Appendix C: Site Visit Reports

Project Level Results

The following table summarizes the project level results of the evaluation team's site visit analysis ranked by ex ante savings.

Table 1: Summary of Project Level Site Visit Results

Project ID	Sample			Ex Ante Savings			Ex Post Savings			Realization Rate		
	Fuel Type	Wave	Stratum	kW	kWh	Therm	kW	kWh	Therm	kW	kWh	Therm
600336	Electric	1	1	5	51,633	0	8	35,771	0	152%	69%	N/A
700213	Electric	1	1	5	36,299	0	5	50,332	0	108%	139%	N/A
700647	Electric	1	1	19	108,439	0	14	120,334	0	74%	111%	N/A
700116	Electric	1	2	46	252,285	0	32	158,163	0	70%	63%	N/A
700120	Electric	1	2	23	199,533	-1,163	0	374,225	-9,337	0%	188%	803%
700386	Electric	1	2	0	193,623	0	0	99,999	0	N/A	52%	N/A
700633	Electric	1	2	59	513,962	29,186	37	224,425	15,794	63%	44%	54%
700959	Electric	1	2	61	266,234	0	0	257,554	0	0%	97%	N/A
601349	Electric	1	3	498	1,424,985	0	199	1,057,327	0	40%	74%	N/A
700002	Electric	1	3	230	2,817,647	0	277	2,274,400	0	120%	81%	N/A
700020	Electric	1	3	443	4,099,074	0	481	4,366,938	0	109%	107%	N/A
700069	Electric	1	3	151	2,321,851	0	354	2,213,219	0	235%	95%	N/A
700132	Electric	1	3	135	1,186,396	0	29	728,143	0	21%	61%	N/A
700155	Electric	1	3	135	1,177,502	0	134	1,177,502	0	100%	100%	N/A
700379	Electric	1	3	168	1,472,364	0	277	2,425,232	0	165%	165%	N/A
601262	Gas	1	1	0	0	19,762	0	0	22,181	N/A	N/A	112%
700159	Gas	1	1	30	259,347	21,942	6	54,822	22,255	21%	21%	101%
600059	Gas	1	2	0	0	113,482	0	0	846,227	N/A	N/A	746%

Project ID	Sample			Ex Ante Savings			Ex Post Savings			Realization Rate		
	Fuel Type	Wave	Stratum	kW	kWh	Therm	kW	kWh	Therm	kW	kWh	Therm
700026	Gas	1	2	0	0	90,510	0	0	2,851	N/A	N/A	3%
700447	Gas	1	2	3	27,287	62,748	3	28,569	71,051	85%	105%	113%
700448	Gas	1	2	0	0	49,183	0	0	11,853	N/A	N/A	24%
700036	Electric	2	1	12	104,566	0	12	58,967	0	100%	56%	N/A
701319	Electric	2	1	26	129,713	0	12	80,126	0	48%	62%	N/A
800034	Electric	2	1	6	48,715	0	16	55,247	0	280%	113%	N/A
601285	Electric	2	2	247	1,244,295	0	90	4,252,927	0	36%	342%	N/A
700047	Electric	2	2	-44	2,036,742	0	-44	768,930	0	100%	38%	N/A
700190	Electric	2	2	39	619,782	0	62	673,240	0	161%	109%	N/A
700394	Electric	2	2	219	1,840,467	0	212	1,782,123	419,902	97%	97%	N/A
700941	Electric	2	2	97	851,391	0	37	183,824	0	38%	22%	N/A
600387	Electric	2	3	1,102	9,203,904	0	1,384	11,880,816	0	126%	129%	N/A
700004	Electric	2	3	1,507	13,205,002	0	999	8,313,095	0	66%	63%	N/A
700016	Electric	2	3	721	5,511,828	0	210	2,517,216	0	29%	46%	N/A
700028	Electric	2	3	1,076	9,424,816	0	1,017	9,567,157	0	95%	102%	N/A
700058	Gas	2	1	-3	-13,357	38,672	-3	-12,770	38,945	99%	96%	101%
700145	Gas	2	1	1	12,179	8,628	1	0	8,628	100%	0%	100%
700242	Gas	2	1	51	442,792	627	42	303,242	591	84%	68%	94%
700641	Gas	2	1	0	0	22,125	0	0	11,297	N/A	N/A	51%
600063	Gas	2	2	0	0	292,126	0	0	294,262	N/A	N/A	101%
700393	Gas	2	2	0	0	71,742	0	0	32,418	N/A	N/A	45%
700396	Gas	2	2	0	0	256,030	0	0	532,073	N/A	N/A	208%
700464	Gas	2	2	0	0	49,629	0	0	11,971	N/A	N/A	24%
Total				**7,065**	**61,071,296**	**1,125,228**	**5,903**	**56,071,097**	**2,332,963**	**N/A**	**N/A**	**N/A**

600059 Project Information

Project ID#:	600059
Measure:	Steam System Leak Repairs
Ex Ante Savings:	0 kWh; 0 kW; 113,482 Therms
Facility Type:	Manufacturing

Measure Description

This project consists of the repair of a steam system to fix a total of 235 leaks that were identified during a system audit. The identified leaks have steam loss rates varying from 4 lbs/hr to 260 lbs/hr, as summarized in Table 2.

