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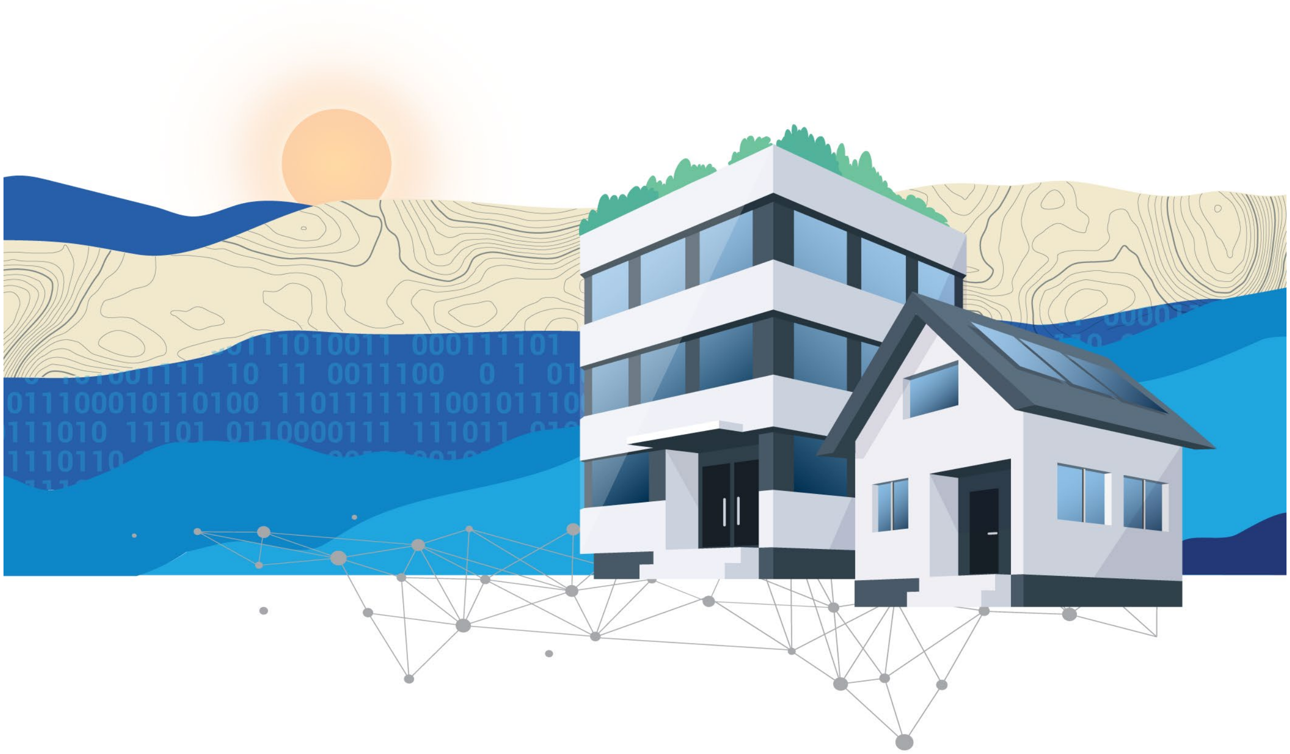

Ameren Illinois Company 2022 Business Program Impact Evaluation Report

Appendix D - Custom Initiative Project Reports

Final
April 28, 2023

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Appendix D. Custom Initiative Project Reports

In this section, we present detailed project-level desk review, remote measurement and verification (M&V), and on-site M&V reports for 11 Custom Initiative projects evaluated as part of the 2022 Business Program impact evaluation.

Project 2200035

Project ID#:	2200035
Measure:	Lighting Controls and LED Retrofit
Savings:	1,137,826 kWh; 110.8 kW
Facility Type:	Manufacturing/Industrial
End Use:	Lighting
Sampled For:	Electric
Wave:	1

Measure Description

This is a lighting retrofit and occupancy sensor installation project at an industrial pasta manufacturing plant. The customer is retrofitting most of the plant's existing metal halide, fluorescent, and high-pressure sodium fixtures with LED fixtures for interior and exterior spaces and installing occupancy sensors for a portion of the interior LED fixtures.

The proposed lighting system will result in electrical savings due to wattage reductions from the LED fixtures and lower operating hours from the occupancy sensors.

Key Findings

The evaluation team found the ex ante energy savings of 1,137,826 reasonable. However, the kW savings was adjusted based on an updated coincidence factor. In the ex ante calculations, the implementation team applied a coincidence factor of 0.81, which is the IL-TRM V9.0 specified standard coincidence factor for manufacturing plants. The verified analysis estimated the actual coincidence factor to be 0.95, based on the hours of operation of the interior lights. This changed the kW saved from 110.8 to 134.3 annually.

The resulting project savings are shown in Table 1.

Table 1. Summary of Project 2200035 Savings

	kWh	kW
Ex Ante	1,137,826	110.8
Verified	1,137,826	134.3
Realization Rate	100%	121%

Summary of the Ex Ante Calculations

The plant operates 24/7 except on Memorial Day, Labor Day, Thanksgiving, and Christmas holidays, resulting in an estimated 8,664 hr/yr runtime for the interior lights. Based on IL-TRM V9.0, the exterior lights have a runtime of 4,303 hr/yr.

The baseline for this project is based on the existing fixtures. There were (510) metal halide fixtures, (4) 4' T8 fluorescent fixtures, and (122) high-pressure sodium fixtures. The total wattage of these lights is 168 kW, with an annual energy consumption of 1,506,211 kWh. The existing lights do not have any control features.

The proposed case for this project is based on LED fixtures. There are a total of (495) proposed LED fixtures. The total wattage of these lights is 61 kW, with an annual energy consumption of 514,251 kWh.

A portion of the interior LED fixtures will have occupancy sensors installed. The energy savings factor (ESF) for the occupancy sensors was 31% based on the IL-TRM V9.0 value. Based on this, the adjusted wattage and energy consumption for all the LEDs are 57.1 kW and 367,904 kWh, respectively.

The energy savings is the difference between the energy consumption of the baseline and the proposed case, which is 1,137,826 kWh for this project. Because exterior lights do not operate during peak hours, there are only demand savings for interior lighting. To calculate the demand savings, the energy savings of the interior lights were divided by the operating hours of interior lights of 8,664 hr/yr.

There are multiple calculation tabs. In our review, the one we referenced was the "LDOS calcs" tab, which is linked to the "Measure 1" and "Measure Summary" tabs in the project workbook.

Savings were calculated as shown in Equation 1.

Equation 1. kWh Energy Savings Formula

$$Energy\ Savings = current\ kWh - proposed\ kWh$$

Early Review Notes

We note that this project was subject to early review prior to authorization. Based on the early review comments listed below, the implementation team appropriately addressed the comments about the ESF value, using 31% as recommended by IL-TRM V9.0. The calculation was also modified to reflect the difference in operating hours of the interior and exterior fixtures. Based on the plant being shut down on Labor Day, Memorial Day, Thanksgiving, and Christmas, the actual hours of operation for the interior fixtures were changed to reflect a better savings estimation.

Our early review comments included the following:

- The ESF of 40% is inconsistent with the ESF values provided in IL-TRM V9.0 Measure 4.5.10, which lists the ESF for interior occupancy sensors to be 24%-31% (or 34%-41% with high-end trim). We recommend that the ESF value in the calculation spreadsheet be modified to match that of the IL-TRM.
- The demand savings do not align with the algorithms provided in the IL-TRM and may be inaccurate because of the reasons below.
  - Not all the fixtures operate 8,664 hr/yr. The exterior fixtures only operate 4,303 hr/yr. We recommend that the demand savings be calculated separately for the interior and exterior fixtures to reflect this difference in operating hours accurately.
  - The ESF value of 40% was used to calculate energy savings. The demand savings were calculated using the energy savings estimate. Therefore, the 40% ESF is included in the demand savings estimate. According to the IL-TRM, the ESF value should be used to adjust hours of operation; therefore, it should only impact energy savings, not demand savings. We recommend that the

demand savings for the lighting and controls measures be calculated separately using their corresponding summer peak coincidence factors from the IL-TRM.

- The evaluation team noticed that the Thanksgiving holiday was only one day when it might be 1.5-2 days based on customer operations. Therefore, the energy savings may be a slight overestimation. We recommend confirming with the customer the number of days they close down for Thanksgiving and other holidays and modifying the calculations accordingly.

Summary of the Verified Calculations

The evaluation team reviewed the existing fixtures and proposed fixtures from the Leidos lighting audit and compared the energy usage data to the utility data. We initially evaluated the savings using IPMVP Option C, by creating weather-normalized regression models of the energy use by the facility pre- and post-implementation. These models were then applied to TMY3 weather data to generate verified energy savings for the project. However, the model created did not meet our validation standards. The evaluation team believes that production data is necessary to create a valid regression model. However, the regression did indicate the ex ante savings were in the ballpark.

The calculations and inputs from IL-TRM V9.0 and customer-provided data were verified. The evaluation team found the kWh savings from the ex ante calculation to be reasonable, but made minor adjustments to the kW savings. We applied a baseline coincidence factor (CF baseline) of 0.95, based on the operating hours of the interior lights to the power savings measure, as opposed to the 0.81 value from the IL-TRM V9.0.

The verified energy and power savings are 1,137,826 kWh and 134.3 kW, respectively. The evaluation team agrees that there are no demand savings for the exterior lights.

Project 2100307

Project ID#:	2100307
Measure:	Energy management system
Savings:	890,217 kWh; 101.6 kW
Facility Type:	Hospital
End Use:	HVAC (fan, cooling)
Sampled For:	Electric
Wave:	1

Measure Description

This project is an HVAC controls upgrade for a hospital campus with floor area of 592,000 square feet. The campus comprises three interconnected buildings and two adjacent medical office buildings. A total of 29 air handling units are included in the project, though at the time of evaluation only 15 had been upgraded. The project includes upgrades of antiquated pneumatic controls and airflow monitoring stations and adjustments to controls sequences. The list of measures provided by the implementation team is as follows:

- Scheduling units to be off during unoccupied periods of operation
- Implementation of set-back during unoccupied periods of operation
- Chilled water temperature reset
- Replacing inlet guide vanes (IGV) with variable frequency drives (VFD) to control fan speed

Key Findings

The evaluation team used a regression model to verify the project savings. The regression analysis results in higher verified savings than was reported in the ex ante calculations. Both demand and energy savings exceed what is estimated by the ex ante calculations. This is partially attributed to incremental improvements to dampers and valves after replacing pneumatic actuators with electronic, recalibration or replacement of airflow monitoring stations, and/or recalibration of outside air dampers. The complexity of calculating savings for these incented improvements precluded their addition in the formal calculations but are still included in the project impacts.

The resulting project savings are shown in Table 2.

Table 2. Summary of Project 2100307 Savings

	kWh	kW
Ex Ante	890,217	101.6
Verified	1,373,202	150.6
Realization Rate	154%	148%

Summary of the Ex Ante Calculations

The implementation team established savings by developing hourly energy models for each air handler: one baseline model and one efficient model. These models use TMY3 weather data, which is then used to calculate mixed air conditions at each hour of the year. The implementer modeled air handler supply airflow using a generalized system airflow demand curve. Cooling and heating loads were determined using the resulting supply airflow and supply air temperatures at each hourly temperature.

Efficient conditions for fan, cooling, and heating usage due to scheduling and unoccupied setback/setup were calculated using occupancy factors that reduce fan usage loads by a fixed amount during unoccupied periods (20% of baseline in cooling mode and 80% of baseline in heating). Chilled water temperature reset savings were calculated by increasing the efficiency value of the cooling system from 1.1 to 1.05 kW/ton at all cooling hours. VFD savings were calculated by replacing the fan power equation for IGV with the one for VFDs.

Formulas used in ex ante calculations to derive baseline and efficient case fan cooling energy use are shown in Equation 2 through Equation 6.

Equation 2. Baseline Fan Energy Use Formula (Inlet Guide Vane)

$$\text{Baseline fan, IGV (kWh)} = 0.0711 + 1.1148 \times \text{fan speed} - 1.8106 \times \text{fan speed}^2 + 1.6246 \times \text{fan speed}^3$$

Equation 3. Baseline Fan Energy Use Formula (VFD)

$$\text{Baseline fan, VFD (kWh)} = 0.21732 + 0.93277 \times \text{fan speed} + 1.74398 \times \text{fan speed}^2$$

Equation 4. Efficient Fan Energy Use Formula (VFD)

$$\text{Efficient fan (kWh)} = (0.21732 + 0.93277 \times \text{fan speed} + 1.74398 \times \text{fan speed}^2) \times \text{occupancy factor}$$

Equation 5. Baseline Cooling Use Formula

$$\text{Baseline cooling (kWh)} = \frac{\text{load}_{\text{cool,pre}}}{12{,}000\,\frac{\text{Btuh}}{\text{ton}}} \times 1.1\,\frac{\text{kW}}{\text{ton}}$$

Equation 6. Efficient Cooling Use Formula

$$\text{Efficient cooling (kWh)} = \frac{\text{load}_{\text{cool,post}}}{12{,}000\,\frac{\text{Btuh}}{\text{ton}}} \times 1.05\,\frac{\text{kW}}{\text{ton}} \times \text{occupancy factor}$$

The approach employed by the implementation team notably did not account for energy and demand savings associated with: (1) increased precision of economizer controls due to replacement of pneumatic actuation with electronic, (2) increased precision of outside air flow rates and building pressurization due to the addition of electronic dispersion type airflow measuring stations or replacement of existing pitot type airflow station with electronic dispersion type, and (3) increased performance due to replacement of pneumatic CHW valves with pressure independent electronic type. These improvements are captured in the evaluation team’s verified savings.

