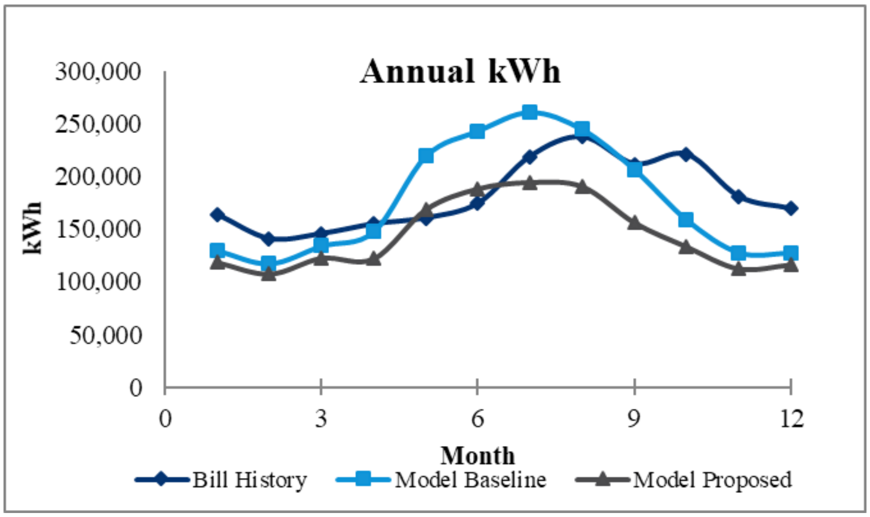
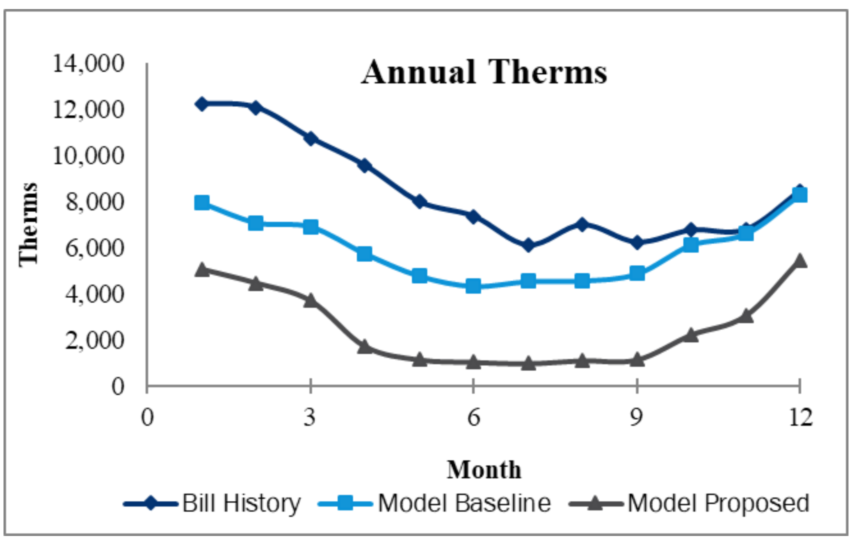


Figure 3. Annual Energy Use, Therms



A summary of the model outputs showing baseline and proposed usage is provided in Table 21.

Table 21. Summary of Energy Savings from Model Outputs

	kWh	Therms
Baseline	2,122,261	71,795
Proposed	1,732,776	31,117
Savings	389,485	40,678

The gas savings from the model outputs was further refined through a cap that limits savings to 28% of total annual metered usage. This resulted in the ex ante savings of 28,420 therms. The kWh savings was not adjusted. Demand savings was calculated by dividing kWh savings by 8,760 hours.

Table 22 shows the ex ante project savings for gas and electric usage.

Table 22. Summary of Project Savings

	Demand Savings (kW)	Annual Energy Savings (kWh)	Gas Savings (therms)
New DDC Controls	24.22	389,485	28,420

The claimed electric savings are 18% of the total billed electric use and the claimed gas savings are 28% of total billed gas usage.

Measurement and Verification Plan

A site visit will be performed during which the completed measures will be verified. The customer will be interviewed regarding the completion dates for each measure. Control set points both before and after the project was completed will also be obtained from the customer or the facilities building automation system (BAS) if available. Screenshots of zone scheduling and temperature set points will be recorded. These will be confirmed against the measure level assumptions used in the building simulations.

Nameplate data for all major HVAC will be obtained. This will include heating and cooling capacities, efficiency, motor horsepower ratings, and VAV minimum set points. This may be done by taking screenshots of building mechanical schedules. Facility layout drawings showing how the various zones are utilized will also be recorded.

The customer will be interviewed in detail regarding the previous operation of the facilities systems and controls. The assumptions listed in the model files will be verified. These assumptions will be used to validate (and if necessary, update) the building simulations to validate the energy savings.

Specific questions include:

- When did the project start, how long did it take to implement, when where the new controls fully functional?
- Other than HVAC, what are the other uses for natural gas?
- Why was the DDC system upgraded? Were sensors working properly before? Was there any scheduling in any of the spaces prior to this project?

- What area does each RTU serve? How is the space scheduled and what are the occupied and unoccupied temperature set points? The project specifically calls out scheduling for RTU 3, were the other RTUs scheduled as part of this project?
- What was the commissioning process like for the new controls? Were staff trained? Were new settings and new monitors checked out?

IPMVP Option C, partially measured retrofit isolation, may be used to establish savings for this project. The claimed savings are high enough that the savings can be verified using a regression model. The customer's billed usage history will be obtained and a billed regression will be completed. While not definitive, this will provide further validation of the modeled energy and natural gas savings.

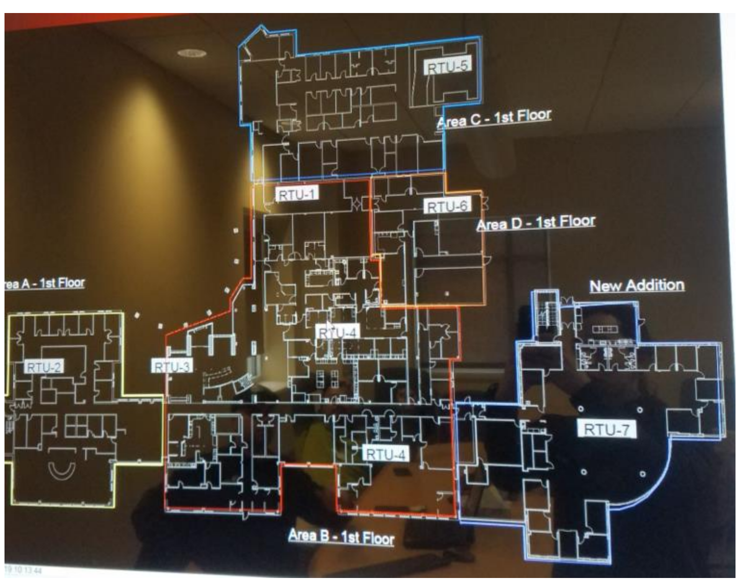
IPMVP Option D, Whole Building Simulation, may also be used to validate and verify the measure level savings estimates. The customer will be asked to provide the model for review. The model assumptions will be updated based on information obtained during the site visit.

Description of Verification

A site visit was completed on February 18, 2019. The site contact was interviewed and the HVAC control system and controls were observed. Prior to the project the building had a control system that was old and did not effectively control the temperature in the building spaces. The project included upgrading to a new control system, replacing temperature sensors, and replacing reheat actuators. The facility attempted to schedule the RTUs with the original control system but due to frequent temperature complaints, the facility frequently cancelled temperature setback schedules.

The site contact confirmed that the project included updates to controls and scheduling for the entire building which is served by seven roof top units (RTUs). The building layout and spaces served by each RTU are shown in Figure 4. RTUs 1 and 3 serve the lab area and pharmacy respectively, these areas have stringent temperature and humidity requirements and could not be scheduled. The remaining RTUs are scheduled with occupied hours from 5:30 am until 8 pm. The typical occupied temperature set point is 68˚F-74˚F. The setback temperature in heating mode is 60˚F and 78˚F in cooling mode.

Figure 4. Building Layout



Calculation Description

The project savings were evaluated using a billed data regression analysis. The regression analysis using the billed data showed that the savings achieved with this project are consistent with the estimated savings described in the application. The project was completed in October 2018 so a full year of billed data was not available for the regression analysis.

The project is installed as described and is achieving the energy savings expected from the initial estimation, therefore no changes were made to the ex ante estimate of energy savings.

Table 1. Ex Ante Savings

New DDC Controls	kW	kWh	Therms
Ex Ante	24.22	389,485	28,420
Verified	24.22	389,485	28,420
Realization Rate	100%	100%	100%

Project 1000681

Project ID#:	1000681
Ex Ante Measure:	GREM Hotel
Ex Ante Savings:	11.71 kW; 102,024 kWh
Facility Type:	Lodging
End Use:	HVAC

Measure Description

The project covers installation of 80 HVAC controls (thermostats) for hotel guest rooms. The HVAC controls comprise wall mounted thermostats with integrated occupancy sensors that sense when a room is unoccupied and reduce heating and cooling run time in unoccupied rooms. The thermostats apply a preset temperature setback when the room is unoccupied. The thermostat includes set point limits to limit the range of temperatures that can be set by guests.