Table 2: Summary of Steam Leak Audit

Quantity	Leak Size (lbs/hr)
45	4
77	16
102	65
11	260

Summary of the Ex Ante Calculations

The ex ante savings for this project are 113,482 therms.

To determine the ex ante savings for this project, it was assumed that each of the 235 steam leaks identified in the steam audit have an average steam loss rate of 5 pounds per hour, yielding a total steam leak rate of 1,175 pounds per hour. It is assumed that the entering supply water has a specific energy of 100 Btu/lb. The steam system runs at 250psi, for which the specific energy of saturated vapor is 1,202.5 Btu/lb. The difference in specific energy between the supply water and the steam is 1,102.5 Btu/lb, and multiplying this by the steam loss rate of 1,175 pounds per hour yields an energy loss rate of 1,295,438 Btu/hour. This is divided by 100,000 to convert from Btu/hour to therms/hour, and multiplied by 8,760 hours per year to determine the annual gas savings. The resulting annual savings is 113,480 therms.

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

Table 3: Summary of Project Savings

Measure	Therms
Steam System Leak Repairs	113,482

Measurement and Verification Plan

IPMVP Option C, Partially Measure Retrofit Isolation, was used to establish savings for this measure.

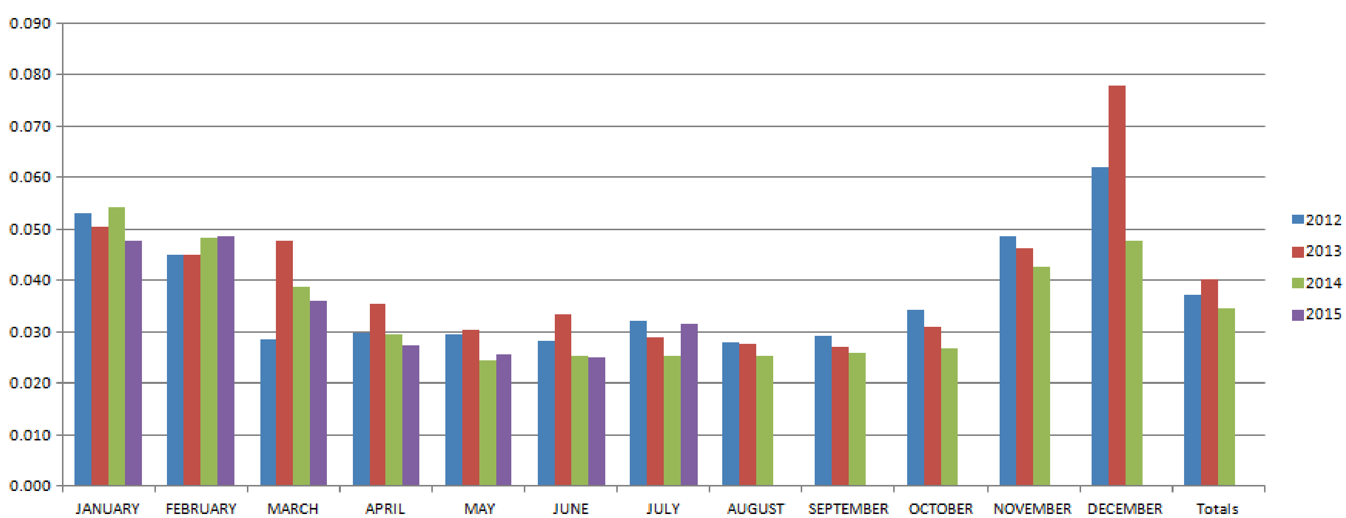
A site visit was completed, during which the customer was interviewed about the work that was completed for this project. During the site visit the following information was collected and/or verified:

- Customer was asked to verify that the leaks specified in the system audit (shown in Table 2) are accurate.

- Steam system specifications recorded:
  - Steam pressure
  - Boiler efficiency – has a boiler tune-up been done recently? Are flue gas test results available?
  - Makeup water temperature
- Was the steam system temperature/pressure ever changed?
- Was the system ever shut down, or does it operate 8,760 hours per year?
- Was the steam used for process, HVAC, or both?
- Was the boiler serving the steam system on its own gas meter?
- Were gas use records available?
- Were any other projects completed, facility changes, etc. recently that would cause the gas use of the facility to change?

A site visit was completed on July 16, 2015, during which a facility engineer provided access to the central plant where the steam boilers are located and where the steam system is monitored and controlled. The steam leak identification and repairs were repaired by an outside contractor within a 1-year timeframe. The steam is used primarily for process heating, though it is also used to heat the facility during the winter. The facility engineer was able to provide a graph showing the gas consumption per unit produced since the beginning of 2012. The gas consumption for facility heating is not broken out from the gas consumption for process heating, so there is some weather dependency to the gas consumption per unit produced. The provided graph is shown below in Figure 1. The facility engineer explained that production levels at the facility have steadily increased over the last few years. The steam system is in use all year, is kept at 250 psi all the time, and no significant changes have been made to the steam system besides the leak repairs.