Early Review Notes

We note that this project was subject to an early review prior to authorization. Our early review comments included the following:

- For all air handlers, fan energy savings are due entirely to the occupancy factor. The fan speed, and underlying air flow rates are identical in the baseline and efficient calculations. This means that fan energy consumption is not actually being modeled in the efficient case but reduced by an assumed percentage during unoccupied periods. The evaluation team's preferred approach would be to model the new heating and cooling loads to determine air flow requirements and use these to calculate fan energy savings. The occupancy factor is used to set cooling loads to zero during unoccupied hours for most air handlers. The evaluation team's preferred approach would be to estimate the reduced cooling loads associated with lower occupancy and reduced ventilation and to use these to calculate unoccupied cooling loads, rather than setting them to zero.

  - Following early review, occupancy factors were changed from 0% to 20% in cooling and 50% to 80% in heating.

- The cooling load is reduced by 0.5 BTUH for air handlers with upgraded airflow measurement equipment, and it is reduced by 0.25 BTUH for air handlers without upgraded airflow measurement. These values are reasonable, but the preferred approach would be to model changes in air temperature and flow, rather than adjusting the cooling load directly.
  - This was unchanged following the early review.
- The implementation team did not explain how the cooling efficiency improvement due to chilled water reset was calculated. A chilled water reset strategy typically varies with outside air temperature or load. A higher water temperature may be adequate when loads are low, but not during times of peak cooling loads. The current methodology does not account for this variability in the efficiency improvement. It also does not use chiller efficiency curves, which provide chiller efficiency value at varying loads. Note that this variation in chiller efficiency occurs even with a fixed water temperature. The evaluation team's preferred approach would be to model chiller efficiency at each hour based on load and water temperature set point, rather than assuming a fixed efficiency for all hours.
  - This was unchanged following the early review.
- The coefficients used in the formulas above appear to be a modified version of the affinity laws. It is unknown how these coefficients were derived, but they appear to reasonable over the loading conditions used.
  - This was unchanged following the early review.

Summary of the Verified Calculations

To verify usage savings, the evaluation team generated a daily regression model using billed energy usage during the baseline period (7/20/2020 to 2/28/2021) and statistically significant modeling criteria. Three outlier dates were removed from the baseline period due to meter read issues. Interval data was not available before 7/20/2020, but the shorter 221-day baseline period was deemed acceptable because the model acceptability criteria were favorable overall. This regression model was applied to the treatment period (1/1/2022 to 9/17/2022) to generate expected daily usage had the project not been implemented. Using the regression model, we calculated expected daily usage for the treatment period and compared that with actual daily usage from the bill history to determine verified savings. Figure 1 depicts the expected usage, actual usage, and cumulative savings over the treatment period. The facility saved 987,482 kWh over the 260-day treatment period.

We also generated another regression model using the treatment period energy use to directly compare baseline and efficient energy use with typical meteorological year (TMY) conditions. Comparing both regression models using TMY data, we calculated an expected annual savings of 1,373,202 kWh over a typical year (see Figure 2).

The regression models use variables listed in Table 3 and Table 4 to predict daily energy usage. Regression model statistics showing acceptability criteria are given in Table 5.

For demand savings, the evaluation team calculated the average daily kW by dividing the expected and actual daily usage by 24. Monthly demand savings is calculated using the difference between the maximum daily kW in the baseline and the maximum daily kW in the treatment period, for the given month. Finally, verified demand savings is calculated as the average monthly demand savings for June, July, and August.

The ex ante calcs reported demand savings as simply the total energy savings divided by 8760, so we also reviewed the proposed measures for peak demand impacts as a sanity check. Some measures, such as unoccupied scheduling and temperature setbacks, would have no impact on peak demand. Certain aspects of the improvements may have a slight impact on peak operation, such as pneumatic valve replacement and outside air recalibration. Other proposed measures would result in peak demand savings depending on specific implementation. For example, changing the chilled water supply temperature from a 38°F setpoint to a reset range of 40-48°F would result in demand savings at the chiller. Given the uncertainty of the implementation of these more complex measures combined with interactive effects, we feel that calculating demand savings using the average daily demand approach is reasonable.

Figure 1. Expected Usage, Actual Usage, and Cumulative Savings

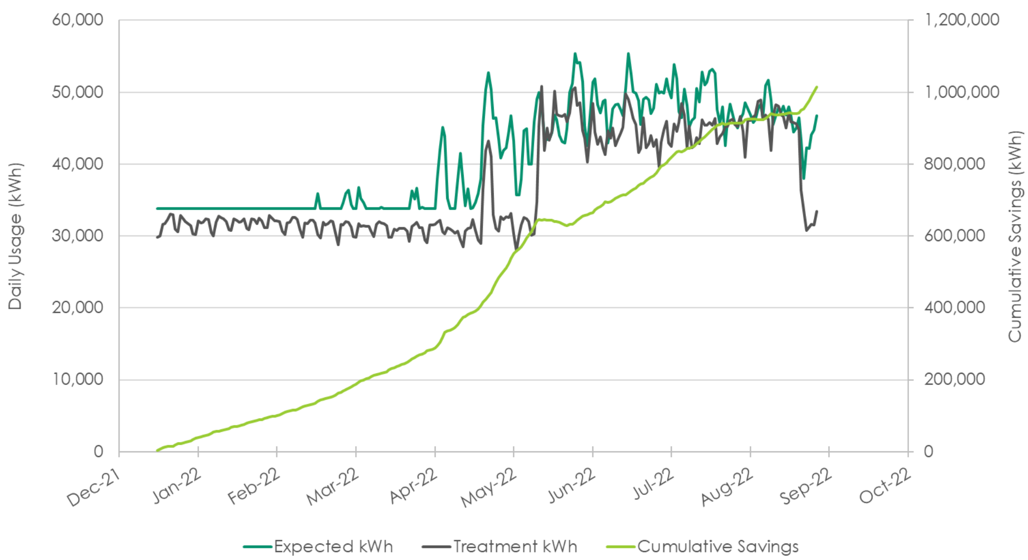


Figure 2. Baseline Usage, Treatment Usage, and Cumulative Savings for TMY Conditions

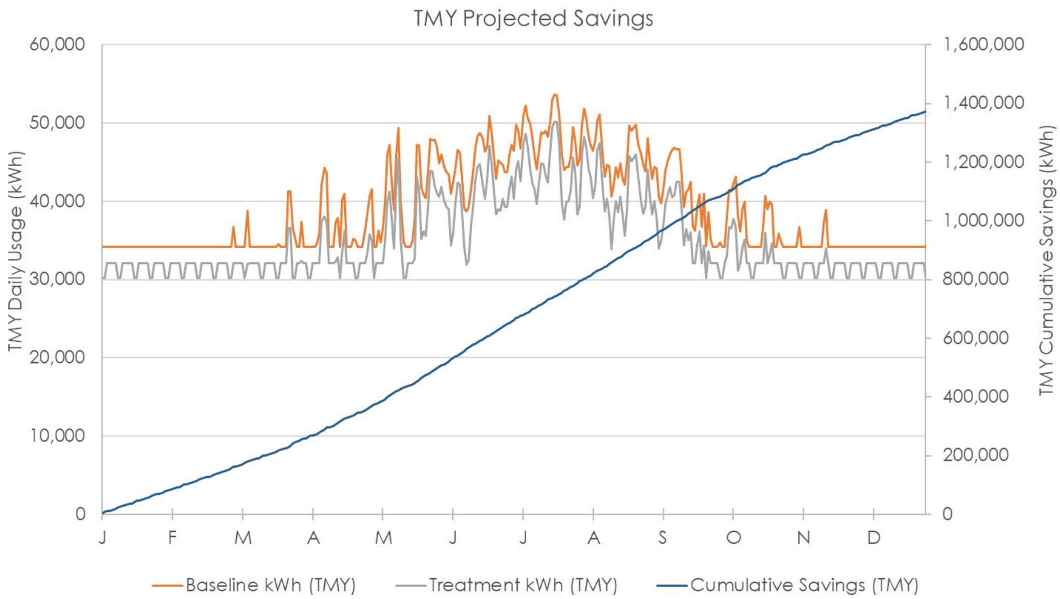


Table 3. Regression Model Variables – Baseline Period

Variable	Definition	Type	Coefficient	t-value
	Constant		34,167.2	120.7
A	Wet_Bulb_Temp_Deg_Above_45_F	Categorical	598.4	26.1

Table 4. Regression Model Variables – Treatment Period

Variable	Definition	Type	Coefficient	t-value
	Constant		32,054.2	91.6
A	Wet_Bulb_Temp_Deg_Above_50_F	Categorical	659.2	25.2
B	Saturday	Numerical	-1,898.7	-2.8
C	Sunday	Numerical	-1,884.7	-2.8

Table 5. Regression Model Acceptability Criteria

Criteria	Target	Baseline	Treatment
Adjusted R Squared	>0.75	0.756	0.720
Coefficient of Variation	<0.2	0.088	0.100
Autocorrelation Coefficient	<0.5	0.560	0.793
Net Determination Bias	<0.005	7.85E-17	3.97E-16
t-values Meet Requirements	>2 or <-2	Pass	Pass

Project 2200026

Project ID#:	2200026
Measure:	New Air Compressors
Savings:	916,440 kWh; 109.1 kW
Facility Type:	Manufacturing
End Use:	Compressed Air
Sampled For:	Electric
Wave:	1

Measure Description

The customer has a compressed air system that serves production equipment in an industrial facility. The existing system consisted of three Gardner Denver reciprocating compressors, one Atlas Copco variable speed drive (VSD) rotary screw compressor, and one Joy Turbo Air compressor. Under normal conditions, the Joy Turbo Air compressor provided a baseload of compressed air, and the Atlas Copco compressor operated as a trim compressor. The three Gardner Denver compressors operated intermittently as needed. The customer replaced the existing compressed air system with a new 350 horsepower (hp) fixed-speed rotary screw air compressor that will provide a baseload and a 400-hp VSD compressor to provide the trim load. A 250-hp fixed-speed compressor was installed to provide additional capacity if needed, or base loading at times of reduced air demand.

Key Findings

The evaluation team conducted an early review of this project and the issues that were raised were addressed by the implementation team in a satisfactory manner, resulting in a realization rate of 100% for the project.

The resulting project savings are shown in Table 6.

Table 6. Summary of Project 2200026 Savings

	kWh	kW
Ex Ante	916,440	109.1
Verified	916,487	109.1
Realization Rate	100%	100%

Summary of the Ex Ante Calculations

The vendor metered compressor power and discharge pressure with data collected at 1-minute increments for 13 days in March 2021. They determined compressed air flow using compressor performance curves. Facility operations during the metering period were atypical due to COVID-19 impacts, so they adjusted compressed air demand data to create a load profile reflective of "typical" operations. They used production data from the same time periods during previous years to establish typical air demand.

The vendor used the adjusted compressed air demand profiles and compressor performance curves to establish the energy use of the existing compressors. They used the same compressed air demand data with the sequencing and specifications of the proposed compressor system to calculate the energy use of the proposed system. The ex ante savings are the difference between the normalized energy use of the adjusted baseline system and the proposed system.

Early Review Notes

The evaluation team completed an early review of this project on August 31, 2021 and, while the ex ante savings were found to follow a reasonable approach, the team identified several issues. The team identified the following comments and recommendations as likely to have the greatest evaluation risk:

- The evaluation team noted that the operating data for the existing Joy Turbo Air compressor was inconsistent with typical centrifugal compressor full-load efficiency. The full-load efficiency of the Joy unit is 24.6 kW per 100 CFM, which is substantially higher than most centrifugal compressors. Typically, centrifugal compressors have an efficiency of between 16 and 18 kW per 100 CFM. The difference in efficiency between the baseline Joy compressor and the new Kobelco compressors is a primary source of savings for this project. Therefore, the baseline compressor efficiencies must be accurate.
  - The vendor responded that this Joy Turbo Air compressor is older, and a performance curve for the specific model was unavailable. Furthermore, the meter measuring this facility's total flow was not calibrated at the time of installation, meaning that while the actual flow at any given time was imprecise, the change in flow over time was precise. Therefore, to estimate the Joy Turbo Air compressor's full load performance, the vendor used an original equipment manufacturer (OEM) specification sheet for a comparable model unit at a different facility. As a sanity check the vendor compared the calculated flow using the OEM performance curve with the facility's uncalibrated flow meter of the Joy Turbo Air compressor. The calculated flow had a correlation of 0.978 with the metered flow, but since the meter was not calibrated, the vendor determined that the OEM specification sheet was a more reliable source for estimating the performance of the Joy Turbo Air compressor than the flow meter. The evaluation team agrees with this decision.
- The evaluation team noticed inconsistencies in the existing compressors' sequencing during the metering period and the adjusted baseline. During the metering period, data show the Joy Turbo Air compressor being shut down during all periods of low compressed air demand, leaving the Atlas Copco as the only compressor operating. In the adjusted baseline, the Joy Turbo Air compressor operates continuously with the Atlas Copco turning off during periods of low demand. It appears that the on/off sequencing of the compressors are reversed between the metered data and the adjusted baseline. This possible error may cause the savings for this project to be overestimated. We recommended confirming the correct sequencing and recalculating savings.
  - The vendor noted that the baseline was adjusted to account for atypical operation, due to COVID-19, observed during the pre-metering period. The vendor's simulation has the centrifugal compressor operating nearly continuously as the base-loaded compressor and is not expected to shut off under normal conditions.

Summary of the Verified Calculations

The evaluation team reviewed the ex ante calculations and made no changes to the approach or result. We interviewed the customer representatives and confirmed that the compressors were installed as presented in the application and there were no significant changes in operation that affect the compressor savings. We did note that the customer reported lower compressor operating pressures due to re-piping, but this was not part of the project application, and no savings were attributed to this factor. The customer also reported that the existing compressors were at, or very near, the end of their useful lives.