Summary of the Ex Ante Calculations

The facility estimates kWh savings of approximately 19% which is within the range observed by the DOE study on these technologies installed in hotel settings (10%-26%). In order to determine the savings, the estimated energy use of the system with the proposed HVAC control is compared to a baseline of the system without occupancy detection or energy management technology of any kind. The actual energy supplied to the room HVAC system in the baseline is not known. The baseline assumes that the energy usage for non-HVAC processes in the hotel is 47% of the lowest monthly kWh usage. This non-HVAC usage is assumed to be static for the entire year regardless of temperature or other variables.

Savings are based on decreased run time of the HVAC system. A model is used to estimate the run time of the HVAC system with the installed thermostats. The estimate of savings assumes that the thermostat will reduce the operating time of the HVAC system by 40%.

Measurement & Verification Plan

During the site visit, the following items should be evaluated:

- Observe that the thermostats have been installed in the guestrooms
- Observe remote management system for the installed thermostats
- Ask about temperature setback range, does this range change seasonally or is it constant?
- Ask about setback optimization and setback limits, does the hotel apply uniform setback limits for rented and unrented rooms?
  - What are the temperature settings for heating and cooling in unoccupied rooms?
  - How long is room unoccupied before the setback kicks in?
  - How do controls prevent setback while occupants are sleeping?
  - What are the temperature limits on guest control?
- Ask facility about assumptions
  - How did they determine that the runtime reduction is 40% for their savings analysis? Is this a reasonable estimate for all months of the year?
  - How did they determine that non-HVAC power usage is 47% of the lowest monthly kWh usage?
- Review actual data that has been collected since the thermostats were installed
  - Can we determine directly or indirectly the decrease in HVAC runtime?
  - What has been the overall monthly decrease in power usage?

Description of Verification

A site visit was conducted on November 12, 2018. The site is a hotel that has installed a guest room energy management (GREM) system to achieve energy savings. The site contact was interviewed about the system operation and set points and installation of the GREM system was physically verified. At the site visit the contact explained that the GREM system is equipped with an occupancy sensor that can turn the room thermostat setting into set back when occupants are not detected. Currently this feature is not being used, instead the hotel housekeeping staff are manually setting the temperatures back when guests are not present in the room. The manual setback method was used prior to installing the GREM system. The unoccupied set points are 72˚F in the cooling season and 67˚F in the heating season. The occupied set points are 71˚F in the cooling season and 70˚F in the heating season.

Figure 5and Figure 6 show the billed data versus heating and cooling degree days used for the regression analysis. From the graphs, it is clear that the GREM system is not achieving significant energy savings.

Figure 5. Billed Data versus Cooling Degree Days

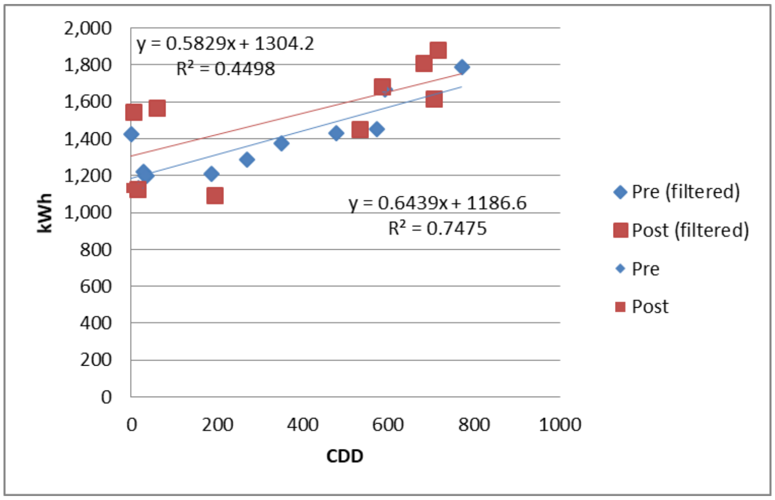
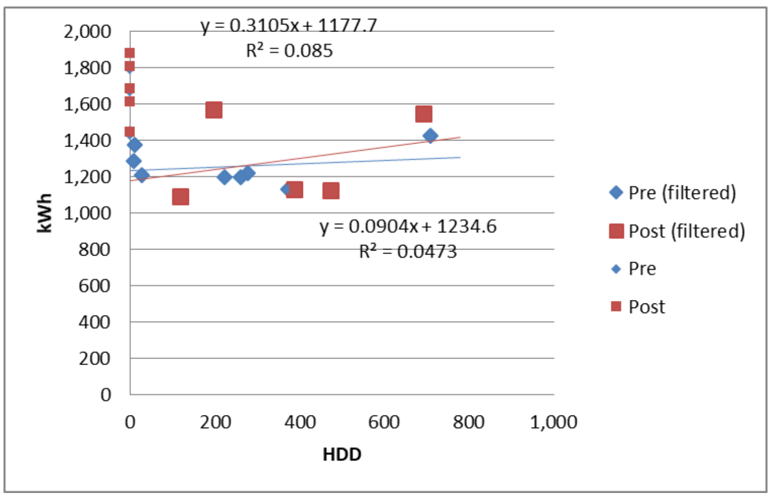


Figure 6. Billed Data versus Heating Degree Days



Calculation Description

This project was evaluated using a regression model correlating heating and cooling degree days determined from TMY3 weather data and utility data from the pre and post project periods. The original claimed savings are greater than 10% indicating that statistical significance can be achieved from the regression model. The regression model calculated only 4,406 kWh of energy savings which is a significant decrease from the estimated 102,024 kWh. The failure of this project to achieve the estimated savings is expected given that the GREM occupancy setback is not being utilized. The low energy savings are also likely to be impacted by the difference in temperature between occupied and unoccupied modes which is less than 5˚F. The regression coefficient of variance of the root mean square error (CV(RMSE)) is 11.6% indicating that the baseline can be considered reasonably accurate.

Table 23 shows the ex ante and verified savings with the realization rate for this project.

Table 23. Verified Savings

GREM Hotel	kW	kWh
Ex Ante	11.7	102,024
Verified	0.5	4,406
Realization Rate	4%	4%

Project 1800067

Project ID#:	1800067
Ex Ante Measure:	Water Cooled Chiller
Ex Ante Savings	68.412 kW, 302,108 kWh
Facility Type:	University
End Use:	HVAC

Project Description

The project covers replacement of an air-cooled chiller with a water-cooled chiller at a university. The specifications for the existing and replacement chiller are shown below.

Table 24. Chiller Specifications

Chiller	Capacity (ton)	IPLV (kW/ton)
YLAA0200HE46X (existing)	194.5	0.7417
YMC2 (replacement)	200	0.3792

Summary of the Ex Ante Calculations

Energy use for the baseline and efficient chillers were calculated using the equations provided below:

$$Average\ load\ at\ full\ capacity\ (kW) = Capacity * IPLV$$

Where:

Capacity = rated cooling capacity of unit

IPLV = intermediate part load value, kW/ton

$$Annual\ energy\ consumption\ (kWh) = Average\ load\ at\ full\ capacity * EFLH$$

Where:

EFLH = equivalent full load hours

The EFLH were estimated based on observation of the run time of the baseline chiller and was equivalent to 4,416 hours per year.

The estimated energy and demand of the existing and replacement chillers and ex ante savings are summarized in Table 25.

Table 25. Ex Ante Savings

Replacement Chiller	Demand (kW)	Energy (kWh)
Existing	144.25	637,018
Replacement	75.84	334,909
Savings	68.41	302,108

Measurement and Verification Plan

The project will be evaluated by confirming the following assumptions and asking additional questions shown below.

- Confirm operating hours of the chiller, if control software is not available to provide trend data for the compressor we will install meters to obtain an estimate of chiller operation.
- Confirm that the equipment is installed as described in the documentation. Where is the old chiller, has it been removed or is it in operation as a backup or in another location?
- Verify and record the nameplate data for the new chiller and the old chiller if available
- Confirm the load on the chiller, are there variations in the load seasonally or daily? How is chilled water used in the summer?
- What are the uses of chilled water onsite? Does chilled water demand fluctuate seasonally?
- What buildings are served by the chiller?
- The calculations are based on full load operation, is the chiller frequently operating at or near full load?
- Have any other projects been completed that increase or decrease the facility electric load?

Description of Verification

A desk review was completed on February 20th, 2019. The Director of Facilities was interviewed. He confirmed the unit was installed and the startup date was in June 2018 as shown in the project documentation. He stated the unit run time hours were 3,529 since startup. This value is equivalent to the unit running until the end of October 2018. The site contact did confirm the unit is shut down during the winter months and only provides building cooling and not process cooling.