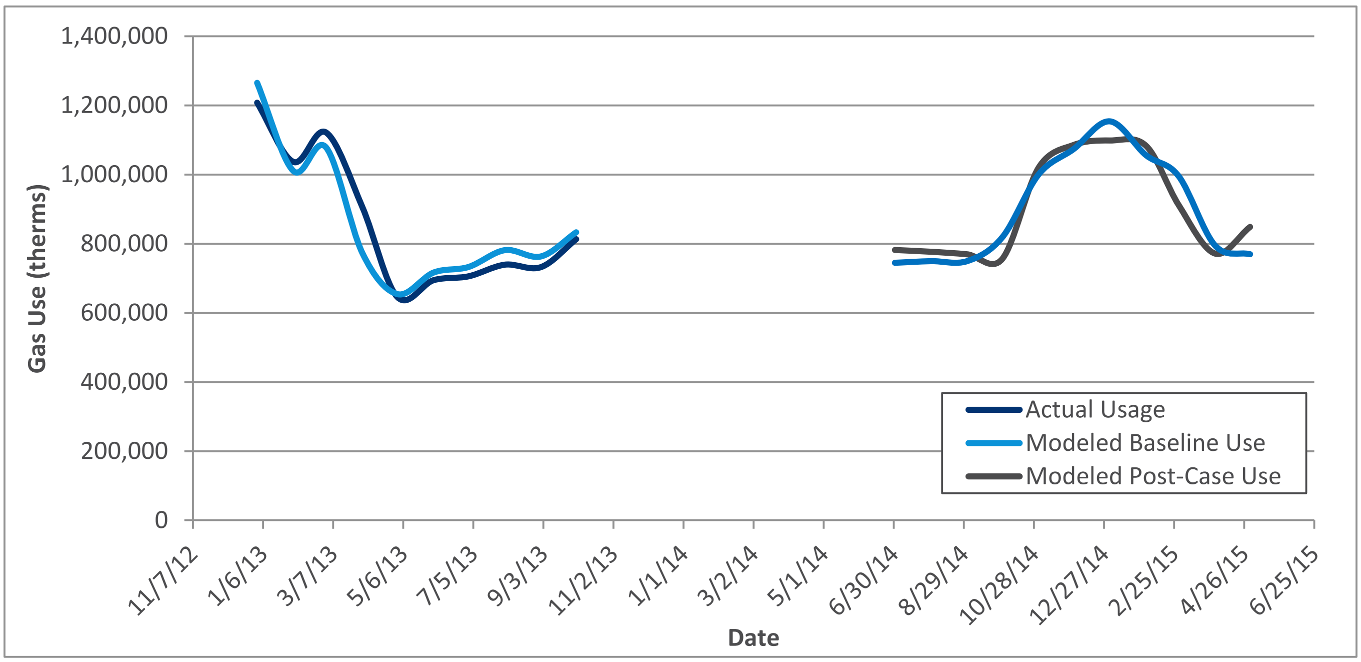
Figure 1: Provided Graph of Gas Consumption per Unit Production



Summary of Ex Post Savings Calculations

The information presented in Figure 1 of gas consumption per unit production was used along with the billed gas use of the facility to determine the monthly production at the facility. The resulting production numbers show that the production at the facility has increased by approximately 15% since the start of the project, which is consistent with the information provided by the customer. To determine the gas savings for this project, a billed data regression was completed, in which the gas use of the facility was normalized to local historical weather data and to the monthly post-case production. The billed data regression completed for this project takes into account the weather-dependency of the gas use, the number of days in each month, and the monthly production levels. The modeled baseline and post-case gas use compared to the actual billed use is shown below in Figure 2.

Figure 2: Modeled and Billed Gas Use Comparison



To check the accuracy of the modeled gas use compared to the actual gas use, the coefficient of variance (CV) was found for both the baseline and the post-case. The CV should be less than 20% for modeled use to be considered a “good” fit, and the CV values for the baseline and post-case gas use were found to be 6.1% and 5.3%, respectively, both within the target CV of 20%. Using TMY3 weather data to determine the baseline and post-case gas use during a typical meteorological year, it was found that the baseline and post-case annual use are 11,669,363 therms and 10,823,136 therms, yielding savings of 846,227 therms. This is significantly greater than the ex ante savings of 113,482 therms.

The ex post savings are significantly greater than the ex ante savings, likely due to the approach taken to estimate savings. Documentation included with the project documentation indicates that the identified and repaired steam leaks ranged in size from 4 lbs/hr to 260 lbs/hr, with a weighted average of 46 lbs/hr and resulting gas savings of 1,217,644 therms. However, for the ex ante savings calculations it was assumed that the average steam leak was only 5 lbs/hr, yielding annual savings of 113,482 therms. The reason that 5 lbs/hr was used for the average steam leak size is unknown. The savings determined with the billed use analysis described above is much closer to the savings found using the list of leaks ranging from 4 lbs/hr to 260 lbs/hr.

A summary of the ex post savings can be found in Table 4.