Project 2200030

Project ID#:	2200030
Measure:	Boiler blowdown controls, chilled water economizing and controls, kitchen exhaust controls
Savings:	1,124,395 kWh; 129.1 kW; 22,509 therms
Facility Type:	Healthcare
End Use:	HVAC
Sampled For:	Electric and Gas
Wave:	2

Measure Description

This project consists of four measures completed at a hospital: (1) Installation of automatic blowdown valves and controllers on boilers. Currently, boiler blowdown is performed manually. The automated controls will optimize the blowdown system and result in gas savings; (2) Addition of a heat exchanger to provide water-side economizing for the chilled water system. Currently, chilled water is supplied by mechanical cooling to meet year-round cooling load. The economizer will provide free cooling and allow for the chillers to be shut off in the winter; (3) Retrofit of the existing valves with pressure-independent control valves in the chilled water system. Currently, the chilled water flow is higher than needed and temperature differential (delta T) is low. The new valves will reduce pumping demand by reducing flow and increasing the delta T; (4) Installation of a demand control system on the kitchen exhaust fans. Currently, the exhaust fans run at full speed all the time. The control system will modulate fan speed based on the amount of smoke and heat in the kitchen exhaust hoods.

Key Findings

The verified electric savings are less than the ex ante savings due to two primary factors. First, it was found that the chilled water delta T is lower compared to the delta T expected by installing the pressure-independent control valves. As a result, the reduction in pumping power is not as large as expected. Second, the average fan speed of the kitchen exhaust fans was found to be higher than expected based on trend data, resulting in an increase in post-implementation fan power compared to what was expected.

The verified gas savings is less than the ex ante savings due to two primary factors. One is a reduction in the boiler gas usage inputs based on confirmation from the site contact that natural gas is used for other end uses besides the boilers. Second, the average fan speed of the kitchen exhaust fans was found to be higher than expected based on trend data, resulting in higher make-up air heating demands compared to the ex ante calculations.

The resulting project savings are shown in Table 7.

Table 7. Summary of Project 2200030 Savings

	kWh	kW	Therms
Ex Ante	1,124,395	129.1	22,509
Verified	747,144	85.8	18,757
Realization Rate	66%	66%	83%

Summary of the Ex Ante Calculations

Boiler blowdown controls:

- The baseline for this measure is the existing boiler blowdown operation, where blowdown is performed manually. The site contact provided their historical blowdown schedule for the previous year, with data on the conductivities of the feedwater and blowdown streams. From this, the implementation team estimated the amount of feedwater required to make up the water that was blown down. Using the total billed gas usage as the boiler input, they estimated the total amount of steam produced as well as the amount of gas required to heat the feedwater.
- In the proposed case, the new controls optimize the blowdown system by only performing blow downs when required instead of on a fixed schedule, reducing the amount of water used for blowdowns. Like the baseline, the implementation team estimated the amount of feedwater required to make up the water that was blown down and the gas required to heat the feedwater. The difference in gas usage between the baseline and proposed case is the ex ante gas savings.

Chilled water economizing and controls:

- The baselines for these two measures are based on the current operation of the chiller system, where the chillers operate year-round. The site contact provided chilled water system data for the period of June through mid-November of 2020. These data include the chilled water supply and return temperatures, the chilled water flow rate, and flow rates through the primary, secondary, and condenser pumps. Using these data, chiller curves, and pump specifications, the implementation team estimated the electric energy used by the chilled water system for the trended period. They extrapolated the electric energy usage to a full year using local weather data.
- In the proposed case, the chillers do not operate at outdoor air temperatures below 40°F. The primary, secondary, and condenser pumps also have lower water flow because of the pressure-independent control valves. Using the same method as in the baseline, the implementation team estimated the annual electric energy used by the chilled water system with no mechanical cooling at outdoor air temperatures below 40°F and the reduced pump flow rates. The difference in electric energy usage between the baseline and proposed case are the electric savings.

Kitchen exhaust controls:

- The baseline for this measure is the current operation, where the kitchen exhaust fans run at full speed 24/7. The implementation team calculated the electric energy usage of these fans using manufacturer specifications.
- In the proposed case, the fans are modulated, and the implementation team estimated an average duty profile for fan speed. Fan speeds were used to calculate fan power and fan energy usage. In addition to fan energy savings, the reduction in exhausted air results in lower heating and cooling demands in the space. The implementation team estimated the gas (heating) and electric (cooling) savings. The difference in electric and gas use between the baseline and proposed case is the energy savings.

Measurement and Verification Plan

This project is being evaluated with a desk review. The evaluation team interviewed the site contact via email to obtain the following information:

- Start and end dates for this project

- Other energy efficiency projects performed at the facility in the last two years
- Confirmation of all natural gas end-uses in the hospital
- Pre- and post-project chiller staging parameters
- Chilled water system configuration details and schematics
- Trend data for the boiler system
- Trend data for the chiller system
- Trend data for the kitchen exhaust system

Early Review Notes

We note that this project was subject to an early review prior to authorization. Our early review comments included the following:

- Because the total billed gas usage was used to calculate the gas savings for the blowdown optimization, the evaluation team requested confirmation that the facility uses natural gas for no other equipment besides the boilers.
  - The site contact confirmed that this was not true, and that gas was used for kitchen equipment, sterilization, and an absorption chiller.
- A significant portion of the savings hinges on achieving a chilled water delta T of 10°F. The evaluation team recommended providing documentation to support a delta T increase from 4°F of 10°F with just the pressure-independent valve retrofits.
  - The site contact provided trend data, from which the average delta T was calculated to be 5.7°F.
- The evaluation team recommended providing documentation demonstrating that the baseline chiller staging was controlled using outdoor air temperatures and switches to load-based staging in the proposed case.
  - This information was provided for the evaluation.
- The proposed chiller calculations appear to reflect an integrated economizer heat exchanger. Whether the economizer is integrated or nonintegrated is a large factor in determining the energy savings. The evaluation team recommended that diagrams or documentation of the chilled water system configuration be provided to show the presence of an integrated economizer heat exchanger.
  - These were provided for the evaluation.
- The evaluation team recommended modelling the proposed economizer use and the chiller use separately.
  - This was addressed in the final savings calculation.
- The proposed chiller model showed chiller cycling that would not reflect actual chiller plant operation when loads are close to the staging changeover points. The model shows that the chillers sometimes cycle on and off every five minutes when the staging changeover point is crossed. In reality, small variations that don't last more than five minutes are just noise in the system, and the chillers wouldn't turn off and on so rapidly.
  - This was addressed in the final savings calculation.

- Chiller efficiency was calculated using a piecewise function. The evaluation team recommended using a curve fit, which offers more precise estimations of performance.
  - This was addressed in the final savings calculation.
- In the chiller calculation spreadsheet, on the pump calculation tabs, the evaluation team was concerned about multiple formulas containing unsourced hard-coded values.
  - These were addressed in the final savings calculation.

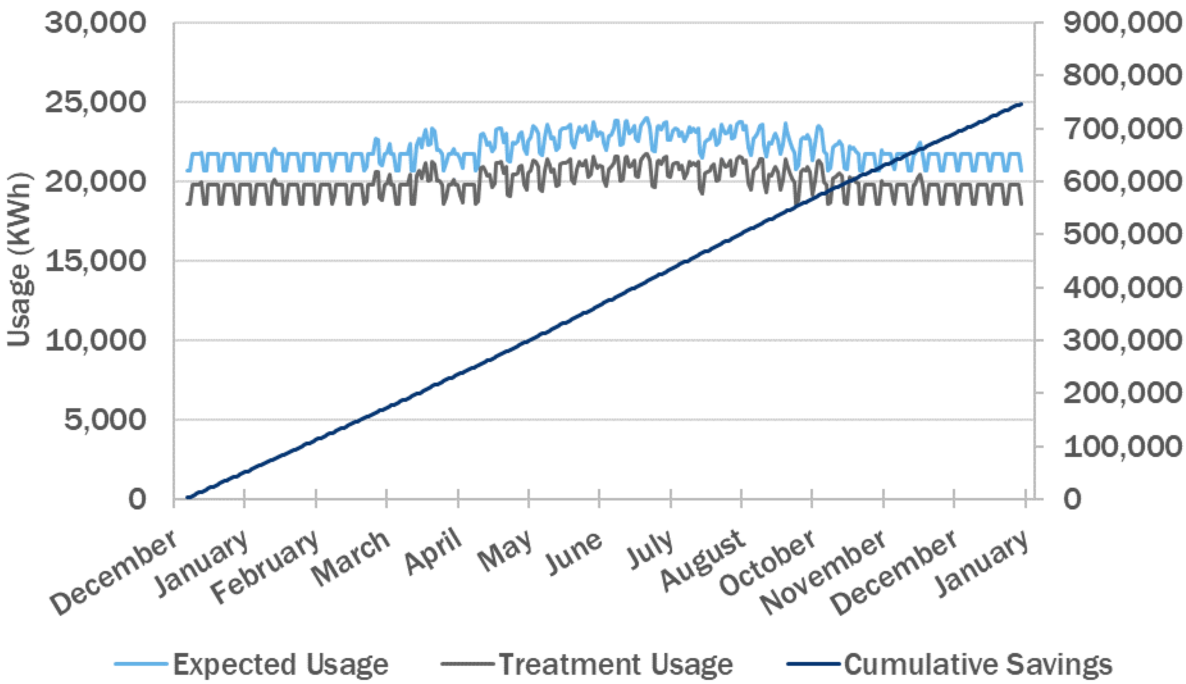
Summary of the Verified Calculations

From the interview, the evaluation team obtained all the information covered in the Measurement and Verification Plan section, except for the boiler trend data. They are summarized as follows:

- Work on this project started on 2/23/2022 and ended on 7/28/2022
- Another controls project claimed to save roughly 400,000 kWh and 134,000 therms was completed in the fall of 2021
- Natural gas is used at the hospital for the boilers, kitchen equipment, sterilization, and an absorption chiller
- Pre- and post-project chiller staging parameters as well as chilled water system configuration details and schematics
- Trend data for the chiller system including plant loads, supply and return water temperatures, and chilled water flow rates
- Trend data for the kitchen exhaust system including runtimes and fan speeds

Upon review of the ex ante electric savings calculations, the evaluation team felt that some of the approaches taken in the analysis may not be reflective of the actual equipment operation. Given that the ex ante electric savings for this project equates to 14% of the annual electric usage of the facility, the evaluation team determined that a weather-normalized regression analysis should accurately quantify the impact this project had on the electric use. Two regression models were generated, one for a pre-project time period of 10/1/2021 to 2/23/2022 and one for a post-project time period of 7/28/2022 to 10/27/2022. The two models were applied to typical meteorological year (TMY) weather data, and the difference between the calculated electric usages was the verified electric savings. Figure 3 shows the modeled usage and savings based on TMY weather data.

Figure 3. Expected and Treatment Energy Usage

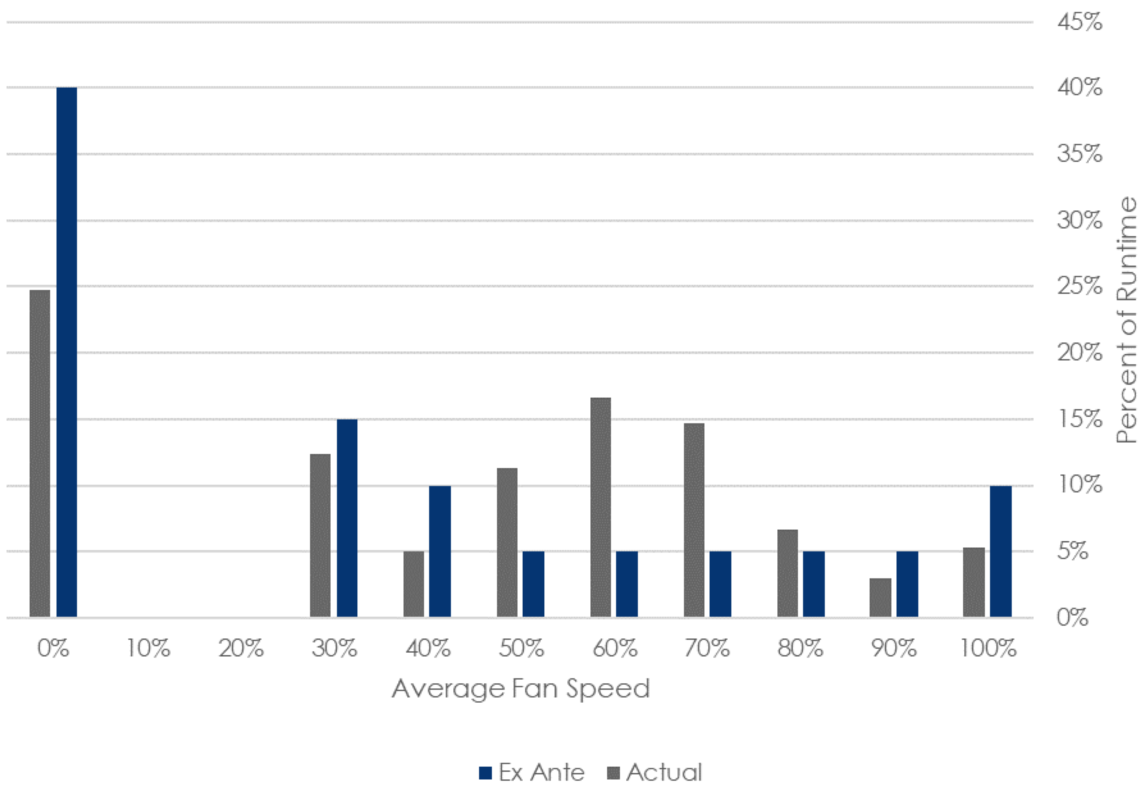


Note: as modeled based on TMY weather data. Cumulative savings over the year.

In the boiler blowdown controls ex ante calculations, the total billed gas usage was used as the input for the boiler usage. However, the site contact confirmed that natural gas was also used for not just the boilers. Therefore, the boiler usage inputs were scaled down using benchmark data for hospitals in the same climate zone. The ex ante calculations were updated with the reduced boiler usage inputs, and the same algorithm was used to calculate the verified gas savings.

In the kitchen exhaust controls ex ante calculations, the implementation team assumed an average fan speed profile. The evaluation team used the trend data for fan speed and determined the actual profile. The ex ante calculations were updated with the actual fan speed profile, shown in Figure 4, and the same algorithm was used to calculate the verified gas savings.