The site contact confirmed the new unit is the only unit for the building and it cools the entire building. Based on the claimed building size of 526,960 SF in the project documentation; the cooling unit size of 200 tons; and rule of thumb of 400 SF/ton of cooling; the building size did not make sense. The building footprint was verified using satellite imagery as approximately 57,000 SF. This value matches up much better with a unit with 200 tons of cooling capacity.

Updated utility data was obtained and reviewed. The estimated annual amount of 3,669,162 kWh and the building size of 57,000 SF was equivalent to 70 kWh/SF. This is much higher than the what is expected for a college building. It is expected that the utility meter represents more than one building and possibly the whole campus and the original SF number likely also represents more than this one building. With this data a regression analysis of savings could not be completed.

The ex ante calculation was reviewed. The original calculation used annual operating hours instead of EFLH. The Illinois Technical Review Manual states the EFLH estimate for a college building is 662 hours. The calculation also states that full load EER should be used to calculate demand. A coincident factor of 91.3% should be used to calculate demand savings.

Calculation Description

Energy and demand savings were recalculated using the EFLH, EER, and coincidence factors provided in the TRM.

Table 26 shows the ex ante and verified savings with the realization rate for this project.

Table 26. Verified Savings

	kW	kWh
Ex Ante	68.41	302,108
Verified	105.8	45,289
Realization Rate	155%	15%

Project 1800072

Project ID#:	1800072
Measure:	Compressed Air Sequencing Controller
Savings:	84.2 kW, 737,921 kWh
Facility Type:	Industrial
End Use:	Process

Measure Description

This project consisted of installing a compressed air management system at a large manufacturing facility. The compressors controlled by the system are summarized in Table 27. The control system includes system air pressure sensors and kW meters for each compressor.

Table 27. Compressor Summary

Comp. #	Description	Type	SCFM	HP	Specific Power
#1	Sullair LS200S-200LWC	Single Stage Rotary WC	980	200	18.1
#2	Gardner Denver ST 200 HP, EBU, 100 psi	Single Stage Rotary WC	1,000	200	16.7
#3	Gardner Denver ST 200 HP, EBU, 100 psi	Single Stage Rotary WC	1,000	200	16.7
#4	Sullair V200S-200LWC	VSD Rotary WC	967	200	18.14
#5	Sullair	VSD Rotary WC	967	200	18.14

Summary of the Ex Ante Calculations

The project documentation includes two sets of metered data. The first set included amp data based on 10-minute averages. The data was taken before the new controller was installed.

The second set of data was collected when the controller was first installed. The second set of data was based on 10-second averages. The data includes compressor operation seven days before the control system was turned on, while the control system was being tuned and set up, and for seven days with the control system in full control of the compressors. This data set provided both the baseline and proposed conditions.

After the completion of the baseline monitoring period, the implementation team discovered a faulty air inlet valve on Compressor #1. This resulted in Compressor #1 operating without producing compressed air. Since this operation would skew the baseline consumption to falsely represent consumption, it was removed from the consumption data. Table 28 provides the daily average demand for each compressor before the new controller was installed. The inlet valve was fixed prior to the implementation of the compressed air management system.

The metered data provided a baseline demand estimate of 453.9 kW. This was multiplied by 8,760 hours to estimate the annual energy usage of 3,976,133 kWh.

Table 28. Baseline Daily Average kW Demand

	Comp. #1	Comp. #2	Comp. #3	Comp. #4	Comp. #5	Total
Saturday	Data Removed	0.6	168.7	52.8	50.1	272.3
Sunday	Data Removed	46.2	10.9	123.6	115.0	295.7
Monday	Data Removed	135.0	147.3	137.9	136.8	557.0
Tuesday	Data Removed	22.9	162.7	137.8	138.4	461.7
Wednesday	Data Removed	134.4	163.3	138.8	139.6	576.1
Thursday	Data Removed	11.4	163.9	138.9	139.8	454.0
Friday	Data Removed	119.7	163.7	138.3	138.7	560.4
Average						**453.9**

A similar set of metered data was used to estimate proposed demand. Since the faulty compressor valve was fixed, all compressor data was included. The metered data provided a baseline demand estimate of 369.7 kW. This was multiplied by 8,760 hours to estimate the annual energy usage of 3,238,213 kWh. A summary of this data is included in Table 29.

Table 29. Proposed Daily Average kW Demand

	Comp. #1	Comp. #2	Comp. #3	Comp. #4	Comp. #5	Total
Saturday	0.0	0.0	0.0	33.8	155.5	189.3
Sunday	0.0	0.0	0.0	109.2	85.4	194.6
Monday	84.3	76.3	0.0	152.9	119.8	433.3
Tuesday	8.7	163.0	0.0	160.4	120.9	453.1
Wednesday	0.0	165.4	0.0	159.9	120.1	445.5
Thursday	14.2	166.0	0.0	158.7	109.8	448.6
Friday	42.9	167.1	0.0	134.2	78.9	423.1
Average						**369.7**

A summary of the baseline and proposed usage is provided in Table 30.

Table 30. Summary of Energy and Demand

	kW	kWh
Baseline	453.9	3,976,133
Proposed	369.7	3,238,213

The ex ante savings for this project are presented below in Table 31.

Table 31. Ex Ante Savings

	Demand Savings (kW)	Annual Energy Savings (kWh)	Gas Savings (therms)
Compressed Air Sequencing Controller	84.2	737,921	0

Measurement and Verification Plan

For the evaluation of this project, a site visit will be completed, the equipment and compressed air system will be inspected, and the site representative will be interviewed. The compressors will be inspected to ensure that the nameplate data matches the compressors described in the project documentation. The compressed air sequencing controller will be physically verified, and its operation reviewed with the site contact.

Specific questions include:

- What are the various uses of compressed air?
- How were the compressors were controlled prior to the completion of the project?
- Was a sequencer previously in place?
  - Alternatively, were the compressors manually turned on & off, or did the compressors automatically turn off above a certain pressure?
- How are the compressors sequenced with the new system?
- How is the flow of the existing and new compressors controlled (load/unload, inlet modulation, etc.)?
- Have there been any other changes made that would impact the amount of compressed air used by the facility (increases or decreases in production, equipment changes, etc.)?
- What pressure did the compressors maintain prior to the project? Was that changed, or is the current pressure set point the same?

The customer will be asked to provide updated trends of the demand of the compressors from the compressed air management system.

Verification

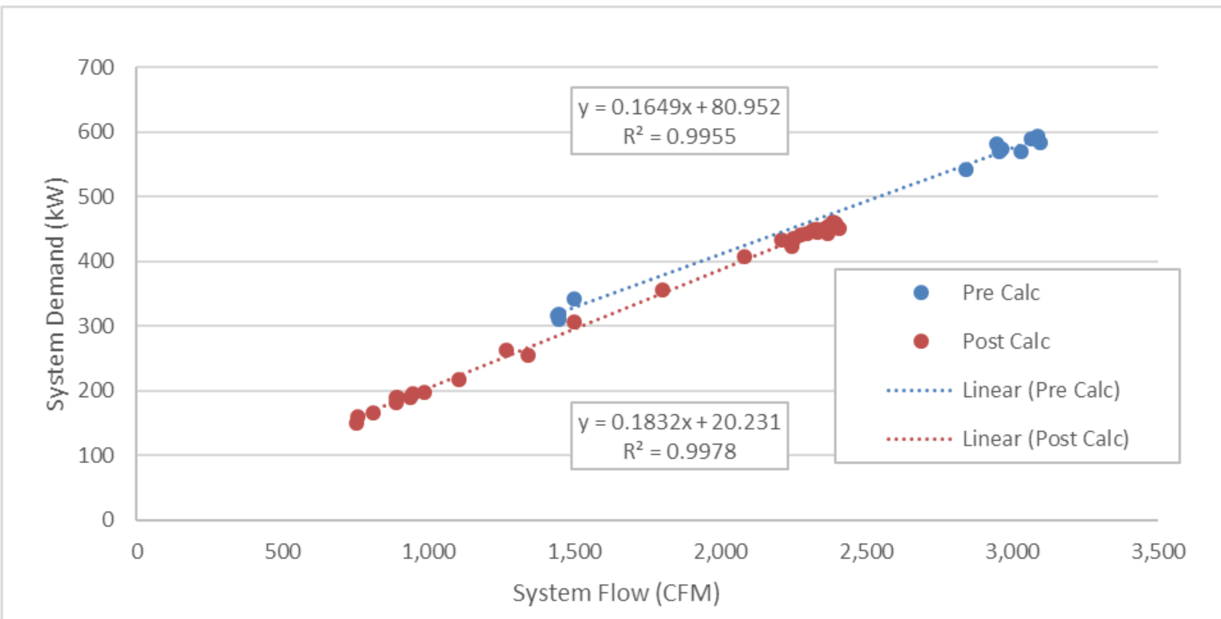
A site visit was completed on October 8, 2018. The site contact was interviewed and the compressors and control system were verified. The facility is a large manufacturing plant. The facility runs two daily shifts on a five day/week schedule. On occasion, to satisfy demand, the facility will run a third shift. The primary uses of compressed air at the facility are ionization and dust blow off. Prior to installing the control system, the compressors did not work together – each one responded individually to a provided set point target.