Table 4: Summary of Ex Post Savings

	kW	kWh	Therms
Ex Ante	0	0	113,482
Ex Post	0	0	846,227
Realization Rate	N/A	N/A	746%

600063 Project Information

Project ID#:	600063
Measure:	Boiler and Chiller System Improvements
Ex Ante Savings:	0 kWh; 0 kW; 292,126 Therms
Facility Type:	Medical

Measure Description

This project consisted of additions and alterations to an existing hospital's heating and cooling systems. The hospital is a natural gas only customer, so only gas savings are claimed. The facility is a total of 1,060,825 square feet including a 151,320 square foot addition. The existing system consisted of (3) 700 BHP steam boilers, (3) high efficiency water boilers, and (1) 100 ton absorption chiller. Of the existing boilers, (1) 700 BHP boiler and (1) of the high efficiency water boilers were standby boilers. The project included installing (2) new 4,000 MBH condensing boilers, installing (1) 100 ton absorption chiller to recover waste heat from the existing chiller system, and (2) 150 BHP steam boilers to replace one of the existing 700 BHP steam boilers.

Summary of the Ex Ante Calculations

The ex ante savings for this project are 0 kWh, 0 kW, and 292,126 therms. No project calculations were provided in the project documentation; however, the project documents mention that a Trane Trace model of the facility with the project alterations and additions was completed.

The ex ante savings for this measure are presented in Table 5.

Table 5: Ex Ante Claimed Savings

Measure	kWh	kW	Therms
Boiler and Chiller System Improvements	0	0	292,126

Measurement and Verification Plan

IPMVP Option D, Calibrated Simulation, were used to establish savings for this project. A site visit was completed, where the following activities were conducted and information collected:

- Visually verified the installation of the new equipment
  - (2) 150 BHP Steam boilers
    - Make & model:
    - Input/output capacity:
    - Combustion efficiency:
  - (2) 400 MBH Condensing boilers
    - Make & model:
    - Input/output capacity:

        - Combustion efficiency:
    - (1) 100 ton absorption chiller recovering heat from the chiller system condensing loop
        - Make & model:
        - Input/output capacity:
        - Operating curve/ efficiency:
- Verified the removal of :
    - (1) 700 BHP steam boiler
        - Make & model:
        - Input/output capacity:
        - Combustion efficiency:
- Verified the following were maintained:
    - (1) 700 BHP steam boiler
        - Make & model:
        - Input/output capacity:
        - Combustion efficiency:
    - (1) 700 BHP steam boiler (back-up)
        - Make & model:
        - Input/output capacity:
        - Combustion efficiency:
    - (1) High efficiency water boiler
        - Make & model:
        - Input/output capacity:
        - Combustion efficiency:
    - (1) High efficiency water boiler
        - Make & model:
        - Input/output capacity:
        - Combustion efficiency:

- (1) High efficiency water boiler(back-up)
  - Make & model:
  - Input/output capacity:
  - Combustion efficiency:
- (1) 100 ton absorption chiller
  - Make & model:
  - Input/output capacity:
  - Operating curve/ efficiency:

- Interviewed the site representative concerning:
  - The system operation, setpoints, etc.
  - Operating hours and any lockout periods, including seasonal use
  - Pre & post-case boiler sequencing
  - Pre & post-case controls(hot water reset schedules)
  - The demand load that the system meets, if the system is used for domestic hot water, HVAC, process, etc.
  - Gas usage at the facility
  - The boiler economizers, temperatures, efficiency, flash steam recover, etc.
  - If the system is a steam system, is it open or closed to the atmosphere
- Verified that the boiler system does not contain other boilers
- If trending was available, trended:
  - Hot Water GPM, hot water temperature (supply & return), & gas consumption
  - Lbs/hr of steam
  - Chilled water GPM, chilled water temperature (supply & return), & chiller kW
  - Absorption chillers GPM, chilled water temperature (supply & return)

Description of Verification

A site visit was completed on 08/27/2015. The site representative was interviewed, the equipment was inspected, and the equipment setpoints were collected.

The project was found to consist of replacing (1) 700 HP boiler with (2) 150 HP boilers, shifting part of the boiler load from the remaining (2) 700 HP boilers to (3) 4,000 MBH condensing boilers, and adding (1) 100 ton heat recovery chiller to meet part of the hospitals base heat load. The hospital gas equipment was found to consist of the boilers, which meet all space heating loads and domestic hot water needs, and (1) laundry dryer.

The pre-case system consisted of (3) 700 HP boilers meeting the facilities entire heating and domestic hot water load. The domestic hot water in the pre-case is serviced by hot water heat exchanger tanks, which were serviced by a steam to hot water heat exchanger. In the pre-case, part of the facility was using hot water for heating and part was using steam for heating.

The post-case system consists of (1) 100 ton dedicated heat recovery Multistack chiller that operates at full load over the course of the entire year. The chiller is used to supplement the baseload on the newly installed 4,000 MBH condensing boilers. Of the installed (4) condensing boilers, (2) boilers were claimed as part of the project and (2) boilers were assumed to be backup; in actuality, (3) condensing boilers are required on cold days in the winter, though the third boiler is required for only approximately 100 hours per year. The steam boiler side operates both the (2) new 150 HP boilers and (1) of the (2) remaining 700 HP boilers. The hot water side of the system meets all of the facility's domestic hot water demands and the hot water heating demands. The steam system side meets the facility's steam heating demands.