Figure 4. Ex Ante vs. Actual Fan Speed Profiles for Kitchen Exhaust System



Project 2200044

Project ID#:	2200044
Measure:	Replace pneumatic paint kitchen with electric
Savings:	1,692,132 kWh and 193.2 kW
Facility Type:	Manufacturing
End Use:	Process
Sampled For:	Electric
Wave:	1

Measure Description

The customer is replacing existing pneumatically-powered pumps and actuators with electric pumps and control equipment for a painting process. The equipment operates continuously.

Key Findings

The evaluation team reviewed the ex ante savings calculations and made a few key adjustments that resulted in a decrease in savings for this project.

The compressed air savings for each new pump and agitator are based on flow rate spot measurements taken at the end-use, measured at 90 pounds per square inch (PSI). From discussions with the site contact, the evaluation team learned that the discharge pressure of the compressors fluctuates between 107 and 110 PSI. The ex ante calculations estimated the energy savings based on the flow rate at the end-use pressure. By adjusting the savings at the compressor to account for the difference between the discharge pressure and pressure at the end-use, the discharge flow rate decreased by 15%, causing a similarly sized decrease in the baseline energy usage.

Additionally, the evaluation team found some errors in the way that the electrical demand of the new pumps and agitators was calculated. For equipment that operates on 480V 3-phase power, the demand savings were calculated in a manner consistent with single-phase power. The evaluation team applied the correct power calculation equations. This results in increased demand and energy consumption for the three-phase units, subsequently resulting in decreased demand and energy savings for those units.

The resulting project savings are shown in Table 8.

Table 8. Summary of Project 2200044 Savings

	kWh	kW
Ex Ante	1,692,132	193.2
Verified	1,286,848	146.9
Realization Rate	76%	76%

Summary of the Ex Ante Calculations

For the baseline demand, the implementation team multiplied the combined rated airflow demand (CFM) for the seven pneumatically-driven pumps and 10 agitators by the facility's compressed air system efficiency to obtain the power draw (kW). The compressed air system efficiency was determined during a previous compressed air audit at the facility. The implementation team then multiplied the power draw by the annual operating hours (8,760) to obtain baseline usage (kWh). The team assumed a constant compressed air demand from the pumps and agitators and a constant compressed air system efficiency.

In the new case, the implementation team used the rated current draw and multiplied by the rated voltage and an assumed power factor (0.93) to calculate the power draw for each piece of equipment. Then, in a similar fashion to the baseline, multiplied power draw by annual hours to get annual electric usage. Where possible, the implementation team compared calculated kW to manufacturer's specifications for accuracy.

Early Review Notes

We note that this project was subject to an early review prior to authorization. Our early review comments included the following:

- It is unclear why seven pumps are being removed but only five pumps are being installed. It is also unclear from the specification data sheet, which model Graco E-Flo DC Motor is being installed. The evaluation team recommends providing documentation to show the project scope, as well as the specific make and model numbers of all proposed equipment.
- No specification sheets were provided for the Graco IPK and GFS Paint Kitchen. We recommend including manufacturer specification data sheets for all equipment to verify equipment characteristics.
- In cells G12:G13, the compressed air efficiency value of 5.2 CFM/kW, obtained from a previous air audit, is only applicable if all the energy efficiency measures identified in the audit were implemented. The evaluation team recommends verifying that the measures were implemented and that this efficiency value is still valid.
- It is unclear how the amperage draws for the new equipment (cells J21:J24), obtained from a PDF provided by Dove Equipment (*2200044_New Kitchen Estimated Amp Usage.pdf*), were calculated. Amperage draw was used to calculate power draw. These power draw values are generally lower than the power draw values listed in the specification sheets provided. Updating the power draw values to match those listed in the specification sheets may result in a reduction in savings. The evaluation team recommends providing documentation describing how Dove Equipment obtained the amperage draws listed in the PDF.
- In cells N21:N24, the power draw values look like they're apparent power. The evaluation team recommends accounting for a power factor to estimate active power, the portion of power that is used to do work, to calculate energy consumption.
- Utility billing data provided in the project documents shows a mean monthly energy consumption of 1.18 GWh, with a standard deviation of ~50,000 kWh. The monthly estimated savings of ~100,000 kWh is approximately two standard deviations from the mean. Using a mean model, the coefficient of variance is approximately 4.3%, indicating a regression analysis could reasonably identify savings as low as 475,000 kWh, based on a fractional savings uncertainty of 50% at a 68% confidence level. Therefore, it is reasonable to assume that if this project is sampled as part of future evaluation activities, the evaluation team will employ a billing regression analysis. We have the following recommendations to ensure proper documentation in support of this possible future analysis.
  - The evaluation team recommends monitoring usage for approximately 3 months post installation to confirm that average monthly energy consumption drops off to forecasted levels.

- The evaluation team recommends collecting production data records from the customer and normalizing energy usage by production to further increase confidence in the claimed savings.

The implementation team corrected the quantity, power draw, and power factor comments from the early review, though the final unit quantities are much higher than the previous analysis causing baseline usage to increase. The ex ante calculation still used an overall compressed air efficiency value from a previous audit, though comments in the calculation file state that this is the system efficiency after all recommended measures were implemented. Also, production data for the facility was not collected, though the billing history suggests monthly usage is not sensitive to production levels.

Summary of the Verified Calculations

The evaluation team completed a review of the ex ante savings analysis and contacted the customer to verify details of the project. During this review and verification process, the evaluation team found several adjustments were necessary to the savings calculations.

In the baseline case, a total of 28 pumps and agitators drew 1,080 CFM of compressed air. The pumps operate at 90 PSI; however, the discharge pressures at the compressors fluctuate between 107 and 110 PSI. In order to generate 1,080 CFM at 90 PSI, the compressors must produce an equivalent of 918 CFM at 108.5 PSI (the midpoint of the discharge pressure range specified by the customer). Revising the compressor calculations for the lower airflow results in a decrease in the baseline energy usage of 273,203 kWh (1,819,385 kWh original to 1,546,182 kWh revised).

In the efficient case, some power draw values were incorrectly derived. These are noted as follows:

- For the Graco Eflo DC pumps, the ex ante calculations assumed a draw of 1.1 amps per pump at 220 volts, but specification sheets for the reported pump model (EC3D41) show these pumps operate on 480-volt three-phase power. Using the provided operating amperage but changing the power formula to be for 480V three-phase power (Volts*Amps*PF*sqrt(3)), the annual energy use of the 10 installed pumps becomes 74,504 kWh, compared to the ex ante calculated consumption of 19,715 kWh.
- For the Graco electric agitators, the ex ante calculations assumed a draw of 0.7 amps per pump at 480 volts. While this is a reasonable amperage given the size of the pump motors (3/4 hp), the calculation file and specification sheets from the manufacturer indicate that the agitator motors operate on three-phase power. the ex ante calculations reflect only single-phase power. Applying a sqrt(3) factor to the calculations to account for the three-phase power increases the annual usage to 47,412 kWh (originally 27,373 kWh).
- For the GFS Paint Kitchen, the calculations also use the single-phase power equation instead of three-phase. Similarly, correcting the power calculation increases the annual usage to 135,462 kWh (originally 78,209 kWh).

In total, these changes increase the post-case annual energy use of the new pumps and agitators by 132,081 kWh (127,253 kWh ex ante, 259,334 kWh verified). As a result of the adjustments made to the compressor energy calculations, and the energy usage calculations for the new pumps and agitators, the verified savings for this project are 1,286,848 kWh. Dividing by 8,760 hours per year yields verified demand savings of 146.9 kW.

Project 2101316

Project ID#:	2101316
Measure:	Compressed Air Controls
Savings:	1,337,081 kWh and 172.1 kW
Facility Type:	Manufacturing
End Use:	Compressed air
Sampled For:	Electric
Wave:	1

Measure Description

The customer is installing new compressed air controls and reprogramming the system to operate the three load/no load and one variable displacement compressors as base load units and the one variable-speed drive (VSD) compressor as a trim unit.

Key Findings

The evaluation team used a combination of a regression model and prescriptive savings calculations to verify the project savings due to the unexpected failure of the VSD trim compressor, which is outside the scope of this project. At the time of verification, the evaluation team found that the customer was using a rental single-speed compressor in place of the VSD compressor as the trim unit, preventing the customer from implementing the same compressor staging strategy as outlined in the project proposal. To account for the reduced energy use of a VSD compressor compared to the rental compressor, the evaluation team used the Illinois TRM[1] to support verified savings estimates and account for the VSD compressor being out of service during the post-case period, and to avoid penalizing the project for a failed equipment outside the scope of the project.

This mixed methods analysis results in lower verified savings than was reported in the ex ante calculations. The resulting project savings are shown in Table 9.

Table 9. Summary of Project 2101316 Savings

	kWh	kW
Ex Ante	1,337,081	172.1
Verified	1,153,261	144.6
Realization Rate	84%	84%

Summary of Ex Ante Calculations

The implementation team calculated ex ante savings for this project using compressor performance curves taken from Compressed Air & Gas Institute (CAGI) specification sheets and performance characteristics at a single operating point for each of the six compressors. The implementer modeled performance characteristics as constant throughout facility operation (8,000 hours/year).

[1] *2022 Illinois Statewide Technical Reference Manual for Energy Efficiency Version 10.0, Volume 2: Commercial and Industrial Measures*. Section 4.7.1, VSD Air Compressor. 2021. pp 713–716

In the baseline case, all six compressors operate simultaneously. Each of the four load/no load compressors are loaded equally at 73% of rated capacity. The VSD and variable-displacement compressors are loaded at 80% and 50%, respectively.

In the new case, three of the four load/no load compressors are fully loaded, and the fourth is disabled. The variable displacement compressor is also fully loaded. The VSD compressor is loaded at 40%.

Early Review Notes

We note that this project received an early review prior to authorization. Our early review comments included the following:

- The difference in the compressor loading profile (% of capacity) between the baseline system configuration and the proposed is a primary source of savings for this project. Given the ex ante savings level, the analysis should be revised or include data to establish how the compressor loads were determined. The current documentation does not specify if compressor power or airflow demand trend data was used to determine compressor load profiles. The evaluation team believes it is unlikely that each of the compressors always operate at a fixed load. Air demand in most plants varies depending on the time of day or day of the week. Therefore, these loading profiles should be supported with operating data. Additionally, short-term metered data can also substantiate the continuous operation of the compressed air system.
  - Metered data was not collected before submitting the ex ante calculation.
- The amount of system storage may affect the estimated performance of the load-unload compressors. The available calculations include a graph of what looks to be a typical performance curve for load-unload compressor control that cites system storage of 3 Gal/CFM-trim compressor capacity. This is a relatively inefficient ratio, meaning that compressor performance (kW/CFM) could be negatively impacted if it is found that the system has more storage than assumed in the analysis. Therefore, the evaluation team recommends confirmation of the total system storage to validate the assumed value.
  - It is unclear whether system storage was confirmed prior to submitting the ex ante calculation.

Measurement and Verification Plan

The evaluation team's primary M&V plan will consist of a review of project documentation and regression analysis. The team will request daily or weekly production data from the customer, for both the baseline period (1/1/2021 to 12/31/2022) and the treatment period (starting 3/1/2022). Using interval data, we will develop a regression model to predict energy use following project completion and compare that to actual energy use to determine savings.

Because the project savings are only 5% of the facility's annual usage, and because there are still unanswered questions from the early review, we will also conduct an on-site visit to verify key operating parameters of the compressed air system. We will ask about other energy efficiency projects that may have been completed in the last two years, or any other changes at the facility that could have a significant impact on its energy use. Also, we will inquire about the effects of the COVID-19 pandemic on-campus activity and the operation of the compressed air system.

We will document the following operating parameters of the compressed air system:

- Nameplate data for all six compressors

- System operating pressure (psi)
  - The customer will be asked if any change was made to the system pressure with the new compressor controls
- Confirm controls installation date
- Annual operating hours
- System compressed air storage volume (gal)
- Confirm control type for compressor 6 (inlet modulation vs variable displacement)
- Confirm compressed air system setup, including:
  - Baseline compressor staging
  - Existence and location of any pressure-reducing valves
  - Downstream pressure setpoints (if applicable)
  - System diagram or schematics, if available

In addition, we will request or manually record trend data for the following:

- Airflow demand for all six compressors (acfm or scfm) for one week
  - If airflow trend data is not available, we will manually log power data for all compressors using DENT loggers for a minimum of one week

Summary of M&V Site Visit

The evaluation team conducted an M&V site visit on January 20, 2023. During the site visit, only five of the facility's six compressors were operating. The new controls were only installed on four of the six compressors. The new compressor controllers appeared to still use cascading pressure differential with local control (not staging, as stated in the project proposal) and do not communicate with each other. Also, the variable-speed drive (VSD) compressor has been nonfunctional for most of 2022 and was still down during the site visit. Facility staff expect the VSD compressor to be repaired sometime in February 2023.