The facility has five compressors and plans to install a sixth by the end of 2018. Of the five existing compressors, one has been taken off line due to a faulty dryer. The offline compressor is the Sullair LS200S-200LWC, compressor #1. The plant is currently running on only four compressors. Compressor #1 was excluded from the baseline energy use calculation because it had a faulty inlet valve and was not producing compressed air. Compressor #1 was repaired and metered data from Compressor #1 was included in the post control installation metering period.

Calculation Description

The verified analysis used the same metered data as the ex ante analysis. The metered kW data from 3/1/2018 to 4/21/2018 was used along with the air compressors performance data and control strategies to calculate the CFM produced by the air compressors. The one week period from 3/3/2018 through 3/9/2018 was used as the pre-case period while the time period between 4/14/2018 through 4/20/2018 was used for the post-case. These are the same time periods used in the ex ante analysis. A system part load curve was developed for both of these time periods and is shown below in Figure 7.

Figure 7. System Part Load Performance Profiles

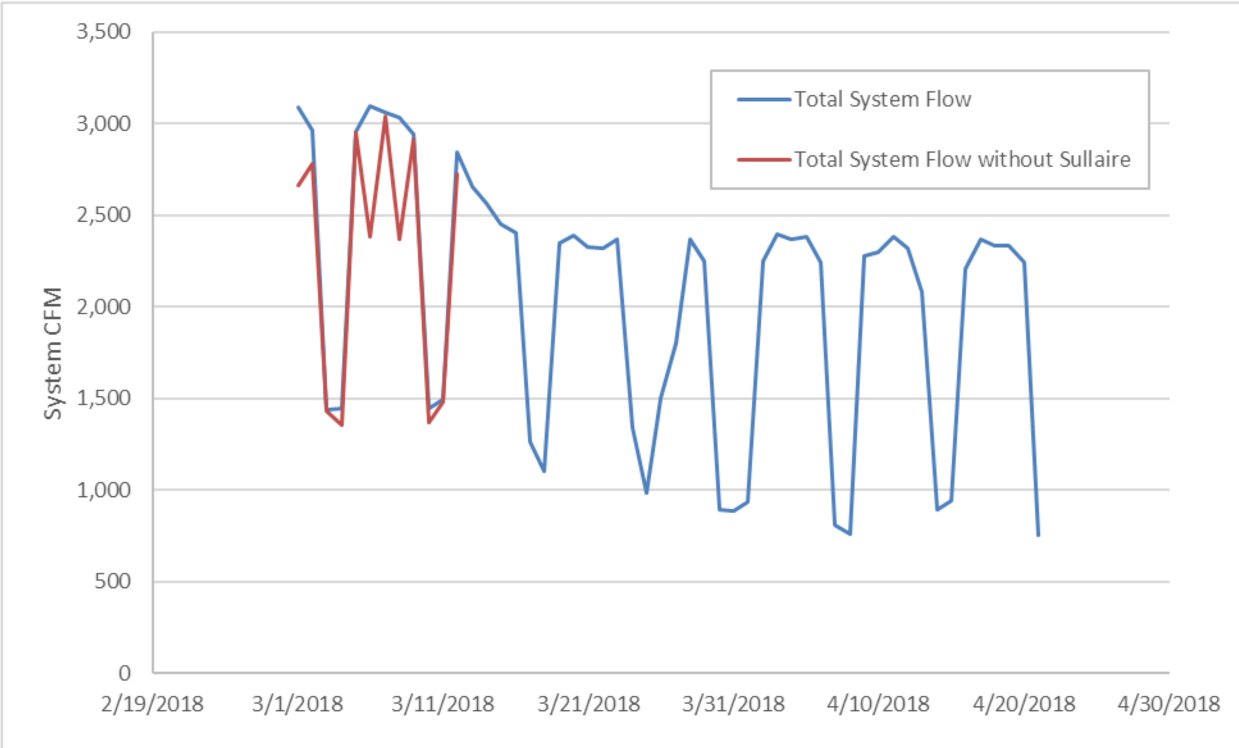


These system performance curves were used along with the calculated CFM data for the entire metering period to calculate the demand (kW) for the pre-case operation and the demand for the post-case operation for all observed CFM levels. The average demand (kW) for the pre-case and post-case was calculated to determine the systems average kW load. The average was used for the entire metered period despite the pre-case showing higher CFM than the post-case period.

During the site visit, one day of kW and CFM data was downloaded from the system's sequencer and the data was found to be consistent with the operating levels observed during the pre-case period. The customer also reported that the data represented typical operation. The 200 HP Sullair air compressor was left in the verified pre-case period. This was removed from the ex ante pre-case analysis due to reported issues with the compressor's controls.

The calculated system CFM was plotted with and without the 200 HP Sullaire compressor, and is shown in Figure 8. From this graph, it is clear the days the Sullaire ran are consistent with the surrounding days when it did not run. While the compressor may have had issues, it was still producing air. This figure also highlights the main difference in savings between the ex ante analysis and the verified analysis. The ex ante analysis only compared the difference in metered demand (kW) and did not consider the amount of CFM the system was producing. During the pre-period the system produced 2,569 CFM on average, while during the post-period it produced 1,903 for a difference of 666 CFM. This difference is only due to the timing of the pre- and post-case metering periods and not a permanent reduction in system air flow.

Figure 8. System CFM Profile



A summary of the verified baseline and proposed usage is provided in Table 32.

Table 32. Summary of Energy and Demand

	kW	kWh
Baseline	415.97	3,643,872
Proposed	392.42	3,437,642

The revised savings estimate and realization rate are shown in Table 33.

Table 33. Summary of Project Savings

Metric	Compressor Controls	
	kW	kWh
Ex Ante	84.20	737,921
Verified	23.54	206,230
Realization Rate	28%	28%

Project 1800084

Project ID#:	1800084
Ex Ante Measure:	Boiler Replacement
Ex Ante Savings:	84,367 therms
Facility Type:	Industrial
End Use:	Process steam

Measure Description

The project covers the removal of a boiler from a system of six steam boilers at a production plant. The facility's main steam system was under loaded so they removed one of the boilers which had reached the end of its life. Per the project documentation, the removed boiler was no longer needed due to changes in production technology.

Summary of the Ex Ante Calculations

The savings were based on estimates provided by the customer and inspections of the boiler that was to be removed. The existing boiler nameplate capacity was 150 boiler horsepower (BHP). Table 34 provides a summary of the calculation. Table 35 provides a summary of savings.

Boiler heat output was calculated based on the rule of thumb that 1 BHP is equal to 33,479 Btu/hr. The average boiler load of 40% and annual operating hours of 4,800 was provided by the customer. The estimate of 70% therms savings was based on the customers estimate. The customer estimated that 80% of the steam produced by the boiler would not be needed after its removal. The ex ante estimate reduced this initial estimate to a more conservative value of 70% savings.

Table 34. Summary of Calculation

Parameter	Value
Boiler Heat Output, Btu/hr	5,021,850
Boiler Efficiency	80%
Boiler Input Capacity, Btu/hr	6,277,313
Average Boiler Load of 40%, Btu/hr	2,510,925
Hours of Operation	4,800
Baseline Usage, Therms	120,524
Proposed Usage assuming 70% reduction in steam flow, Therms	36,157

Table 35. Summary of Ex Ante Savings

	Therms
Pre-Case Usage with Boiler at 40% Load, 4,800 hours per year	120,524
Post-Case Usage with 70% reduction in steam usage	36,157
Savings	84,367

Measurement & Verification Plan

During the site visit, the following items should be evaluated:

- Observe the installed boiler system and confirm that Boiler #5 has been removed and does not operate
- Determine the capacity and efficiency of the remaining five boilers
- Questions to ask at the site visit
  - When was the project completed?
  - How was the reduction in steam demand reduced? What changes to production technology occurred?
  - How often did boiler #5 run prior to the project?
  - At what load did boiler #5 run prior to the project?
  - What are other uses of natural gas on site?

Description of Verification

A site visit was completed on Monday February 11th. The Plant Engineer responsible for the project was interviewed. He confirmed the project was completed November 30, 2018. The boiler replaced in this project served a specific production line in the plant. The steam was used in a heat exchanger that heated the liquid product. A screenshot of the process was taken. The flowrate of the liquid being heated was 39.6 GPM. The inlet temperature was 99.7 F and the outlet was 145.7 F.

The production line ran 24 hours a day, 7 days per week. The line was shut down for periodic CIP cleaning but the site contact was not aware of the frequency. The steam line in this area was not connected to the main steam system serving the rest of the plant.

Boiler #5 was rated at 100 HP for 100 psi steam and originally built in 1990. Its continued operation was a safety concern and the boiler had reached the end of its useful life. Combustion reports were available in the project documentation showing the boiler combustion efficiency in 10% load increments.