It should be noted that the project documents list the pre-case system as having a (100) ton heat recovery chiller, but this was found to not be the case due to the heat recovery chiller that was found onsite having been installed late in 2014 and being brought online as part of the project in the spring of 2015.

The post-case steam system was found to operate the (2) 150 HP boilers in a lead/lag configuration. When the outdoor air temperature is lower than 70°F, the facility boiler staff manually turns on (1) 700 HP boiler as the lead boiler with the (2) 150 HP boilers being second and third in the sequence. During the summer time, only (1) of the 4,000 MBH hot water condensing boilers is needed at about 40% load. During the winter, on cold days, (2) of the 4,000 MBH hot water condensing boilers are needed at full load capacity and (1) at low to high capacity.

Calculation Description

The completed ex post calculations consisted of an ASHRAE bin analysis of the pre and post-case boiler systems, which took into account the boiler constant and variable loads, boiler cycling, boiler shell losses, piping heat loss, boiler efficiency curves, and a variety of less influential factors. The boiler models used TMY3 typical weather data for the region to normalize the pre and post-case boiler systems operation, based on the number of hours at each temperature bin.

In the pre-case, the entire heat load was met by (3) steam lead/lag boilers. In the post-case, the heat recovery chiller was used to offset a portion of the hot water boilers constant load. The remaining hot water constant load and variable load was met by the facility's (3) 4,000 MBH condensing boilers. The remaining portion of the load was applied to the improved boiler system, which operates the (2) new 150 HP boilers in lead/lag configuration and then switching over to the (1) 700 HP steam boiler at approximately 70°F as the lead boiler. The pre-case boiler load was estimated based on the site representative's description of operation and further established based on a bill regression of the facility's pre-case system. A bill regression of the post-case system could not be performed because of new construction at the facility. The post-case hot water usage loads were established based on the observed hot water boiler loads during a hot day in the summer and based on the site representative's description of the hot water boiler operation on the coldest days in the winter. The heat recovery chiller was assumed to be fully loaded all year based on the site representative's description. The post-case steam boiler load was established by subtracting the hot water boiler load from the pre-case boiler load and subtracting the heat recovery chiller's load.

The savings for this project were consistent with the Ex Ante analysis. A summary of the Ex Post savings can be found in Table 6.

Table 6: Summary of Ex Post Savings

	kW	kWh	Therms
Ex Ante	0	0	292,126
Ex Post	0	0	294,262
Realization Rate	N/A	N/A	100.7%

600387 Project Information

Project ID#:	600387
Measure:	VFDs installed on Bag house fans
Ex Ante Savings:	1102 kW; 9,203,904 kWh; 0 Therms
Facility Type:	Industrial

Measure Description

This project consisted of installing VFDs on the (4) baghouse fans for a new construction baghouse. Of the (4) fans installed, (3) were claimed due to one being a back-up fan. The project also included a cooling penalty for the added heat load to the electrical room, which is conditioned. The additional heat load is due to the VFD inefficiency.

Summary of the Ex Ante Calculations

The ex ante calculations were provided in the project documentation. The HVAC annual energy usage and the fan annual energy usage was calculated for both the baseline and installed (post) cases. The fan power (kw) for both cases was calculated by CFM bins with the percentage of time being used to calculate the annual usage (kWh) at each bin.

The fan power is calculated using the following equation:

$$Fan_{kW} = 0.746 * \frac{Fan_{BHP}}{Motor_{eff} * VFD_{eff}}$$

The Fan BHP was defined according to hard-coded values for each of the CFM levels and therefore the specific equations for how these values were calculated is not known.

It should be noted that in the pre-case the fan speed was assumed to be at 100% over all CFM levels with the fan load factor decreasing as the CFM level decreases. In the post-case, the VFD modulates the fan speed to match the CFM requirement, maintaining a constant fan load factor.

The ex ante savings for this measure are presented in Table 7.

Table 7: Ex Ante Savings

Measure	Therms	kWh	kW
VFDs installed on Bag house fans	0	9,203,904	1102

Measurement and Verification Plan

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

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

The site representative was interviewed about the typical operation of the fans and the process they serve. In particular, the site representative was interviewed concerning the number of heats[1] that the bag house serves per day, the CFM level during each stage of the heat, the number of heat lines served, and the typical load profile over an average day that the fans experience. In addition, the site representative was interviewed concerning the number of heats completed on a daily, weekly, monthly, and annual basis. Data concerning the fan operating speeds, fan power, heat profile, or number of heats per day was collected from the site representative if available. The site representative was interviewed concerning the facility's expected operation over the course of the next year and concerning their previous year's operation, specifically concerning how many heats the bag house is expected to serve. Any available metered data or operating profiles was collected.

Description of Verification

A site visit was completed on 09/14/2015. The site representative was interviewed and the equipment was inspected. VFDs were confirmed to be installed on each of the (4) 1,750 HP baghouse fans with (1) fan being a back-up fan. The project was confirmed to be a new construction project. No heats were scheduled during the time of the site visit, so CFM rates and fan power could not be recorded. During the time of the site visit, the baghouse was operating in idle. The electrical room was confirmed to be air conditioned.