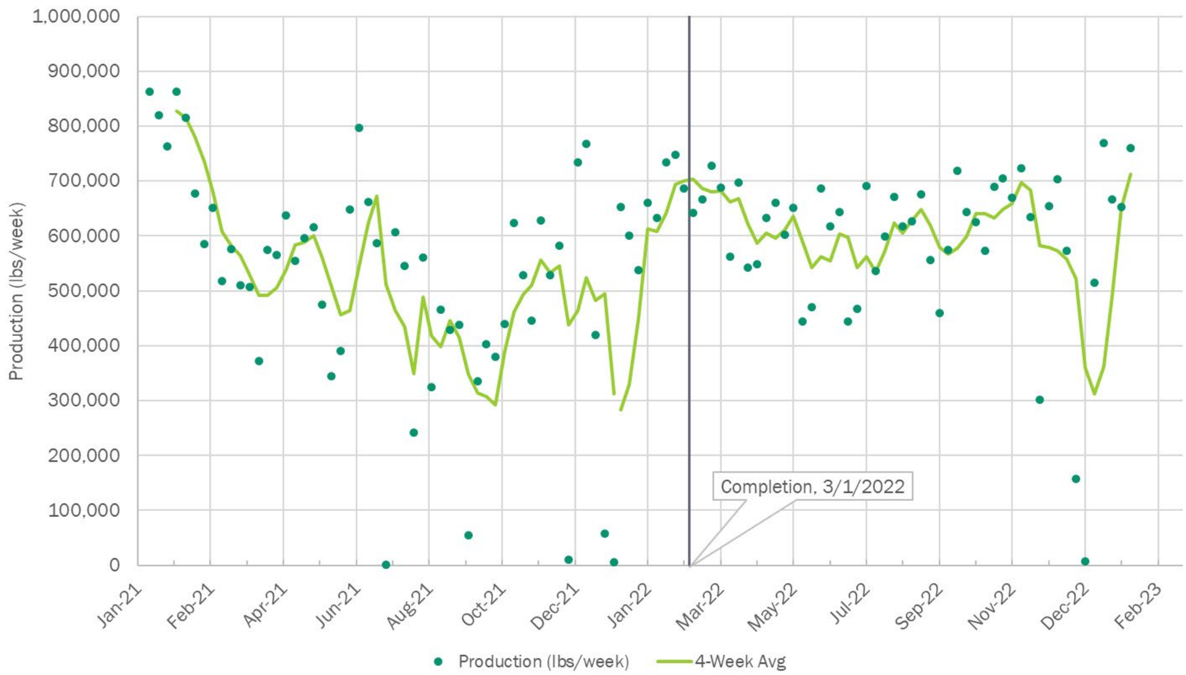
The compressed air operating pressure is about 120 pounds per square inch (psi), with local cascading pressure differential setpoints to enable additional compressors when system pressure drops below 115 psi. Facility staff indicated that it is standard practice to enable two load/unload compressors and the VSD compressor and fully load those units before enabling additional compressors. This is not the proposed staging setup as described in the project documentation (three load/unload compressors and one variable-displacement compressor fully loaded, with the VSD compressor trimming based on compressed air demand).

The facility has three 3,000-gallon storage tanks and one approximately 750-gallon storage tank, all tied together to serve the compressed air system.

The production lines operate three shifts Monday through Friday and partial shifts on some Saturdays.

Since completing installation of the new controls on March 1, 2022, two new production lines have been added to the facility. The average weekly production increased from approximately 510,000 lbs/week in 2021 to almost 600,000 lbs/week in 2022. Production data, including the rolling 4-week average and completion date for the new controls is given in Figure 5.

Figure 5. Customer Production Data from 2021 and 2022



Compressed air trend data was not available to collect from the new controls, nor was the evaluation team able to deploy energy loggers on the compressor equipment.

Summary of Verified Savings

To verify savings, the evaluation team used a mixed methods approach, first using billing regression analysis to determine facility energy savings and then engineering calculations to account for the rental single-speed compressor in place of the VSD compressor. The evaluation team generated a weekly regression model using billed energy usage during the baseline period (1/1/2021 to 12/31/2021) and statistically significant modeling criteria. This regression model was applied to the treatment period (3/1/2022 to 2/3/2023) to generate expected weekly usage had the project not been implemented. The regression model uses variables listed in Table 10 to predict weekly energy usage. Regression model statistics showing acceptability criteria are given in Table 11.

Table 10. Regression Model Variables

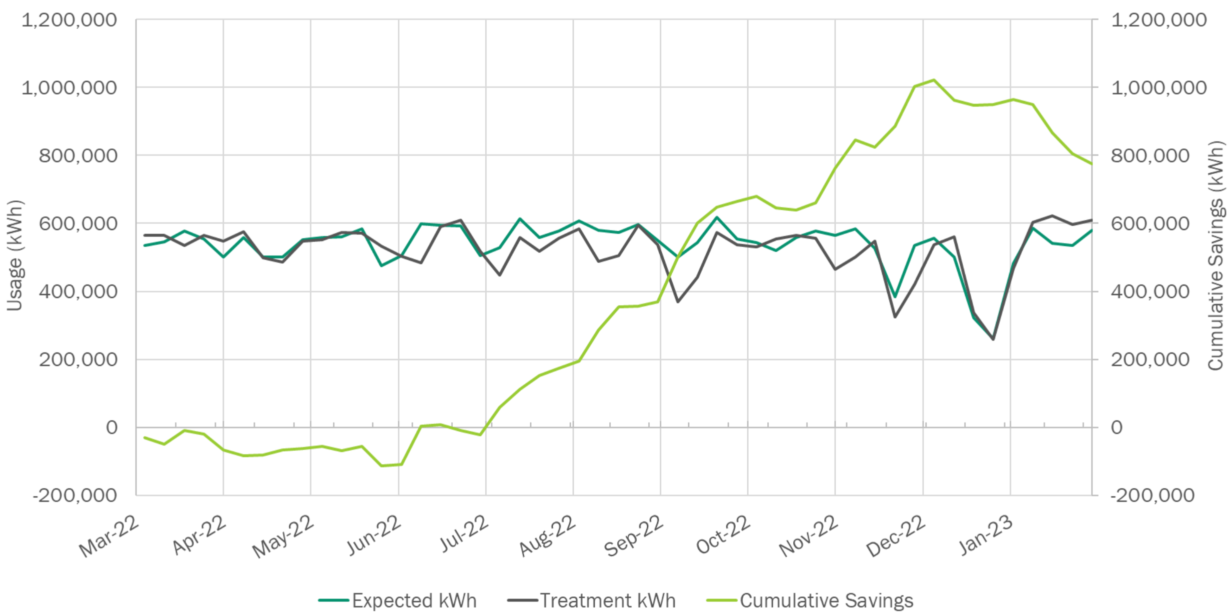
Variable	Definition	Type	Coefficient	t-value
	Constant		256,128.7	14.7
A	Production_lbs-per-wk	Numerical	0.4	15.9
B	CDD	Numerical	325.8	4.1

Table 11. Regression Model Acceptability Criteria

Criteria	Target	Baseline
Adjusted R Squared	>0.75	0.831
Coefficient of Variation	<0.2	0.078
Autocorrelation Coefficient	<0.5	-0.219
Net Determination Bias	<0.005	2.01E-16
t-values	>2 or <-2	Pass

Using the regression model, we calculated expected daily usage for the treatment period and compared that with actual daily usage from the billing history to determine verified savings. Figure 6 depicts the expected usage, actual usage, and cumulative savings over the treatment period. The facility saved 776,068 kWh over the 342-day treatment period. Roughly extrapolated to a full year, the annual savings would be 828,260 kWh.

Figure 6. Expected Usage, Actual Usage, and Cumulative Savings



The evaluation team determined that, while the compressed air controls project was not implemented as described, the modeled savings do reflect real-world efficiency gains at the facility. Because no other energy-related projects were completed during this timeframe, the savings observed can be attributed to the this project. Specifically, the customer did invest in optimizing the compressed air controls and reducing the runtime of some of the compressors.

For demand savings, the evaluation team calculated the average weekly kW by dividing the expected and actual weekly usage by 168 kW. Monthly demand savings are calculated using the difference between the maximum weekly kW in the baseline and the maximum weekly kW in the treatment period, for the given month. The verified demand savings are calculated as the average monthly demand savings for June, July, and August.

However, due to the VSD compressor at the facility being offline for repairs, and use of a lesser efficient single-speed rental compressor in its place, the energy use during the post-case period was higher than under normal operating conditions. To account for this, the evaluation team used engineering calculations from the ILTRM section *4.7.1 VSD Air Compressor* to estimate the difference in energy consumption between the rental compressor and the VSD compressor.

Based on the size of the compressor (250 HP), the amount of compressed air storage at the facility, the hours of operation specified by the site contact, and the deemed savings factors listed in the IL-TRM, the difference in annual energy use was calculated as 325,001 kWh and 39 kW of demand. This amount was added to the savings estimates produced from the regression analysis. The resulting total project savings are 1,153,261 kWh and 144.6 kW, yielding realization rates of 84% for both energy and demand.

Project 2200189

Project ID#:	2200189
Measure:	Natural Gas-Fired Generator
Savings:	149,015 therms
Facility Type:	Industrial
End Use:	Facility power generation
Sampled For:	Gas
Wave:	1

Measure Description

This project involved the installation of an efficient natural gas-fueled electric generator system for a new indoor grow facility. The facility currently does not have electric service, so the generators will be used to provide power to the facility until grid service can be provided. After this time, the generators will continue to provide power to the facility during daily peak demand hours. Energy savings are achieved by using a higher efficiency generator than the cheapest available option and by reducing peak electric demand. This project was completed on July 31, 2021.

Key Findings

The evaluation team found during an on-site review that the generator system is being used at a lower average capacity than predicted, but for a longer time than originally planned. The site does not have electric service as intended, so the usage of the generator system is higher, resulting in increased savings. As a result, the evaluation team determined that the verified energy savings are higher than the ex ante savings. The results are shown in Table 12 below.

Table 12. Summary of Project 2200189 Savings

	Therms
Ex Ante	149,015
Verified	237,275
Realization Rate	159%

Summary of the Ex Ante Calculations

The implementation team calculated gas savings by comparing the efficiencies of the baseline and new generator models. The baseline technology used was a minimal-cost natural gas-fueled electric generator system that can meet the demand requirements of the facility. The facility design demand is 3,600 kW and was provided by the site contact. Since the generator models selected for the baseline and new cases had different output power ratings, the number of units required for each generator system to meet the facility demand is different. Each system includes one additional generator for redundancy. The implementation team determined the load profile of the system using gas engine modeling software and efficiency data from the equipment specification sheets. The equipment runtime was calculated by summing the AIC on-peak demand period for an entire year and adding 10 minutes per day to account for equipment startups and shutdowns.

Measurement and Verification Plan

This project was evaluated with an on-site review. An evaluation team member visited the site to obtain updated information on the project and key points related to the energy savings. From the evaluation team's review of the ex ante calculations, key points of interest include:

- Verification of the facility demand (3,600 kW)
  - If the demand has changed, what is the new demand? Will additional generators be required to meet a larger demand?
  - Is trend data available that shows the facility demand?
- The annual runtime of the generator system
  - Is the system only being used during on-peak hours? Are there any additional times when the system will run?
- Any additional energy savings measures implemented in this project, such as heat recovery on the generator exhaust

Summary of the Verified Calculations

The evaluation team obtained electric usage data from the site contact during the on-site review. The data consists of the monthly electricity output of the generator system since the beginning of the site full production period (July 2022) through the most recent date available (December 2022). The data show that the site's average demand is lower than the value assumed in the ex ante calculations. The evaluation team also learned that the site does not have electric service as originally planned when the ex ante calculations were performed. These differences mean that although the site demand is lower than anticipated by the Implementation Team, the runtime is much longer, and therefore the natural gas savings was found to be higher than the ex ante calculation. The results are shown in Table 13 below.

Table 13. Summary of Ex Ante and Verified Savings

	Baseline (Therms)	Proposed (Therms)	Savings (Therms)
Ex Ante	1,198,723	1,049,709	149,015
Verified	2,253,953	2,016,667	237,275

To provide the verified savings value, the evaluation team used the same calculation method as used in the ex ante calculations. The annual runtime was changed to a full year (8,760 hours). The facility demand was replaced with the average value obtained in the data from the on-site review. The baseline and proposed generator heat rates were re-calculated using the new demand. The difference between the efficiencies of the baseline and proposed systems is less than in the ex ante calculations, but due to the higher runtime, the overall savings is greater. A comparison between the inputs for the ex ante and verified calculations is shown in Table 14 below.

Table 14. Summary of Ex Ante and Verified Generator Operation

	Demand (kW)	Runtime (hours)	Baseline Heat Rate (Btu/kWh)	Proposed Heat Rate (Btu/kWh)
Ex Ante	3,600	3,163	13,658	11,960
Verified	1,825	8,760	14,102	12,618

Project 2200051

Project ID#:	2200051
Measure:	Energy Management System Upgrades
Savings:	389,654 kWh; 0.0 kW
Facility Type:	Medical
End Use:	HVAC
Sampled For:	Electric
Wave:	2

Measure Description

This project replaces an existing pneumatic control system with new Automated Logic controllers, sensors, actuators, and variable frequency drives (VFDs) in a medical facility. These upgrades were installed on four air handling units (AHUs), the hot water heating system, and the chilled water system. These upgrades will provide AHU scheduling, economizer control, variable speed fan control, discharge air temperature (DAT) resets, variable pump speed control, hot water (HW) reset, and chilled water reset.

Key Findings

The evaluation team made several adjustments to the savings calculations, but they all had only minor impacts on the total verified savings. Adjustments in the verified analysis included addition of VFD efficiency for the all-weather pump (AWP) to the calculations, updating of the maximum mixed air temperature of two of the AHUs under proposed conditions to equal the maximum return air temperature (RAT), and revision of the switchover date of the two-pipe system to start cooling in April.

The primary reason for the increase in peak demand savings is that the implementation team assumed that there would be no savings during peak operation while the evaluation team established baseline and proposed demand during the 1 PM to 5 PM period from June through August.

The resulting project savings are shown in Table 15.

Table 15. Summary of Project 2200051 Savings

	kWh	kW
Ex Ante	389,654	0.0
Verified	391,914	56.8
Realization Rate	101%	N/A

Summary of the Ex Ante Calculations

The implementation team used a custom hourly analysis spreadsheet calculation to estimate the savings from the various upgrades included in the project. The spreadsheet uses TMY3 data to calculate fan energy, pump energy, heating energy, and cooling energy for baseline and proposed conditions. Under baseline conditions, fans and pumps operate at 100% speed for 8,760 hours per year, AHU DATs are fixed, and outdoor air damper positions are fixed at 10%. Heating hot water and chilled water temperatures are also fixed.