The Plant Engineer explained that while the boiler could be replaced, the main steam system in the plant had excess capacity. This excess capacity was due to another area of the plant being shut down. The area that had been shut down was an empty space with no production activities.

This project included running a steam line to the area served by the old boiler. The new steam line was physically verified. The operation of the boilers serving the main steam system was observed nameplate data recorded. Three of the four boilers had economizers and one boiler had O2 trim controls. These boilers were controlled by a sequencer and were on line constantly with little cycling. Combustion test reports were provided for three of these four boilers in the project documentation.

Calculation Description

The energy needed to heat the fluid in the process served by the old boiler was calculated using Equation 1. The fluid being heated was a type of fruit drink. Since the exact liquid being heated was not known, typical values were chosen. This resulted in a heating load of 68,696 therms per year.

Equation 1. Energy to Heat Liquid:

$$Q = GPM\ x\ SG\ x\ SH\ x\ \Delta T\ x\ 8{,}760/100{,}000$$

Where:

Q = annual energy use in therms to heat liquid
GPM = flow rate of liquid, 39.6 GPM
SG = specific gravity, 1.05 for apple juice
SH = specific heat, 0.82 for grape juice
ΔT = temperature difference = (145.7 – 99.7) = 46 F

The boiler heat input for the process was estimated for both the existing boiler and the main steam boilers. The combustion test reports provided the basis for boiler efficiencies. The jacket losses were assumed. The cycling losses were also assumed based on general rules of thumb. Since the main steam system boilers did not cycle, the losses related to cycling were minimized.

Table 36. Boiler Efficiencies Pre-Case and Post-Case

Parameter	Boiler #5	Main System Boilers
Boiler Combustion Efficiency (from combustion test reports)	79%	82.9%
Jacket Losses	1%	1%
Cycling Losses	10%	0.5%
Seasonal Efficiency	**68%**	**81.4%**

Pre-case and post-case usage was estimated by dividing the estimated heat load of 68,696 therms per year by the seasonal efficiency of the pre and post case boilers. This is summarized in Table 37.

Table 37. Summary of Verified Savings

	Therms
Pre-Case Usage with Boiler 5 with 68% efficiency running for 8,760 hours	101,772
Post-Case Usage Main Steam Boilers at 81.4% efficiency for 8,760 hours	84,367
Verified Savings	**17,405**

Table 38 shows the comparison of ex ante and verified savings along with the project realization rate.

Table 38. Project Realization Rates

Boiler Replacement	Therms
Ex Ante	84,367
Verified	17,405
Realization Rate	21%

Project 1800103

Project ID#:	1800103
Measure:	LED-UV Curing Modules
Savings	84.17 kW, 673,380 kWh
Facility Type:	Industrial
End Use:	Process

Measure Description

This project involves the retrofit of a printing press with ultraviolet (UV) LED curing modules to cure the ink on the paper. The LED curing modules are packaged units that include an array of LED curing lights, a cooling system, and a lighting control system. Two modules were installed on the printing press to replace the existing IR/UV ink drying system. One module was located between print units five and six just before the paper is turned over. The second module was located between units nine and ten to cure the ink on the backside of the paper. Each curing module has a small chiller to keep the units cool.

Prior to the retrofit, the printing press had a UV curing system that employed mercury vapor lamps. The project documentation explained that the mercury vapor lamps produce ozone gas which requires proper ventilation.

The new modules use less energy. They also emit a narrower spectrum of light to assist in the curing process. The new modules do not produce the ozone gas produced by mercury vapor lamps so they do not require the associated ventilation for ozone gas.

Summary of the Ex Ante Calculations

The baseline energy usage is based on measured data. The baseline equipment for this project included one infrared (IR) dryer and one UV dryer. The equipment was estimated to run 8,000 hours per year. The project documentation indicates that instantaneous measurements amps, power, and power factor were taken on the baseline equipment. The baseline calculations assume that the equipment runs on 480 volts and three-phase power. A summary of this data is shown in Table 39.

Typically, we expect mercury vapor lamps to run on 120 volt single phase power. It is also unclear whether the ventilation, described for removing ozone, is included in this power measurement and whether the ventilation system is still in place. The ex ante calculation and baseline equipment being measured will be investigated while on site.

Table 39. Baseline Equipment Energy Consumption

Press Equip.	Volt	Amp	PF	kW	Hours	kWh
IR dryer	480	112	0.849	79.05	8,000	632,419
UV dryer	480	93	0.844	65.26	8,000	522,041
Totals				**144.31**		**1,154,460**

The power level of the equipment post-retrofit was provided by the manufacturer. Annual energy consumption was calculated using an estimated value of 8,000 hours per year. A summary of post-retrofit equipment consumption is shown in Table 40.

Table 40. Post-Retrofit Equipment Demand and Energy Consumption

Press Equip.	kW	Hours	kWh
LED UV Curing Module 1	15.0675	8,000	120,540
LED UV Curing Module 2	15.0675	8,000	120,540
Chiller Module 1	15.0000	8,000	120,000
Chiller Module 2	15.0000	8,000	120,000
Totals	**60.135**		**481,080**

A summary of the baseline and post-retrofit usage is provided in Table 41.

Table 41. Summary of Energy and Demand

	kW	kWh
Baseline	144.31	1,154,460
Post-Retrofit	60.135	481,000

The ex ante savings are presented below in Table 42.

Table 42. Ex Ante Savings

	Demand Savings (kW)	Annual Energy Savings (kWh)
LED-UV Curing Modules	84.17	673,380

Measurement and Verification Plan

For the evaluation of this project, a site visit will be completed, the new equipment will be verified, and the site representative will be interviewed. The customer will be asked to confirm press operating hours and whether any holidays are observed where the press is shut down. The customer will also be asked about the ventilation system for the baseline system and it current operations status.

The customer will be asked about the baseline equipment. It will be confirmed whether the baseline equipment was supplied by three phase or single phase power. The baseline power consumption calculation will be reviewed.

There is no post-case operating data available, so instantaneous measurements of voltage, amps, power, and power factor will be taken on the new equipment to confirm kW estimates in ex ante calculations.

Alternatively, the project savings may be verified using a regression analysis. The electric usage of this equipment and electric savings for this measure are expected to be a significant portion of the facility usage. The ex ante savings are approximately 11% of baseline energy usage. Therefore, if possible the savings will be verified through a billed data regression approach for pre and post operation.

Description of Verification

A site visit was completed on November 13th, 2018. The site contact was interviewed and the LED curing modules were observed. The facility staff confirmed that the printing press runs 24/7 with the lights on 18 hours per day 7 days per week. The baseline and the savings calculations were updated with the revised operating hours of 6,570 hours per year. The new LED curing lights have two light modules that share a common chiller module. The Chiller module runs whenever the lights are on. During operation the lights flicker on and off at a high frequency. The frequency of on/off oscillation was not known and could not be measured.

The verified calculation estimates the lights are on for 66% of the operating hours of the LED module operation. This is equivalent to 66% of 6,570 hours per year or 4,420 hours annually.

At the time of the site visit the LED modules were not available for metering of power consumption and power factor. The facility confirmed that the original IR and UV modules and the LED modules operate using a 480 volt power source. Name plate information for the LED modules and chiller was obtained from the manufacture. The rated wattage of each module is 14.9 kW and the chiller is rated at 29 kW.

Calculation Description

The ex ante savings calculations and methodology was reviewed and found to be appropriate. The baseline power consumption was updated using the operating hours estimate provided at the site visit of 6,570 hours per year (18 hours per day 7 days per week). Using the revised operating hours estimate and the provided wattage of the UV and IR dryers, the baseline power consumption was revised to 948,100 kWh per year. No change was made to the wattage estimate of the UV and IR dryers of 144.31 kW.

Table 43. Revised Baseline Equipment Energy Consumption

Press Equip.	Volt	Amp	PF	kW	Hours	kWh
IR dryer	480	112	0.849	79.05	6,750	519,374
UV dryer	480	93	0.844	65.26	6,750	428,726
Totals				**144.31**		**948,100**

The energy savings from the LED curing modules were updated based on information collected at the site visit and provided by the manufacturer. The updated values and calculations are shown below in Table 44. The wattage rating of the LED modules and the chiller were updated to be consistent with manufacturer specification. The operating hours were updated to 6,570 hours per year (18 hours per day 7 days per week). The verified calculation estimates the lights are on for 66% of the operating hours of the LED module operation.

Table 44. Revised Post-Retrofit Equipment Demand and Energy Consumption

Press Equip.	kW	Hours	kWh
LED UV Curing Module 1	14.9	4,402	65,262
LED UV Curing Module 2	14.9	4,402	65,262
Chiller	29	6,570	190,530
Totals	**58.8**		**321,054**

The revised energy savings are shown below in Table 45.

Table 45. Revised Summary of Energy and Demand

	kW	kWh
Baseline	144.31	948,100
Post-Retrofit	58.8	321,054

The total ex ante and verified savings are shown in Table 46. The demand savings increased slightly with the update to the new equipment power ratings. The energy savings were decreased slightly so that the kWh realization rate is only 93%. The energy savings were decreased due to the decrease in hours for the baseline and post-retrofit cases. The hours of use were decreased based on discussion with facility staff.