The site representative was interviewed concerning the heat operating profiles and the number of heats per day. A list of required CFM levels for a single heat was acquired and the daily number of heats at the time of the site visit was found to be only (15) heats. The site representative could give no information on potential changes in operation due to that information being strictly confidential and not available to anyone outside of the company. The facility was found to operate two separate lines over the course of the day with half of the heats being conducted on one line and the other half being conducted on the other line. No metered or trended data was available and no production data of any kind was available.

Calculation Description

The ex post calculations consisted of modifying the ex ante calculations based on the gathered data. Using the CFM rates per heat, a baghouse CFM profile was created assuming that the heats are divided between the two production lines with the heats per each line being equally distributed throughout the day. Specifically, the CFM requirements were calculated based on which point of the heat each line is experiencing during each minute of the day. The CFMs were then binned into every CFM level combination with the number of minutes the baghouse is at each bin over the course of a normal day assuming (15) heats per day. The fan BHP for both the baseline and post cases was then calculated based on a CFM versus BHP curve developed from the ex ante calculation's hard-coded BHP values at the various CFM levels. This was done because the site representative was not able to provide any fan information or fan curves. The total fan kW was then calculated using the same equation as the ex ante calculations:

$$Fan_{kW} = 0.746 * \frac{Fan_{BHP}}{Motor_{eff} * VFD_{eff}}$$

The increase in savings is due to the reduction in the number of heats that the facility operates per day from the ex ante calculation assumed (32) heats per day to the (15) heats per day that were occurring during the

[1] A heat is one unit batch process on an individual production line at the facility.

site visit. At (15) heats per day, that bag house operates in idle mode a significant more amount of time than at (32) heats per day. The motor efficiency curve used in the ex post calculations was based on motor master. A motor master curve was used to calculate the savings due to the fact that the ex ante provide motor curve does not appear to be consistent with typical motor curve and due to the fact that no information on the motor curve or sources for the motor curve was provided. A summary of the ex post savings can be found in Table 8.

Table 8: Summary of Ex Post Savings

	kW	kWh	Therms
Ex Ante	1102.0	9,203,904	0
Ex Post	1356.3	11,880,816	0
Realization Rate	123%	129%	N/A

700002 Project Information

Project ID#:	700002
Measure:	Replace Metal Halide lights with LED fixtures with occupancy sensors
Ex Ante Savings:	2,817,647 kWh; 230.12 kW
Facility Type:	Industrial

Measure Description

The customer replaced (512) 400W metal halide (MH) light fixtures, (445) 250W MH fixtures, and (6) 1000W MH fixtures with (963) 146W LED fixtures. The project documentation indicates that all of pre-implementation fixtures operated continuously and (663) of the installed fixtures are controlled by newly-installed occupancy sensors and operate an average of 477 hours per year.

Summary of the Ex Ante Calculations

The ex ante savings for this project are 230.12 kW and 2,817,647 kWh.

The baseline for this project was considered to be the existing light fixtures. It was assumed that the input power was 455W for the 400W MH fixtures, 295W for the 250W fixtures, and 1080W for the 1000W MH fixtures. The input wattage of the post-retrofit LED fixtures was 146W according to the manufacturer literature.

All of the lights that were in place prior to the completion of the project operated continuously. Of the (963) LED fixtures installed for this project, (300) operate continuously just as the pre-implementation fixtures did, and (663) are controlled by occupancy sensors. A lighting/occupancy study completed at the facility indicates that the lights controlled by occupancy sensors are expected to operate only 5.44% of the time, or 477 hours per year.

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

$$Energy\ savings\ (kWh) = Baseline\ FL\ kW \times \frac{8{,}760\ hours}{year} - Installed\ FL\ kW \times \frac{post - implementation\ hours}{year}$$

$$Demand\ savings\ (kW) = \ Baseline\ FL\ kW - Installed\ FL\ kW$$

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

Table 9: Summary of Project Savings

Measure	kWh	kW
Replace Metal Halide lights with LED fixtures with occupancy sensors	2,817,647	230.12

Measurement and Verification Plan

IPMVP Option A, Partially Measure Retrofit Isolation, was used to establish savings for this measure.

A site visit was completed, during which the customer was interviewed about the work that was completed for this project. During the site visit the following information was collected and/or verified:

- Quantity, wattage, and operation of pre-implementation fixtures – did they all operate continuously? Were the new fixtures installed as a 1-for-1 replacement?
- Verified quantity, model numbers, and wattages of installed fixtures – (963) 146W LED fixtures, (663) controlled by occupancy sensors.
- Were any areas of the facility conditioned during the summer? If so, what is the type and efficiency of the cooling equipment, what are the space temperature setpoints, and does the system have economizer capabilities?
- Was there any seasonal variations in the use of the facility?

During the site visit Hobo UX90 light on/off loggers or Hobo U12-012 lumen level loggers were installed to monitor the operation of approximately 10 the light fixtures controlled by occupancy sensors. The loggers were installed such that at least one light in each area of the facility was metered, and due to the potential of being installed in corrosive environments the installed loggers were put in protective bags.