The proposed supply fan (SF) speeds depend on building occupation, running at 80% speed while occupied, 40% speed when unoccupied, and 70% speed when students might be present. Return fan (RF) speeds vary in an equivalent manner, with speeds equal to SF speeds minus 10%. Outside air dampers modulate between 10% and 100% to provide economizing. Mixed air temperatures (MAT) for two AHUs varies between 88°F at 0°F outdoor air temperature (OAT) to 55°F at 50°F OAT, while the other two units have a 75° F maximum MAT. Supply air temperature after the cooling coil varies from 55°F at 65°F OAT to 60°F at 55°F OAT. Supply air temperature varies from 90°F at 0°F OAT to 55°F at 70°F OAT. The two-pipe system for heating and cooling water switches to cooling on March 15 and is set to heating on October 15.

VFDs were installed to control speed of the 3-horsepower (HP) heating hot water pumps, with speed varying from 100% at 10°F OAT to 40% at 60°F. VFDs were also installed on the 15-HP all-weather pump (AWP), with speeds varying from 100% at 25°F OAT to 40% at 60°F and 100% added at 80°F OAT. The AWP is expected to run 8,760 hours per year.

Early Review Notes

We note that this project received an early review before authorization. Early review comments included the following:

- The HW Pump and AWP VFD calculations in the Custom Project Workbook use a fan/pump power exponent of 2.2, while other calculations use 2.7. The evaluation team recommends using the following equation for all fan and pump power calculations:

$$HP_C = HP_D\left[\left(1-\sqrt{\frac{H_{min}}{H_D}}\right)*\left(\frac{F_C}{F_D}\right)+\sqrt{\frac{H_{min}}{H_D}}\right]^3$$

  Where:

  H_D = Design pressure

  H_{min} = Minimum static pressure setpoint

  F_D = Flow at design conditions

  F_C = Flow at current conditions

  HP_D = Horsepower at design conditions

  HP_C = Horsepower at the current condition

  - The implementation team retained the 2.2 and 2.7 affinity factors but because these are closed systems, static pressures are not a factor, and the factors used are acceptable. The evaluation team recommends using the formula above whenever the system operates with a significant static head, e.g., cooling towers.

- The HW pump and AWP VFD calculations in the Custom Project Workbook use motor efficiency (cell B11) and VFD efficiency (H21:H3644) interchangeably. These should be two separate inputs. The evaluation team recommends including both motor efficiency and VFD efficiency in the power calculation.

  - The implementer used TRM values to establish savings for the HW pump but did not include VFD efficiency to the AWD pump calculations.

- Electrical demand savings are calculated by dividing energy consumption by 8,760 hours. This would give average demand, not peak demand. Average and peak are only the same thing if demand is constant year-round. In this case, the proposed design shuts down at night, and consumption varies significantly with occupancy and OAT. The evaluation team recommends revising the demand savings calculation.
  - The implementation team did not claim demand savings in the final submission.

Summary of the Verified Calculations

The evaluation team reviewed the calculations provided with the documentation and found them reasonable, except for establishing peak demand kW. We determined peak demand savings using the TMY3 calculations provided by considering the average baseline and proposed demand kW for the 1 PM to 5 PM periods from June through August.

The evaluation team made several adjustments to the savings calculations for total verified savings. VFD efficiency was added to the calculations for the all-weather pump (AWP); the maximum mixed air temperature of two of the AHUs under proposed conditions was updated to equal the maximum return air temperature (RAT), and lastly, the switchover date of the two-pipe system was adjusted to start cooling in April.

Project 2100318

Project ID#:	2100318
Measure:	Indoor Ag Process Improvements
Savings:	337,492 therms
Facility Type:	Indoor Agriculture
End Use:	Cannabis Grow Room Glider Benches
Sampled For:	Gas[a]
Wave:	1

[a] Project was initially sampled in the electric sample frame. As described below, the project was found to save natural gas rather than electricity and therefore was shifted to the natural gas sample frame. Because the project was sampled in a certainty stratum, the sampling approach remains acceptable.

Measure Description

The customer operates an indoor cannabis grow facility. This measure includes the addition of glider benches as a platform for plants rather than stationary benches. Traditional benches have walkways or aisles between them, allowing for watering and tending to the plants. Glider benches can slide back and forth, so only a single aisle is necessary for the room, and that walkway can shift from one set of benches to another. This will allow the customer to increase the square footage of the canopy (plants) without increasing the square footage or lighting in the facility.

The new facility is an addition to an existing facility, but the utility doesn't have enough electrical capacity at the address to satisfy the additional load of the addition. The customer has installed three natural gas-fired generators with sufficient capacity to meet the new load and runs the addition in 'island mode', i.e. there is no connection to the electrical grid. The customer gets its natural gas from AIC, so all electrical energy savings have been converted to gas savings for this project.

Key Findings

The verified savings for this project are slightly lower than the ex ante savings due to several factors. The primary difference is due to the evaluation team's use of customer-supplied compressor operation trends to establish proposed HVAC equipment demand power and energy. The implementation team did not have this information available and estimated equipment power based on rated efficiency without accounting for varying loads. Our approach resulted in lower baseline equipment power, which reduces the potential for savings. We also reduced lighting hours to account for harvest periods, slightly lowering the verified savings.

The resulting project savings are shown in Table 16.

Table 16. Summary of Project 2100318 Savings

	Therms
Ex Ante	337,492
Verified	317,212
Realization Rate	94%

Summary of the Ex Ante Calculations

The implementation team estimated savings by calculating the energy savings per gram of product. The sliding benches will allow the customer to change the aisle location to access plants as needed. Space for only one aisle is needed, resulting in additional bench area and increased facility productivity. The benches were installed in ten identical rooms, with the same number of lights and the same type of cooling. The baseline layout has 1,696 square feet (sq ft) of canopy per room, while the proposed design has 2,720 sq ft per room. The lighting did not change with the new layout, but an additional 32-ton air conditioner was installed for each room to handle the latent cooling load increase due to the higher number of plants in each space. Figure 7 and Figure 8 below show the pre- and post-case room layouts.

Figure 7. Pre-Case Room Layout

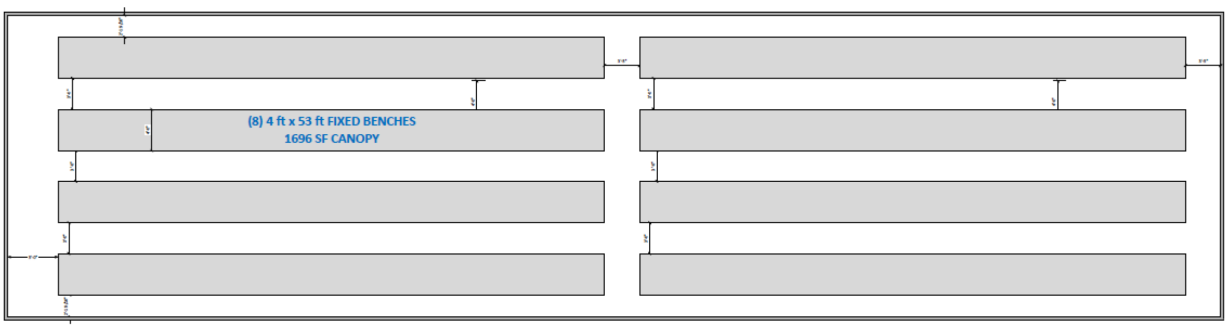
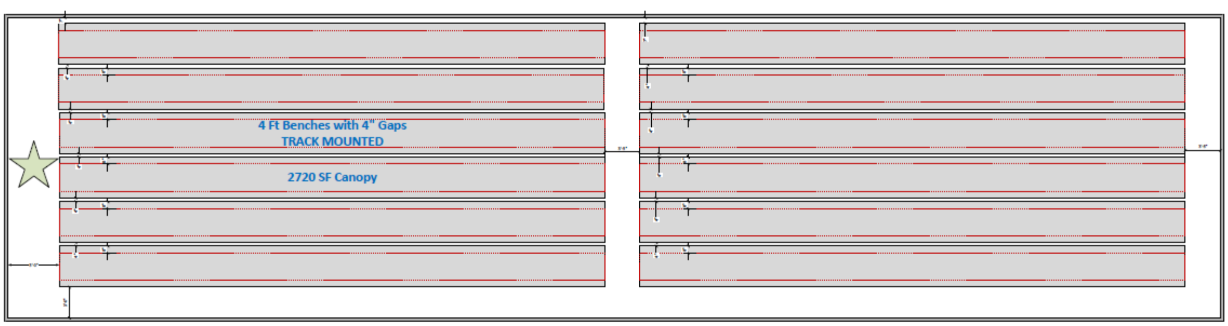


Figure 8. Post-Case Room Layout



The savings come from reducing energy use intensity (EUI) per gram of product. To determine total lighting energy usage, the implementation team calculated the total lighting wattage for 144 fixtures at 1,060 Watts, each operating 4,380 hours per year. They estimated baseline cooling energy, assuming two 32-ton air conditioning units would operate at full capacity for 8,760 hours per year. That resulted in a baseline EUI of 2.24 kWh/gram/year, including lighting and HVAC.

The proposed lighting energy usage is the same as the baseline usage. The implementation team estimated proposed HVAC energy usage assuming that three 32-ton air conditioning units would operate at full capacity for 8,760 hours per year, which resulted in a proposed EUI of 1.68 kWh/gram, including lighting and HVAC. They multiplied the EUI difference, 0.55 kWh/gram, by the total baseline production of 5,090,374 grams per year to establish total energy savings. They determined electrical demand savings (kW) by dividing the total kWh saved by 4,380 hours.

The implementation team established therm savings by determining the gas energy equivalent of electrical energy savings. The generator vendor provided results of their modeling program that established average system heat rate of 11,960 Btu/kWh. They used that result and electrical energy savings with Equation 7to establish gas savings.

Equation 7. Ex Ante Gas Savings

$$Gas\ Savings = (Baseline\ Energy\ Usage - \ Proposed\ Energy\ Usage)kWh * 11{,}960 \frac{Btu}{kWh} \div 100{,}000\ Btu/Therm$$

Early Review Notes

We note that this project received an early review prior to authorization. Early review comments included the following:

- It is unclear how the additional cooling requirements were determined. The sensible loads should stay constant between the baseline and the proposed cases. In the indoor cannabis grow industry, sensible loads significantly contribute to cooling requirements.[2] This project may have greater savings if the same cooling tonnage can be used in the pre- and post-cases. The latent loads will increase with the increased canopy, but calculating the magnitude of that increase and the increased cooling requirement explicitly may show that a smaller additional air conditioner could meet the additional load or that the existing air conditioners can meet the additional load. Either of these scenarios would result in greater savings.
  - The implementation team included an extra AC unit for the proposed case but assumed that all units would operate continuously at full capacity in the baseline and proposed cases.
- Another issue the evaluation team identified is that the kW/ton values used in the HVAC calculation (2.4 kW/ton) need to be lowered. Assuming the EER values provided are correct, the air handler should have an efficiency of 0.84 kW/ton (using the formula kW/ton = 12 / ARI EER). Making this change to the calculation will reduce the kW per unit to 26.9 kW for all air handlers in the baseline and proposed cases. Reducing the kW per air handling unit will decrease the proposed energy usage (including lighting) to 10,338,552 kWh, down from 23,242,032 kWh per year. The overall savings will be 2,462,948 kWh per year and 562.32 kW (down from 3,355,642 kWh per year and 766.13 kW). Note that this adjustment to the calculation brings the calculated baseline energy usage to 7,982,112 kWh/year, which is much closer to the actual current facility usage based on billed energy usage. While comparing billed data to this calculated baseline energy consumption may not be valid if this is a new construction project, the EER values provided in the calculation do not correspond to the kW/ton values, which warrants investigation.
  - The implementation team made this adjustment.
- Finally, the "Calculations_REV" workbook noted a lighting change from 1,000 watt high-pressure sodium (HPS) lamps to 645 watt LEDs. There is a note to disregard this tab of the workbook, but the evaluation team believes it is prudent to remind the implementation team to delete this tab if a lighting measure is not a part of this project. That said, if the facility pursues a lighting change, the wattage should be changed from 1,000 watts to 1,080 watts for the HPS lights, and a waste heat factor of 8% should be included in the calculation. The wattage should be changed because 1,000 watts is the nominal wattage, but the actual fixture wattage is 1,080 watts, including ballast and lamp.

[2] https://www.desert-aire.com/sites/default/files/Tech-Note-Grow-Room-Load-Calculation-Application-Note-DA125.pdf

- The implementation team adjusted the lighting input wattage to 1,080 watts for baseline and proposed cases. They did not include a waste heat factor but assumed that the extra AC unit in each room would satisfy additional sensible cooling loads.

Measurement and Verification Plan

The evaluation team will conduct a site visit to verify the installation of the movable benches and discuss the grow operation for the ten affected rooms. The following questions will be asked.

- How many hours per day are in each growth cycle phase, and how many days are the plants in each phase (germination, vegetative growth, flowering)?
- Did lighting stay the same, or were any fixtures added?
- Are the lights operated with the same settings (color spectrum & brightness) during all operating hours?
- What are the downtime durations to remove and replace plants in each room?
- AC unit model numbers and specifications.
- Cooling loads for each room-we will request trend data if available.
- Actual production per room (annual grams produced) before and after the project was completed
- Changes to facility operation, including total production and plant varieties.

Summary of the Verified Calculations

The evaluation team reduced lighting hours of operation to account for five harvests per year but otherwise adopted the lighting savings calculations provided by the implementers. The HVAC calculations developed for AIC project 2100319 were used for Agronomic IQ units to establish the proposed energy usage of the ten new flower rooms.

The evaluation team collected the compressor operating status for three of the new flower rooms, assuming they represented all new rooms in this facility addition. The IQ unit-rated EER and percent compressor operation were used to estimate the average power for each of the three units in each flower room. This approach was used to estimate cooling power for three units in each flower room, with one unit at 16.6 kW, one at 9.8 kW, and one at 4.2 kW. Each room has a dedicated dry cooler, estimated to have 11.3 kW of input power. Each IQ unit has two 8-horsepowerower motors that are expected to run continuously. Fan motor power was calculated using Equation 8.