Table 46. Ex Ante Savings

LED-UV Curing Modules	kW	kWh
Ex Ante	84.17	673,380
Verified	85.51	627,046
Realization Rate	102%	93%

Project 1800136

Project ID#:	1800136
Measures:	Free Cooling on Chiller
Savings:	70,262 therms
Facility Type:	Hospital
End Use:	Cooling

Measure Description

The project is completed at a hospital. The hospital was struggling to meet their cooling load during periods of low (<46˚F) outdoor air temperature with the existing gas-fired chiller. The primary cooling load of concern was the fan coil units in the patient tower. The chiller was not able to operate with the low outdoor air temperatures due to the low temperature of condenser water entering the chiller.

The unmet cooling load varies from 1300 tons to 400 tons when outside air temperature is between 45˚F and 30˚F. The hospital considered two options to meet the cooling load. The first option was used as the baseline for this project and the second option is the chosen savings measure.

Option one was to retrofit one of the existing gas chillers to allow it to operate at a colder condenser water inlet temperature. The second option was to install a heat exchanger between the condenser and the chilled water systems. The heat exchanger allows chilled water to be supplied to the building without operating the gas chillers during cold weather operation.

Additional savings are achieved through a humidity control strategy. This will be achieved by using the free cooling system to offset using air-side economizing in other areas of the hospital. While air-side economizing provides an economical method for cooling, it also adds a humidification load by bringing in drier outside air.

Summary of the Ex Ante Calculations

Chiller Free Cooling

The baseline is calculated using the unmet cooling load at each outside air temperature for 45˚F down to 30˚F and a gas chiller COP of 2.48. The yearly hours at each temperature are estimated using TMY3 binned weather data. The total expected energy use to provide this cooling with the gas-fired chiller is 62,404.8 therms per year.

The savings calculation assumes that the gas-fired chiller will not run at any time when the temperature is between 45˚F and 30˚F. Given that the gas compressor is not expected to run, the energy savings compared to the baseline is 62,404.8 therms per year.

Humidification Savings

Additional savings are achieved by running the air handling units (AHUs) at minimum outside air when the system is in free cooling mode using the water-side economizer. The humidification savings are also calculated using TMY3 binned weather data. The savings from this measure are calculated by comparing operation of an air-side economizer with the waterside economizer.

The calculation assumes the air-side economizer brings in enough outside air so that the discharge air temperature to the space is 55°F. The waterside economizer is expected to use 25% of the outside air flow that would be used by the air-side economizer. This is assumed to be the minimum outside air required by the space. The space requirements are 70˚F and 30% relative humidity.

For each temperature bin, the amount of drier outdoor air saved is calculated. This is used to calculate the pounds of moisture saved and the amount of steam needed to humidify the air. Therms saved is calculated using a boiler efficiency of 80%. The total gas savings are 7,857 therms. Table 47 summarizes the ex ante savings for this project.

Table 47. Summary of Project Savings

	Demand Savings (kW)	Annual Energy Savings (kWh)	Gas Savings (therms)
Chiller Free Cooling	-	-	62,405
Humidification Savings	-	-	7,857
Total	-	-	**70,262**

Measurement and Verification Plan

For the evaluation of this project, a site visit will be completed. IPMVP Option A, Partially Measured Retrofit Isolation, will be used to validate and verify the measure level savings estimates. The installation and operating conditions of the chiller will be verified. The customer will be asked about the operating hours of the chiller, uses of chilled water, and the typical cooling load required by the building. If available, trended data will be collected for the chiller water and the chiller pump. This data will be used to estimate the amount of cooling provided by the free cooling system.

The customer will be asked about the building HVAC system operation. If available, the building data acquisition system (DAS) will be viewed and screenshots of relevant system diagrams and settings will be collected. The review of the HVAC system will focus on how the building is cooled and ventilated. The humidification savings claimed in this project are expected for a system with a variable outside air economizer. Based on the savings from waterside free cooling from the chiller, we do not expect that the building has an outside air economizer. This will be confirmed at the site visit.

The customer will be asked about the baseline assumptions and the initially unmet cooling load which provided the stimulus for the free cooling project. The customer will be asked about additional projects that have been completed at the facility that have potential to impact natural gas use.

The ex ante calculation approach seems to be reasonable, but the assumptions will be confirmed based on the information obtained during the site visit. The spreadsheet model used for the ex ante calculation will be updated based on information collected during the site visit.

Specific questions for this project include:

- Why would the gas chiller be chosen to provide cooling for this space in the winter versus an electric chiller?
- How is outside air provided to the patient tower?
- What parts of the building use airside economizing in the winter?
- Is there trend data available showing that airside economizing has been affected with the availability of the free cooling system?
- What are the other uses of natural gas other than heating?

Does the air-side economizing mode result in any change in operation of the AHU fans?

Description of Verification

A site visit was completed on December 11th, 2018. The site contact was interviewed and the chiller plant changes were verified. The chiller plant has four 1,700 ton capacity chillers. Two chillers are gas and two are electric. The facility representative confirmed that the facility primarily runs the gas powered chillers. The facility prefers the gas powered chillers to the electric chillers because they have a negotiated natural gas contract that allows them to run the gas powered chiller at a significantly reduced cost compared to the electric chillers.

The building currently has outside air economizing abilities on their air handling units. The project documentation included a calculation for humidification savings which were achieved by providing excess free cooling capacity to the building air handling unit coils. The site representative confirmed that the facility has not made any changes to the air handling units. The humidification savings for this project have been zeroed out.

At the site visit the data acquisition system (DAS) was observed and the facility representative attempted to query the inlet and outlet temperatures from the chiller. This data is either not collected by the DAS or is not stored in the DAS and could not be obtained from the facility to estimate the cooling load.

Calculation Description

The ex ante savings calculations and methodology was reviewed and found to be appropriate. Therefore, the ex ante analysis was used as the basis for the verified calculations. The cooling load on the chiller could not be verified directly from the chiller plant inlet and outlet temperatures. The load used in the ex ante calculations has not been changed.

No changes were made to the ex ante calculation for savings from the chiller free cooling. The humidification savings were zeroed out because the facility did not make the necessary changes to their HVAC system to achieve these savings.

The total ex ante and verified savings are shown in Table 48.

Table 48. Summary of Project Savings

Chiller Free Cooling	Therms
Ex Ante	70,262
Verified	62,405
Realization Rate	88.8%

Project 1800184

Project ID#:	1800184
Ex Ante Measure:	Recuperative TO vs. Regenerative TO
Ex Ante Savings	418,158 therms
End Use:	VOC destruction

Measure Description

The project covers installation of a regenerative thermal oxidizer (RTO) at a production facility. The RTO is being installed for volatile organic carbon (VOC) destruction. The facility is increasing production and introducing a new process (higher quality wood finishing) that has increased the total VOC production at the facility. The increased VOC production has resulted in the facility requiring an RTO. Prior to the project that facility was not required to destroy VOCs, with the addition of the new production processes federal regulatory requirements require the facility to install a thermal oxidizer.

The facility considered two different types of thermal oxidizers, a recuperative TO and a regenerative TO. The facility is using the recuperative TO as the baseline and has installed a regenerative TO which uses less energy than the recuperative TO. The facility has considered a thermal oxidizer with a rated throughput rate of 70,000 SCFM for both the baseline and the installed RTO.

Recuperative Thermal Oxidizer (Baseline)

The recuperative thermal oxidizer gas usage is estimated using the following equation

$$Therms/hr=(70{,}000\ SCFM)*(60\ min/hr)*(25.09 - 0.74)*(1 - 0.79)$$

The source and meaning of the hard coded number values is not documented. The thermal oxidizer has an assumed inlet temperature of 100˚F and a temperature inside of the thermal oxidizer of 1350˚F. The oxidizer is expected to run 4,500 hours per year and to be idle 4,260 hours per year. The IL TRM gives a baseline efficiency for recuperative thermal oxidizers of 70%, the rated efficiency for this unit is 73%. The thermal oxidizer is not expected to consume gas during idle mode. The estimated yearly gas use is 817,501.5 therms.