The data collected with the installed loggers was used to develop average weekly profiles of the operation of the metered lights. The developed weekly profiles were used to determine the expected annual operation of the installed lights and their operation during peak periods. This operation was compared to the energy use of the metal halide lights that were in place prior to the completion of the project to determine the savings for this project. The ex post energy savings calculations can be summarized with the following equation:

$$Energy\ savings\ (kWh) = Baseline\ FL\ kW \times \frac{8{,}760\ hours}{year} - Installed\ FL\ kW \times \frac{avg\ operating\ hours}{week} \times \frac{52.14\ weeks}{year}$$

To determine the summer peak demand savings for this project, the average operation of the installed lights was found for periods from 4-7 PM Monday thru Friday during the summer months. The ex post demand savings calculations can be summarized with the following equation:

$$Demand\ savings\ (kW) = Baseline\ FL\ kW \times 100\%\ peak\ period\ operation - Installed\ FL\ kW \times metered\ peak\ period\ \%\ operation$$

Description of Verification

A site visit was completed on 08/25/2015. The site representative was interviewed and the equipment was inspected.

A survey of the installed lighting was completed and the claimed quantity of (963) LED fixtures was found to be reasonable. Due to the complex layout of the facility, an exact count was not possible to complete. According to the site representative, the installed quantity is accurate based on the fact that as they installed fixtures, they added them to the quantity installed. A spare LED fixture was inspected and found to be 146 watts.

The site representative was not able to provide any information as to the quantity of fixtures replaced, though he was able to confirm that the replaced fixtures were 250 W, 400 W, and 1,000 W metal halide fixtures.

The lights that were not occupancy sensor controlled were confirmed to operate on a 24/7 schedule. The site representative was not able to provide any information on the quantity of occupancy sensor controlled fixtures. Seven light loggers were installed on representative occupancy controlled fixtures to record the fixture operating hours. It should be noted that during the site visit, there were numerous fixtures that were observed to be on even though they were controlled via occupancy sensors and there were no occupants nearby. While this may just be due to timing, it was noted as unusual for newly installed occupancy sensors.

Calculation Description

The ex post savings were calculated using the same methodology used in the ex ante analysis. The savings were determined for two separate measures. The first was the replacement of (240) 455 W metal halide fixtures, (54) 295 W metal halide fixtures, and (6) 1000 W metal halide fixtures with (300) new LED fixtures. The quantity of fixtures was multiplied by the wattage of each fixture to determine the total baseline and post-case connected kW. The energy savings were determined using the following equation:

$$Energy\ savings\ (kWh) = Baseline\ kW \times \frac{8{,}760\ hours}{year} - Installed\ kW \times \frac{8{,}760\ hours}{week}$$

Where the *Baseline kW* was 131.61 kW and the *Installed kW* was 43.80 kW. All of the fixtures for this measure were determined to operate all year. Therefore, the CF for this measure was 1.0. Thus, the demand savings was found by subtracting the installed kW from the baseline kW in the previous equation. The ex post results for this measure were 102.26 kW and 769,216 kWh of energy savings.

The savings for the second measure also involved replacing fixtures, but also included the installation of occupancy sensors to reduce the operating hours. There were a total of (272) 400 W metal halide and (391) 295 W metal halide fixtures. The data collected using the light level meters installed at the facility showed that the occupancy sensors were not turning the lights off as often as was initially anticipated. The results of the logger analysis can be seen in Table 10.

Table 10: Lighting Logger Summary

Logger Number	% On Time	Annual Hours	CF
325	98.6%	8,636.9	93.3%
451	25.9%	2,270.4	19.3%
661	100.0%	8,760.0	100.0%
2741	33.6%	2,941.0	27.2%
2867	99.7%	8,732.5	100.0%
2943	100.0%	8,760.0	100.0%
3104	28.8%	2,520.2	29.2%
Average	**69.5%**	**6,088.7**	**67.0%**

The average on time and run time hours were significantly higher than what was assumed in the ex ante analysis. The logger data is also consistent with the observations made during the site visit of fixtures remaining on after no occupants were nearby. All of the fixtures, which had loggers installed, were confirmed to have occupancy sensors installed prior to the installation of the light logger.

The savings for the second measure were calculated using the same methodology and equations as the first measure. However, the baseline hours of use were set to 8,760, and the post-installation operating hours were set to 6,089 hours per year. Additionally, the coincidence factor was adjusted to 67% for the post-installation case to account for the off time provided by the occupancy sensors. This results in 174.25 kW of demand and 1,505,184 kWh of energy savings.

A summary of the ex post savings can be found in Table 11.

Table 11: Summary of Ex Post Savings

	kW	kWh	Therms
Ex Ante	230.12	2,817,647	0
Ex Post	276.51	2,274,400	0
Realization Rate	120%	81%	N/A

700004 Project Information

Project ID#:	700004
Measure:	Compressed Air: OEM optimization for 4 units of air compressor system
Ex Ante Savings:	1,507 kW; 13,205,002 kWh; 0 Therms
Facility Type:	Industrial

Measure Description

This project consisted of re-working (4) of the facility's (21) 4,000 HP centrifugal compressors. The (4) compressors that were re-worked were the worst performers out of the (21) compressors. After being reworked, the (4) compressors would be among the best performers. Of the (21) compressors, the facility historically operates (16) compressors continuously. Based on the historical usage of the equipment, re-working the worst compressors would essentially bring them up from zero hours of operation and shift all of the other compressors in the sequence down by (4) compressors.