Equation 8. IQ Unit Fan Motor Power

$$IQ\ Unit\ Fan\ Motor\ Power = \frac{2\ motors * 8\ hp *\ .65\ load\ factor * 0.746\ kW/hp}{91\%\ motor\ efficiency}$$

$$IQ\ Fan\ Motor\ Power = 8.5\ kW$$

We estimated the proposed energy usage for the HVAC equipment using Equation 9.

Equation 9. Proposed IQ Unit Energy Usage

$$Proposed\ HVAC\ Energy\ Usage\ kWh = \left(\sum(IQ\ Proposed\ Compressor\ kW + Fan\ kW) + \sum(Dry\ Cooler\ kW)\right) * 8510\ Hours$$

$$Proposed\ HVAC\ Energy\ Usage\ kWh = 5{,}741{,}230\ kWh$$

The evaluation team maintained the implementation team's assumption that the baseline rooms would only need two AHUs compared to the three AHUs required for the proposed case. It was assumed that the baseline IQ compressor power would be proportional to the ratio of the baseline canopy area to the proposed canopy area. That ratio is 62.4%, so the total proposed compressor kW per room was multiplied by that factor to determine the baseline cooling needed. It was assumed that the baseline AHU fans and dry coolers would operate continuously. Dry cooler power was estimated to be 2/3 of the proposed dry cooler, accounting for only two units running in the baseline case. Baseline energy usage for the HVAC equipment was calculated using Equation 10.

Equation 10. Baseline IQ Unit Energy Usage

$$Baseline\ HVAC\ Energy\ Usage\ kWh = \left(\sum(IQ\ Baseline\ Compressor\ kW + Fan\ kW) + \sum(Dry\ Cooler\ kW)\right) * 8510\ Hours$$

$$Baseline\ HVAC\ Energy\ Usage\ kWh = 3{,}715{,}212\ kWh$$

The customer reported that production had met expectations, estimated to be 8,163,808 grams per year. The evaluation team used this value to calculate energy usage intensity (EUI) for the proposed operation, as shown in Equation 11 and Equation 12.

Equation 11. Proposed Lighting Energy Usage Intensity

$$Proposed\ Lighting\ kWh\ per\ Gram\ Product = 6{,}685{,}632\ kWh \div 8{,}163{,}808\ grams$$

$$Proposed\ Lighting\ kWh\ per\ Gram\ Product = 0.819\ kWh\ per\ Gram\ Product$$

Equation 12. Proposed HVAC Energy Usage Intensity

$$Proposed\ HVAC\ kWh\ per\ Gram\ Product = 5{,}741{,}230\ kWh \div 8{,}163{,}808\ grams$$

$$Proposed\ HVAC\ kWh\ per\ Gram\ Product = 0.703\ kWh\ per\ Gram\ Product$$

The evaluation team established the proposed energy usage by multiplying the EUIs by baseline production to normalize the baseline energy usage for the lighting and HVAC. The results were subtracted from the baseline energy usage to establish 2,516,944 kWh in lighting savings and 135,386 kWh in HVAC savings for 2,652,330 kWh of total energy savings.

The evaluation team converted electrical energy savings to gas savings using the same approach as that taken by the implementation team.

The evaluation team did not adjust gas usage by peak demand because the new facility is not connected to the electrical grid.

Project 2100319

Project ID#:	2100319
Measure:	Efficient Air Handlers
Savings:	413,854 therms
Facility Type:	Indoor Agriculture
End Use:	HVAC
Sampled For:	Gas[a]
Wave:	1

[a] Project was initially sampled in the electric sample frame. As described below, the project was found to save natural gas rather than electricity and therefore was shifted to the natural gas sample frame. Because the project was sampled in a certainty stratum, the sampling approach remains acceptable.

Measure Description

The customer operates an indoor cannabis grow facility. This measure is for a 27,200-square-foot new construction grow area designed with Agronomic IQ air handlers rather than the baseline Carrier rooftop units (RTUs) in the rest of the facility. The new construction space includes one genetics room, four vegetative growth rooms, and ten flower rooms. The proposed HVAC system has refrigerant coils with a better sensible to latent cooling load ratio, providing more efficient humidity control than the baseline Carrier RTUs.

The new facility is an addition to an existing facility, but the utility doesn't have enough electrical capacity at the address to satisfy the additional load of the addition. The customer has installed three natural gas-fired generators with sufficient capacity to meet the new load and runs the addition in 'island mode', i.e. there is no connection to the electrical grid. The customer gets its natural gas from AIC, so all electrical energy savings have been converted to gas savings for this project.

Key Findings

The verified savings for this project are less than the ex ante savings due to several factors. The implementation team used rated full-load amps (FLA) to establish operating power for all equipment, which overestimates power because the FLA does not account for partial loading. The evaluation team used trended data and rated equipment efficiencies to determine power demand, resulting in much lower demand and energy usage for the baseline and installed equipment. These adjustments reduced the baseline equipment's energy consumption, reducing the potential for savings.

The evaluation team reduced the hours of operation to account for five harvest periods in the flower rooms per year. Redundancy in the systems was also accounted for. The trend data collected indicated that the cooling capacity of the installed units provides the equivalent of an extra unit for each room. The implementation team did not have access to post-case trend data; therefore, it was assumed that all HVAC units would run continuously at the same capacity based on data collected from the existing facility.

The resulting project savings are shown in Table 17.

Table 17. Summary of Project 2100319 Savings

	Therms
Ex Ante	413,854
Verified	356,468
Realization Rate	86%

Description of Ex Ante Calculations

The implementation team determined that the baseline for this project is equal to the systems serving existing spaces in the facility. The baseline RTU is a packaged unit with modulating electric resistance reheat and direct expansion (DX) cooling with 40 tons of cooling capacity and efficiency equal to the existing Carrier RTUs. The RTUs provide cooling and dehumidification for the genetics room (one RTU), three vegetative rooms (two RTUs each), and ten flower rooms (three RTUs each). Each RTU has a demand of 81 kW at full load, which the implementation team determined using rated full-load amps at 460V. The baseline RTUs also have reheat coils to maintain space temperature. The implementation team used a spreadsheet dehumidification model using watering and feeding schedules for each room to determine latent cooling loads and compressor run times. This model resulted in an estimated 83.3% run time, rounded down to 80% to be conservative. The implementation team established reheat power using trended on-time data from the existing grow rooms and estimated reheat power to average 20.2 kW. They used the results with Equation 13 to establish baseline energy usage.

Equation 13. Baseline Energy Usage

$$Baseline\ Energy\ Usage\ = \left(\sum RTU\ full\ load\ kW * 80\% + 20.2\ kW\right) * 8760\ Hours$$

$$Baseline\ Energy\ Usage\ = 26{,}263{,}764\ kWh$$

The proposed case has a total of (37) Agronomic IQ air handling units (AHUs), each with 32 tons of cooling capacity and 57 kW full-load input power, which the implementation team determined using rated FLA at 460V. The IQ AHUs have liquid-cooled condensers to capture rejected heat from the dehumidification process and use it for reheat. Heat recovery reduces the energy used by electric resistance reheats, and excess energy is rejected through roof-mounted dry coolers. The implementation team estimated dry cooler power using rated full load amps (FLA), resulting in 76.0 kW for each room. They estimated run time using a humidification model like the baseline model, resulting in an 87.5% average run time for the IQ AHUs. They used the results with Equation 14 to establish proposed energy usage.

Equation 14. Proposed Energy Usage

$$Proposed\ Energy\ Usage\ = \left(\sum IQ\ full\ load\ kW * 87.5\% + 76.0\ kW\right) * 8760\ Hours$$

$$Proposed\ Energy\ Usage\ = 22{,}803{,}375\ kWh$$

The implementation team established therm savings by determining the gas energy equivalent of electrical energy savings. The generator vendor provided results of their modeling program that established average system heat rate of 11,960 Btu/kWh. They used that result and electrical energy savings with Equation 15 to establish gas savings.

Equation 15. Ex Ante Gas Savings

$$Gas\ Savings = (Baseline\ Energy\ Usage - \ Proposed\ Energy\ Usage)kWh * 11{,}960\,\frac{Btu}{kWh} \div 100{,}000\ Btu/Therm$$

Early Review Notes

We note that this project received an early review prior to authorization. Early review comments included the following:

- This appears to be the same new construction facility as project 2100318. If so, please ensure the proposed case of one is the baseline of the other, so there is no double counting of savings.
- Alternatively, knowing that the increased number of plants from project 2100318 increases the latent load in the flower rooms, it is also assumed that the per unit cooling tonnage for the proposed case in project 2100318 needed to increase from 32 tons to 40 tons. The evaluation team saw no tonnage increase in the calculations for project 2100318 (additional 32-ton air handlers were added instead), so if the increased latent load in project 2100318 does necessitate larger air handlers, then that should be factored into project 2100318. Either way, the calculations need to be consistent and mutually exclusive.
  - The implementation team did not adjust the calculations to set baseline RTU capacity to equal the proposed capacity. The evaluation team assumed the cooling and dehumidification loads for the baseline operation would equal the proposed operation. The load was determined using trend data for current operating conditions. The calculations and results did not depend on unit capacity.

The evaluation team will investigate the potential interaction between projects 2100318 and 2100319. Project 2200189, which involves installing an efficient gas-fired generator at this facility, was also selected in the evaluation sample. This project was investigated during the on-site visit as well.

Measurement and Verification Plan

The evaluation team will conduct an on-site inspection to verify the installation of the Agronomic IQ air handling systems. The system operation will be discussed with the site representative, and the following questions will be asked.

- Have there been any system changes or operation changes since installation?
- Are all rooms in continuous use? How much time is needed to remove and replace plants?
- If the rooms are not all in continuous use, what are the normal total hours of use for the various rooms? (Genetics, growth, flower)
- Is trend data available for existing and new rooms' electric reheat & compressor status?
- Is natural gas heating used to add CO_2 to the rooms?
- Are there any other dehumidification strategies in place?
- Are these the same rooms that got the glider benches from project 2100318?

Verified Savings

The evaluation team collected compressor operating status for three of the new flower rooms, assuming they represented all new rooms in this facility addition. The IQ unit-rated EER and percent compressor operation was used to estimate the average power for each of the three units in each flower room. This resulted in much lower estimated cooling power, with one unit at 16.6 kW, one at 9.8 kW, and one at 4.2 kW. These values do not include fan motor power. The site representative reported that they had disabled the reheat coils on the new units due to their modulation, which quickly cycles the coils to achieve partial loading and causes problems with the gas generator operation. However, the customer does maintain room temperatures within an acceptable range.

Dry cooler power was estimated using fan motor horsepower, and power was added for a nominal ¼-HP pump for 17.2 kW for each flower room. The two vegetative rooms have larger dry coolers, estimated to have 22.8 kW input power. Annual hours of operation were reduced by ten days to account for five harvest periods per year, taking 48 hours each. These results were used with Equation 16 to establish proposed energy usage.

Equation 16. Verified Proposed Energy Usage

$$Proposed\ Energy\ Usage\ kWh = \left(\sum(IQ\ compressor\ kW) + \sum(Dry\ cooler\ kW)\right) * 8510\ Hours$$

$$Proposed\ Energy\ Usage\ kWh = 5{,}252{,}231\ kWh$$

The evaluation team used the collected data to determine baseline operating conditions. It was assumed that cooling and dehumidifying loads would equal the proposed loads. A new construction baseline using packaged rooftop units (RTUs), a minimum rated 10.0 EER, and 32 tons of cooling capacity with electric resistance reheat were used. It was assumed that baseline fan power would equal the proposed fan power because air movement is needed continuously for pre- and post-case conditions. The baseline RTUs are air-cooled and do not have separate dry coolers, as found in the proposed case.

The evaluation team established RTU power using the same cooling loads found during the current operation. Each unit was assumed to provide the same cooling at 1.2 kW/ton at a 10.0 EER. Reheat power was calculated using data the implementation team collected for their analysis. The data indicated that the reheat coils in the existing rooms were on about 34% of the time, and existing compressors would run about 83% of the time. It was assumed that each RTU had a single 60 kW electric coil to provide reheat. The new rooms were designed with redundancy, so to avoid assuming non-operating RTUs would need to reheat, it was assumed that reheat operation would directly correlate to compressor operation. Reheat power was established for two existing RTUs using Equation 17.

Equation 17. Estimated Baseline Reheat Power Runtimes

$$Reheat\ as\ \%\ of\ compressor\ operation = Average\ Reheat\ run\ time\% \div Average\ Compressor\ run\ time\%$$

$$Reheat\ as\ \%\ of\ compressor\ operation = 41.1\%$$

The results of Equation 4 were then used to establish reheat for each RTU as a function of compressor operation, as shown in Equation 18.

Equation 18. Estimated Baseline Reheat Power

$$Reheat\ Power\ kW = 41.1\% * Compressor\ run\ time\ \% * 30\ kW$$

Annual hours of operation were reduced by ten days to account for five harvest periods per year, taking 48 hours each. These results were used with Equation 19 to establish baseline energy usage.

Equation 19. Verified Baseline Energy Usage

$$Baseline\ Energy\ Usage\ kWh = \left(\sum RTU\ compressor\ kW + Reheat\ kW\right) * 8510\ Hours$$

$$Baseline\ Energy\ Usage\ kWh = 6{,}062{,}669\ kWh$$

The evaluation team converted electrical energy savings to gas savings using the same approach as that taken by the implementation team.

The evaluation team did not adjust gas usage by peak demand because the new facility is not connected to the electrical grid.

The evaluation team also noted that the proposed annual energy usage established by the implementation team was 22,803,375 kWh. In comparison, the total annual output of the gas generators is expected to be about 16,000,000 kWh. The estimate of 5,252,231 kWh energy usage does not include fan power, which is estimated to be approximately 2,000,000 kWh, for about 45% of energy usage in this addition. Most of the remaining electric use of the facility will be for the grow lights. Note that there is no electrical connection between the existing building and the addition, and no energy is shared between the old and new areas.