Regenerative Thermal Oxidizer (Installed)

The gas use for the regenerative (installed) thermal oxidizer was determined using the Institute of Clean Air Companies (ICAC) energy balance method. The facility assumes that the RTO will operate 5,000 hours per year and will be idle the remaining 3,760 hours per year. The energy balance equation is shown below and inputs are shown in Table 1. During idle mode the gas use is estimated at 25% of the operating gas use rate calculated from the ICAC energy balance. The calculated yearly gas use during operating mode is 336,147.8 therms and the yearly usage during idle mode is 63,195,8 therms.

$$QT = QI + Qcc + QRL - QVOC$$

$$QI = FI \times 1.10 \times (TO - TI)$$

$$QCC = FCC \times 1.10 \times (TO - TA)$$

$$QVOC = VOC \times HC \times (\% \text{ Dest} / 100)$$

Table 49. RTO Equation Inputs

Parameter	Definition	Value
QT	Gas Usage of Regenerative Thermal Oxidizer (Therms)	Calculated
Q_I	Heat to raise temp to F1 (BTU/hr)	Calculated
Q_{CC}	Heat to raise temp of Fcc (BTU/hr)	Calculated
Q_{RL}	Radiative heat loss from RTO (BTU/hr)	Calculated
Q_{voc}	Heat release from oxidation of VOC (BTU/hr)	Calculated
F_1	Process air (SCFM)	70,000
F_{cc}	Combustion air (SCFM)	1,618
T_I	RTO inlet air temp (˚F)	100
T_A	Ambient combustion air temp (˚F)	80
T_O	Average RTO outlet temp (˚F)	175.28
VOC	Lbs/hr of VOC to the oxidizer	33
H_C	Weighted average for heat of combustion of VOCs (BTU/lb)	12,500
% Dest	Guaranteed VOC destruction rate	98.00%

Table 50. Summary of Baseline and Post-Retrofit Consumption

	Therms
Baseline	817,502
Post-Retrofit	399,344

Table 51. Ex Ante Savings

	Therms Savings
Recuperative TO vs. Regenerative TO	418,158

Measurement & Verification Plan

During the site visit, the following items should be evaluated:

- Observe the installed thermal oxidizer and confirm the capacity of 70,000 SCFM
- Confirm combustion air CFM
- Confirm RTO inlet air temp, ambient temp, outlet temp, and typical temperature inside of the RTO
- Confirm lbs/hr of VOC to the oxidizer

Questions to ask at the site visit:

- When was the project completed?
- Has the facility installed the additional production processes as expected?
- Have there been any significant increases or decreases in production since installation of the RTO?
- Have there been any regulatory changes to VOC destruction requirements since installation of the RTO?

Description of Verification

A site visit was completed on February 18, 2019. The site contact was interviewed about the operation of the thermal oxidizer and the installed equipment was verified. The facility contact confirmed the operating hours of the thermal oxidizer to be 24 hours per day five days per week. The operating hours have been updated in the ICAC calculation and the gas use for the installed and baseline thermal oxidizers has been recalculated. The assumptions of inlet, outlet, and ambient temperatures were confirmed to match the ex ante calculation. The facility representative confirmed that the production rates at the facility have remained consistent since installation of the thermal oxidizer in October of 2018.

Calculation Description

The site contact could not provide documentation or explanation for the ex ante baseline calculation. The baseline calculation has been revised to use the method described in the Illinois Technical Reference Manual (TRM) version 7.0. The method described in the TRM is identical to the ICAC method. The average outlet temperature from the recuperative thermal oxidizer is calculated based on an assumed efficiency of 70%, the default value provided in the TRM. The estimate of energy consumption for the baseline increases significantly when using the TRM method which causes the estimated savings to increase for this project. The revised savings estimate and realization rate are shown in Table 51.

Table 52. Verified Savings

Recuperative TO vs. Regenerative TO	Therms
Ex Ante	418,158
Verified	993,317
Realization Rate	236%

Project 1800156

Project ID#:	1800156
Measures:	VSDs on Pumps
Savings:	106.767 kW, 935,276 kWh
Facility Type:	Industrial
End Use:	Petrochemical Production

Measure Description

The project includes retrofitting existing oil rigs by installing variable speed drives (VSDs) and 40 HP motors on the oil rig pumps. The project covers retrofitting pumps on twenty oil rigs. The twenty rigs have a total of fifty 40-HP pumps. The pumps operate 8,760 hours/year.

Three rigs that are not included in this project already have VSD pumps installed, those rigs were metered before and after VSD drives and motors were installed. The realized savings on the three metered pumps were used to estimate the saving from the installation of the fifty additional VSD pumps.

The installed VSDs include a sensor free pump off controller that allows the rod pump to be slowed automatically instead of shutting down the well. The drive has some amount of learning or memory feature which allows it to choose an optimal speed for the pump based on an individual well's inflow rate to maximize production from the well.

Summary of the Ex Ante Calculations

Three rig pumps, which are not included in this project, were metered for 30 minutes before and after installation of VSD pump motors. The average of the energy use of the three pumps with and without VSD motors was used to estimate savings.

The projected annual energy use for the metered pumps was determined from the average metered energy use and by assuming the pumps operate 8,760 hours per year. The average energy use of the pumps was multiplied by 2 to estimate hourly use; 8760 hours per year. The value was then divided by 1,000 to convert from Wh to kWh. Table 53 provides a summary of the pre- and post- retrofit metering data.

Table 53. 30-Minute VSD Pump Energy Consumption Pre- and Post- Retrofit

Rig Pump ID	Original Nameplate HP	New Nameplate HP	Metered Wh without VSD	Metered Wh with VSD
Pump1	unknown	40	3,193	2,373
Pump 2	unknown	40	6,973	5,083
Pump 3	unknown	40	5,599	5,106
Average Energy Use for 30-minute period, Wh			**5,255**	**4,187**
Projected Annual Energy Use per Pump, kWh			**92,068**	**73,362**

The expected savings per pump are 18,706 kWh. These savings were multiplied by 50 to get the expected savings for all 50 pumps, or 935,276 kWh. The energy usage is divided by 8,760 hours to get demand savings of 106.767 kW.

The documentation shows that the new VSD pumps are all rated at 40 HP. The original pumps that were replaced by the VSDs ranged in horse power rating from 15 to 40 HP. The ratings of the metered pumps are not provided.

The ex ante savings for this project are presented below in Table 54.

Table 54. Ex Ante Savings

	Demand Savings (kW)	Annual Energy Savings (kWh)	Gas Savings (therms)
VSDs on Pumps	106.767	935,276	0

Measurement and Verification Plan

For the evaluation of this project, a site visit will be completed. The VSD pumps will be verified on a sample of the rigs and the site representative will be interviewed. Motor nameplate data will be recorded. The customer will be asked about the operating hours of the rigs and the typical production at each oil well. The well test records will be reviewed for all wells included in this project. The well test records will show the average volumetric production for each well, these tests are performed every six weeks. The well production will be compared with the pump run time and load factor.

The customer will be asked about the baseline equipment. The HP rating of the baseline pumps will be confirmed. It will be confirmed that the three metered pumps are reasonably representative of the complete pumping operation and that the thirty minute data logging period was representative of typical pump operation. The customer will be asked about the metered pumps horse power rating, stroke length, and RPM. The customer will also be asked about how the pumps were controlled in the baseline condition.

To verify control and operation of the pumps, data loggers will be installed to monitor the energy use of a sample of the pumps. The loggers will record demand, power factor, and energy at 10-minute intervals and will be left in place for a minimum of two weeks. Instantaneous measurements of voltage, amps, power, and power factor will be taken at the time of deployment or removal to calibrate logged data.

The data collected will be analyzed to determine the operating conditions of the pumps under post-retrofit conditions. The data will also be used to confirm annual hours of operation. Logged data will be used to calculate average post-case pumping power. The results will be extrapolated to annual operation to establish total post-case energy use. The annual hours of operation will be used to estimate baseline energy use as well.

Specific questions for this project include:

- How was the on/off operation of the pumps controlled before and after the VSD retrofit?
- Are there any seasonal demand or weather conditions that impact operation of the pumps?
- Are the pumps equipped with run timers?
- What was the HP rating of the motors that were replaced?