Project 2200055

Project ID#:	2200055
Measure:	HVAC
Savings:	1,002,298 kWh; 114.4 kW
Facility Type:	Educational
End Use:	HVAC
Sampled For:	Electric
Wave:	3

Measure Description

In two dormitories, the customer is replacing an existing direct digital controls (DDC) system that is past its useful life with a new system. These upgrades will allow for reliable scheduling of the buildings, proper economizer control, and functional discharge air temperature (DAT) resets. The customer is also improving the operation of its two cooling plants with new control strategies. These strategies include implementing a chilled water reset based on outside-air dry bulb temperature and a condenser water reset based on outside-air wet bulb temperature to optimize chiller performance.

Key Findings

The evaluation team found the ex ante calculations to be reasonable. This project was subject to an early review, and the evaluation team made the changes recommended during the early review in the verified savings analysis.

The resulting project savings are shown in Table 18. Note that although the resulting realization rate is 100%, the cooling plant savings increased slightly, and the dorms controls savings decreased slightly as a result of the changes made by the evaluation team.

Table 18. Summary of Project 2200055 Savings

	kWh	kW
Ex Ante	1,002,298	114.4
Verified	1,002,989	114.5
Realization Rate	100%	100%

Summary of the Ex Ante Calculations

Savings for the cooling plant optimizations were modeled using data from an existing cooling season which was then adjusted using the proposed operating parameters. The savings for the air handling units (AHUs) and energy recovery ventilators (ERVs) in the dormitories were estimated using a custom 8,760 hourly spreadsheet that calculates the savings from adjusting minimum airflows, discharge air temperature resets, and equipment scheduling. Table 19 and Table 20 below list the energy efficiency measures implemented at the cooling plants and dormitories.

Table 19. Cooling Plant Improvements

Measure	Baseline System	Proposed System
Chilled Water Reset	Constant chilled water temperature setpoint of 45°F	Chilled water temperature setpoint resets between 45°F and 50°F at outdoor air temperatures of 75°F and 55°F, respectively
Condenser Water Reset	Constant condenser water temperature setpoint of 78°F	Condenser water temperature setpoint resets to 7°F above the ambient wet bulb temperature.

Table 20. Dorm Room Improvements

Measure	Baseline System	Proposed System
Scheduling	Units always operating in occupied mode	Units scheduled to operate in occupied mode when students are present. Units operate in unoccupied mode over winter break and the summer.
DAT Reset	Units maintain a constant discharge air temperature of 63°F	Discharge air temperature setpoint is reset between 45°F and 60°F based on outdoor-air dry bulb temperature

Early Review Notes

We note that this project received an early review prior to authorization. Our early review comments included the following:

Condenser Water and Chilled Water Reset Savings for Cooling Plant Workbooks

- The evaluation team recommends individually modeling each cooling tower fan's speed and associated power consumption. After the baseline consumption is modeled with the sum of the individual fan consumptions, the proposed model can apply the appropriate fan penalties to the baseline's combined power consumption to calculate the proposed condenser fan consumption. Figure 9 and Figure 10 below show what can happen if the fans are modeled as a group of fans running at an average speed. Even though three fans run at roughly the same rate in the five minutes before and after the fourth fan runs (Figure 9), when the fourth fan runs at a significantly lower speed, it reduces the calculated power consumption for that period (Figure 10).
    - This recommendation was not implemented in the ex ante calculations, so the evaluation team updated the GCC and RENCO chilled water plant calculations to calculate each cooling tower fan speed and associated power consumption individually.

Figure 9. Fan Quantity and Average Speed

AC	AD
No. of Fans Runnin	Average Speed
3	97.57
4	83.78
3	99.37
4	74.83

Figure 10. Fan Speed and Cooling Tower kW Consumption

CT-1 Speed	CT-2 Speed	CT (kW)
98%	0%	56
84%	0%	53
99%	0%	58

- The evaluation team recommends the following formula for all fan and pump power calculations to improve savings accuracy. The data used to represent the fan speed on a scale of 0-100% needs to be adjusted so that 0% is associated with the fan's minimum speed, usually between 12-25Hz when enabled. 100% speed should be related to the motor's power consumption at 60Hz. We note that the model already does the latter.

  This recommendation also applies to the *Dormitory Custom Workbook* calculations.

  - The implementation team revised the ex ante calculations to utilize Equation 20 for any fan power calculations.

Equation 20. Fan and Pump Power Calculation Equation

$$HP_C = HP_D\left[\left(1-\sqrt{\frac{H_{min}}{H_D}}\right)*\left(\frac{F_C}{F_D}\right)+\sqrt{\frac{H_{min}}{H_D}}\right]^3$$

Where

H_D = Design pressure

H_{min} = Minimum static pressure setpoint

F_D = Flow at design conditions

F_C = Flow at current conditions

HP_D = Horsepower at design conditions

HP_C = Horsepower at the current condition

- The evaluation team noted that this revision was not implemented in the ex ante calculations. The calculations were revised to include a VFD efficiency of 97%.

- Figure 11 below shows the calculation of the peak power consumed. To be more accurate, the evaluation team recommends including VFD efficiency at least with a constant value to calculate the peak kW.
  - The evaluation team noted that this revision was not implemented in the ex ante calculations. The calculations were revised to include a VFD efficiency of 97%.

Figure 11. Cooling Tower Fan kW Calculation

1	*Chillers Cooling Tower Fan*				
2		**HP**	**LF**	**Motor Eff**	**kW**
3	**CT-1 Fan**	30	0.8	91%	19.7
4	**CT-2 Fan**		0.8	91%	0.0

- The calculation does not model the potential impact of additional energy being consumed from the distribution pumps transporting water from the plant to campus buildings. The evaluation team recommends including a pumping penalty for these distribution pumps when the chilled water is reset above its minimum set point.
  - This recommendation was not implemented in the ex ante calculations and could not be included in the verified calculations because the customer and vendor could not provide additional information on the chilled water pumping system to the evaluation team.

Dormitory Custom Workbook

- It is unclear what the max kW calculation refers to on each input sheet. See Figure 12 below for an example peak kW calculation. To be more precise, the evaluation team recommends separately breaking out brake horsepower, motor efficiency, and VFD efficiency.

Figure 12. Total Fan kW Calculation Example

	Baseline	Proposed
Unit CFM	30000	=B3
Min OA CFM	6000	=B4
RAT	trend calc	75
Total Max SF kW	=35.39*0.746	=B6
Total Max RF kW	=18.21*0.746	=B7
Heating AFUE	0.8	0.8
Cooling (kW/Ton)	1.18	1.18

  - This recommendation could not be implemented because the customer and vendor could not provide information on the supply and return fan nominal HPs.

- For the AHU3_BLX.01.11.22 calculation, the maximum zone discharge air temperature of 105°F, seen in Figure 13, is higher than the other zones consistently modeled in other calculations. The evaluation team recommends confirming the maximum zone discharge air temperature for this zone and providing documentation confirming the equipment was designed to supply that high of a temperature.

Figure 13. Discharge Air Temperature Reset Schedule for AHU

Zone Level Average SAT			
	Baseline	Proposed	
OAT Max Zone Heating	10	10	deg F
Max Zone DAT	105	105	deg F
OAT Min Zone Heating	85	75	deg F
Min Zone DAT	55	55	deg F

  - The vendor provided screenshots of the proposed control system, which verifies that some of the AHUs have a maximum zone discharge air temperature setpoint greater than 100°F. This value was not updated in the verified calculations.

- For the AHU3_BLX.01.11.22 calculation, Figure 14 shows the outside air reset as resetting the discharge air temperature between 55°F and 65°F. However, the proposed OSAT reset sheet shows discharge air temperature values between 55°F and 65°F outside air temperature calculated as being higher than the maximum discharge air temperature of 65°F. See Figure 15 below for an example. The evaluation team recommends updating this equation to calculate the discharge air temperatures between 55°F and 65°F correctly and to cap the values outside of this range to a maximum of 65°F and a minimum of 55°F.

Figure 14. Outside Air Reset Schedule

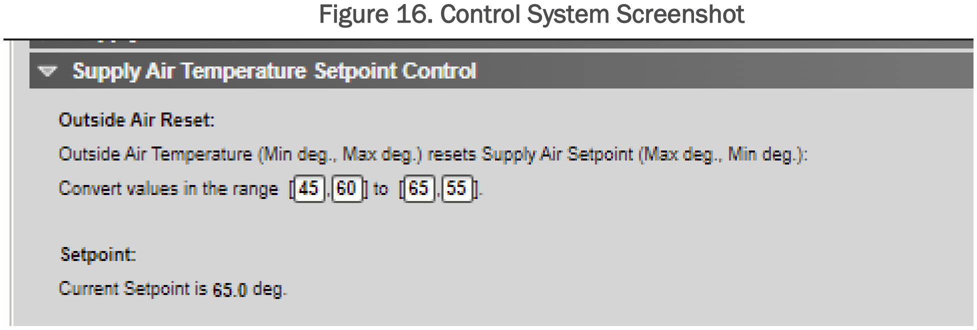
OAT Reset			
	Baseline	Proposed	
OAT Max Heating Reset	70	55	deg F
DAT Max Heating Reset	58	65	deg F
OAT Max Cooling Reset	80	65	deg F
DAT Max Cooling Reset	58	55	deg F

Figure 15. Calculated Discharge Air Temperature Set Point

AHU 1		
OSA	Baseline	Proposed
57	58	66
61	58	67
61	58	68
61	58	69
61	58	70
59	58	71
59	58	72
61	58	73
61	58	74
61	58	75
63	58	76
61	58	77
59	58	78
57	58	79
56	58	66
60	58	67
59	58	68
56	58	69
56	58	66
56	58	67
57	58	66
61	58	67
63	58	68
64	58	69
63	58	70

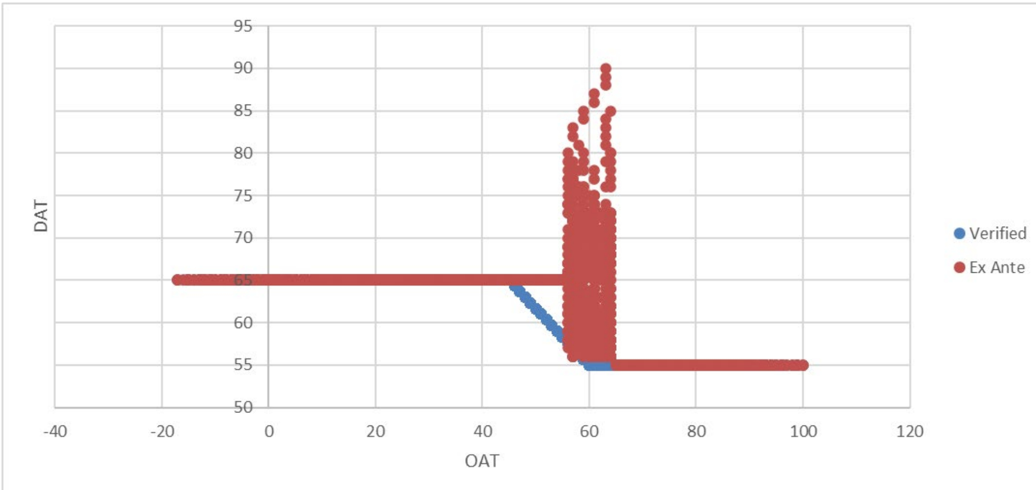
- The evaluation team confirmed the supply air temperature reset control points with the vendor, as shown in Figure 16. The formulas in all the dorm AHU calculations were updated to model the supply air temperature reset correctly. Figure 17 below illustrates the difference between the ex ante and verified DAT reset formulas. Note that the DAT reset inputs were adjusted to match the values shown in Figure 16.

Figure 16. Control System Screenshot



Note: Used as confirmation of supply air temperature reset strategy

Figure 17. Ex Ante vs. Verified DAT Reset Formula Results



- For the XXXXX_AHU_3.0 0.1.11.22 (name redacted for confidentiality reasons) calculation, Figure 18 shows that the outside reset does not have a deadband, so the discharge air temperature alternates between the max heating reset to the max cooling reset as the outside air temperature goes above and below 55°F OAT as shown in Figure 19. Typically, there is a deadband between the outdoor air temperature limits where the discharge resets linearly, so equipment doesn't short cycle. The evaluation team recommends confirming and documenting that this was the intent of the reset. If this was not the intent, we recommend fixing the calculation to include a deadband.

Figure 18. Outside Air Reset Schedule

OAT Reset			
	Baseline	Proposed	
OAT Max Heating Reset	55	55	deg F
DAT Max Heating Reset	54	65	deg F
OAT Max Cooling Reset	55	55	deg F
DAT Max Cooling Reset	54	55	deg F

Figure 19. Calculated Outside Air Temperature Reset

DAT Reset		
OSA	Baseline	Proposed
51	55	65
52	55	65
53	55	65
54	55	65
57	55	55
61	55	55
61	55	55
61	55	55
61	55	55
59	55	55
59	55	55
61	55	55
61	55	55
61	55	55
63	55	55
61	55	55
59	55	55
57	55	55
54	55	65
52	55	65
48	55	65

- The evaluation team updated the OAT Max Cooling Reset input to 60°F to allow for a deadband.

Summary of the Verified Calculations

The evaluation team reviewed the ex ante calculations to ensure the implementation team made the recommended revisions in the early review. It was found that not all of the recommendations were implemented in the ex ante calculations, so the evaluation team made the necessary revisions to the chilled water plant and dormitory calculations, which included updating the formula used to calculate the cooling tower fan energy consumption in the chilled water plant analysis and updating the discharge air temperature setpoint formula used in the dormitory calculations. The updates made to the chilled water plant calculations increased the overall project savings because the cooling tower fan penalty associated with resetting the condensing water temperature was reduced. The revisions to the discharge air temperature formula resulted in decreased project savings. This is because the discharge air temperature setpoint formula used in the ex ante calculations contained an error that resulted in higher discharge air temperature setpoints than the high limit cutoff of 65°F. A higher discharge air temperature setpoint requires less cooling energy and results in more savings. Therefore, when the error was corrected and the discharge air temperature setpoint was reduced, the cooling usage increased, resulting in reduced project savings.