Description of Verification

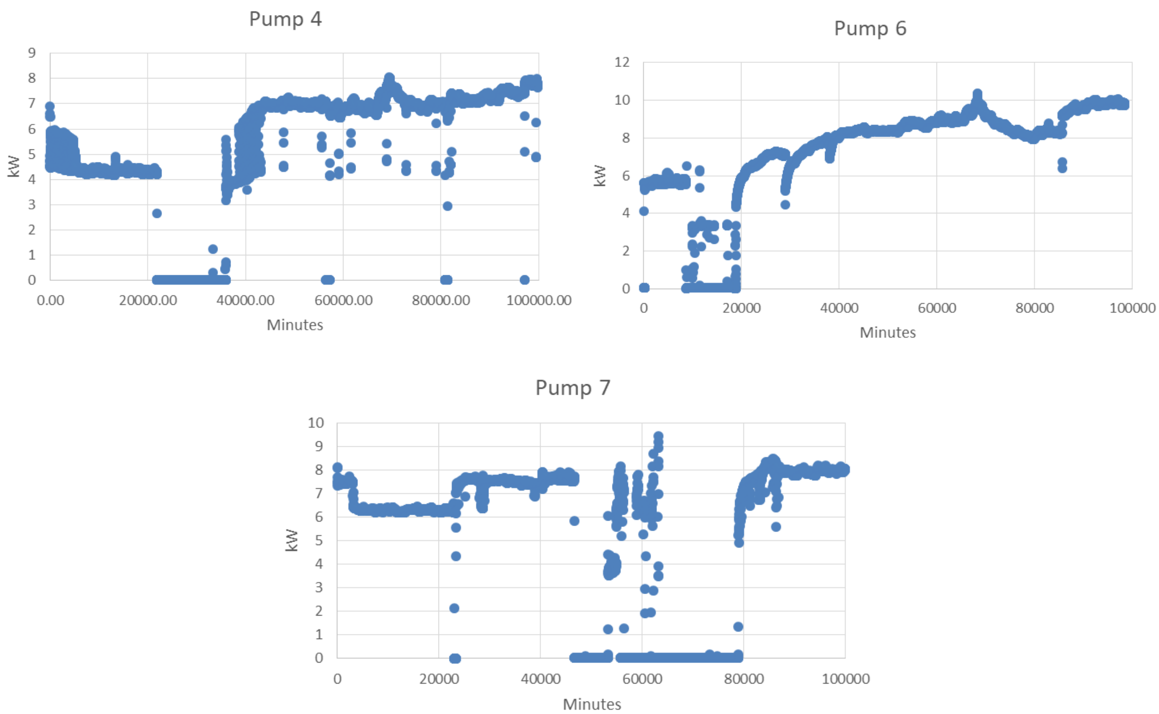
A site visit was completed on December 11, 2018. The site contact was interviewed, and a sample of the installed equipment was verified. The site contact was asked about typical production from each of the ex ante metered wells based on recent well test records. Three additional pumps were metered for a period of six weeks. Table 55 shows the full set of metered data with well names and recent production rates.

Table 55. Pump Energy Consumption and Production Rates

Rig Pump ID	Original Nameplate HP	New Nameplate HP	Well Production Rate (bbl/day)	Average kW without VSD	Average kW with VSD
Ex Ante Metered Data					
Pump1	unknown	40	4.5	3.19	2.37
Pump 2	unknown	40	4.5	6.97	5.10
Pump 3	unknown	40	5.7	5.60	5.10
Verified Metered Data					
Pump 4	40	40	6.8	-	4.53
Pump 5	25	25	0.0	-	0.0
Pump 6	40	40	8.9	-	6.21
Pump 7	10.8	25	10.8	-	7.18

The metered data shows that the pumps typically run at constant full speed. Metered data for three of the four metered pumps is shown in the graphs in Figure 9. The metered data shows that the pumps ran at near constant speed for the entire metering period. Metered data is not shown for Pump 5. This pump has a production rate of 0 barrels per day and did not turn on at any time during the metering period. Pump 7 has a period where it is not running, at the site visit the representative explained that this off period occurred when the pump was shut down for repairs.

Figure 9. Metered Pump Data



Calculation Description

The energy savings from the VFD drives were determined by considering the average decrease in motor speed and the decreased operating hours from the metered data. The demand (kW) use that was observed in the metering period was assumed to be the demand at maximum motor speed. Spot measurements of speed and demand at the site visit confirmed that this assumption is reasonable. The energy savings for each metered pump were determined from the difference between the maximum and average metered demand and the observed operating hours extrapolated from the metering period to a full year of operation. Table 56 shows the projected annual savings from each of the metered pumps. The average demand and energy savings from the metered pumps were multiplied by the total number of pumps in this project (50) to determine the savings for the whole project.

Table 56. Estimated Energy Savings from Metered Data

Pump Name	Verified Metered Data				
	Average kW	Max kW	Yearly Hours	Savings kW	Savings kWh
Pump 4	4.53	6.89	6,451	2.36	15,196
Pump 5	0.0	-	-	-	-
Pump 6	6.21	7.44	6,849	1.22	8,375
Pump 7	7.18	9.45	6,841	2.27	15,547
			Average	**1.95**	**13,039**

Table 57 shows the ex ante and verified savings for this project.

Table 57. Verified Savings

VSDs on Pumps	kW	kWh
Ex Ante	106.767	935,276
Verified	0	0
Realization Rate	0%	0%

Project 1801596

Project ID#:	1801596
Measures:	VSD's on Transfer Pumps
Savings:	1,340,000 kWh, 268.0 kW
Facility Type:	Mineral Extraction/Mining
End Use:	Process
Project ID#:	1801596

Measure Description

The project was completed at a silica mining facility. Variable speed drives (VSDs) were installed to control the flow rates of two centrifugal 600 HP pumps. The pumps are used to transfer material from a fresh water pond to an unused pit.

Summary of the Ex Ante Calculations

The source of the final savings value is not clear. The savings presented in the application are hard-coded and unsourced. A simple calculation was included as a reality check to the claimed savings of 1,340,000 kWh and 268 kW submitted on the application. The calculation assumed (2) pumps running 5,000 hours per year at a 65% load factor and 42% savings due to the VSDs resulted in 1,270,216 kWh and 254 kW. This was considered close enough to accept the claimed savings.

The documentation also includes savings calculations performed on a vendor's proprietary program. A version assuming a duty cycle that expects one pump to operate 10% of the time at 50% speed, 10% at 100% speed, and 20% of the time at 60%, 70%, 80%, and 90% speed. Total operating time was assumed to be 5,000 hours per year. The total savings using this program were 871,016 kWh.

Table 58summarizes the ex ante savings for this project.

Table 58. Summary of Ex Ante Savings

	Demand Savings (kW)	Annual Energy Savings (kWh)
Transfer Pump VSDs	268	1,340,000

Measurement and Verification Plan

For the evaluation of this project, a site visit will be completed. IPMVP Option A, Partially Measured Retrofit Isolation, will be used to validate and verify the measure level savings estimates. The installation and operating conditions of the pumps will be verified. The customer will be asked about the operating hours, speed control, and operating conditions. If available, trended data will be collected for the pumps.

Specific questions for this project include:

- What controls the pump speed?
- Are these existing pumps in a new application?
- What is the total static head pressure on the pumps?
- Is there trend data available?
- Do both pumps run together, or is it a run/standby configuration?

Description of Verification

A site visit was completed on February 19th, 2019. The site contact was interviewed, the pump inspected, and project discussed.

The pumps associated with this project were purchased and delivered by the company that was hired to perform the dredging operation of the holding pond. Dredged material will be a suspended mixture of sand and water. The ratio of sand to water will vary with the dredging operating.

The pumps are connected in series, with one pump near the dredging operation pumping to the inlet of the second pump on the hill overlooking the pond. It is estimated that the pumps are about 1,000 feet apart with a 200-foot difference in elevation. The second pump discharges into the second pond through 16" flexible plastic piping. The pond is about two miles from the pump and is at a lower elevation than the pump.

The pumps are used units with 600 HP motors and Warman centrifugal pumps. No information about the pumps was available, so the design head and flow could not be determined. The motor and pump were mounted on a large skid, along with a control panel with VSD. The customer was concerned that the VSD may be in poor condition, and therefore not reliable, so a new VSD was installed in a small dedicated shed for each unit.

The pump speeds will be controlled by the dredging equipment operator to match the flow rate of the dredging operation. The equipment is scheduled to operate continuously, 24/7, and the project is expected to take at least five years. The dredging will not take place during the winter months. At the time of the verification visit, the pumps had not yet been started up or commissioned due to cold weather.

Verification of Savings

Because these pumps were not yet operational at the time of our site visit, it is not possible to estimate actual operating conditions for the pumps, including the actual operating speed range of the VSDs. The pump specifications were also not available at the time of this evaluation, so the operating points of the pumps could not be accurately determined. Finally, the evaluation team does not believe that the baseline conditions assumed for this project's calculations have been clearly determined or elaborated.

The ex ante savings calculations and methodology were reviewed and found to be generally unsatisfactory. The ex ante savings approach assumed that the conditions seen by both pumps are the same and do not account for the actual arrangement of the pumps. Under the as-installed setup, the first pump will be subjected to a high static head pressure as it pumps the slurry to a higher elevation to the inlet of the second pump. Therefore, the operating range of the first pump will likely be limited to a relatively narrow band of speed settings. The second pump may have a greater operating range as the discharge of that pump will have a negative static head. However, that pump will be subjected to a high dynamic head due to the distance, about two miles, of tubing needed to reach the second pit. Based on conversations with the customer, the VSD speeds will vary much less than assumed in the ex ante calculations. Also, because of the atypical geometry of this system, the affinity factors used in calculating savings as a function of speed will be closer to 2.0 than the 3.0 factor commonly used in these calculations.

The ex ante calculations appear to use a 100% load factor for the pump motors. This is higher than generally accepted for motors in centrifugal pump applications. In the absence of pump and motor specifications, the verified analysis estimates a 70% load factor.

Given the above uncertainties of the project, the evaluation team's concerns about the ex ante methodology used to estimate savings from the project, and a lack of a clearly defined baseline that can be used to assess this project, the evaluation team does not believe a savings claim for this project is supported at this time.

The total ex ante and verified savings are shown in Table 59.

Table 59. Summary of Project Savings

	kWh	kW
Ex Ante	1,340,000	268
Verified	0	0
Realization Rate	0%	0%

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