Summary of the Ex Ante Calculations

The ex ante calculations were provided in the project documentation. The ex ante calculations essentially calculated the savings by taking the average kW of the pre-case metered data and the average kW of the post-case metered data and subtracted the post-case average from the pre-case average to determine the power reduction based on 8,030 hours of operation a year for the rebuilt compressors. It should be noted that the post-case kW was adjusted to account for (1) month of rebuilt compressor shut down time per year in order to account for the annual average kW, but the pre-case kW did not take into account any shut down times. This can be seen in the equations below.

$$Pre_{kW_{Operating}} = The\ Pre\ Case\ system\ kW\ while\ the\ plant\ is\ operating.$$

$$Post_{kW_{Operating}} = The\ Post\ Case\ system\ kW\ while\ the\ plant\ is\ operating.$$

$$Pre_{kW_{Average.Annual}} = Pre_{kW_{Operating}}$$

$$Post_{kW_{Average.Annual}} = Pre_{kW_{Average.Annual}} - \left(\left(Pre_{kW_{Operating}} - Post_{kW_{Operating}}\right)\frac{8{,}030\ Hours}{8{,}760\ Hours}\right)$$

The error is that the pre-case average annual kW does not take into account the shutdown period and that this error propagates to the post-case average annual kW, which would have correctly accounted for the plant shutdown had the pre-case average annual kW been correctly calculated.

The Ex Ante savings for this measure are presented in Table 12.

Table 12: Ex Ante Savings

Measure	Therms	kWh	kW
Compressed Air: OEM optimization for 4 units of air compressor system	0	13,205,002	1,507.42

Measurement and Verification Plan

IPMVP Option A, Partially Measured Retrofit Isolation, was used to establish savings for this project. Note that onsite metering was be possible.

For the evaluation of this project, a site visit was completed, the equipment and compressed air system was inspected, and the site representative was interviewed. The equipment was inspected to make sure that the specific (4) compressors have been re-worked and are now being operated near the beginning of the sequence. The site representative was interviewed concerning which compressors have been taken offline and what the power draw of the system was before and after the project, as well as the CFM levels at those times. If trended data was available, it was collected. In addition, the site representative was interviewed concerning any other projects being completed at the facility that may influence the possibility of collecting updated information.

Description of Verification

A site visit was completed on 09/04/2015. The site representative was interviewed and the equipment was inspected.

The (4) compressors that were listed as being re-worked were confirmed to have been re-worked. During the site visit, (15) of the compressors, including all of the (4) re-worked compressors were found to be running. Since the completion of this project, the facility has done other compressed air projects that were claimed under different projects, including re-working other compressors. The compressors that were found to not be running during the time of the site visit were confirmed to have been displaced by the (4) newly re-worked compressors.

While onsite each compressor was inspected and each was found to be operational. The compressor sequencing program was also inspected and updated information was taken to verify that the metered data provided in the project documentation was accurate. According to the site representative, there have not been any significant changes in the production of the facility. This project was found to be consistent with the information provided in the project documentation.

Calculation Description

The ex post calculation utilized the data for the amperage reduction for each compressor. The ex ante calculation determined the savings by comparing the entire compressor plant demand from June and July of 2014 (before the compressor rebuild) to January of 2015 (after the rebuild). Since the pounds of product produced during the post period was greater than the baseline period, no further correction for production was estimated.

However, during the baseline period, the compressed air system produced an average of 330,626 CFM. During the post-installation period, the compressed air system produced an average of 284,336 CFM, a reduction of 46,290 CFM or 14.0%. This project involved rebuilding compressors and adjusting the compressor sequence. This would not have this significant of an impact on the CFM produced from the compressed air system, and must have resulted from other operation differences at the facility during that time period. Therefore, it is not appropriate to compare the entire system kW both before and after the project was completed, as the CFM load was significantly different during the two periods.

The ex post calculations therefore utilized the amperage data for each of the four rebuilt compressors both before and after the project was completed. This determined the actual difference in operating power of the compressors before and after the rebuild, while excluding the effect of the lower CFM needs of the facility.

This calculation methodology is nearly identical to that which was used during the pre-approval analysis of this project.

The baseline data was taken from the measured amp data for each of the four effected compressors from January 2014, prior to the rebuild. The post-installation amperage was taken from the amperage measurements found in the January 2015 data. Additionally, based on the measured compressor amperage data, the compressors were found to run 95% of the time. Therefore, the hours of operation were assumed to be 8,322 hours per year. A summary of the ex post calculation can be seen in Table 13.

Table 13: Ex Post Calculation Steps

Baseline Compressor Amps	2,097
Baseline Compressor kW	13,148
Post Compressor Amps	1,938
Post Compressor kW	12,149
Hours	8,322.00
Demand Savings	999.15
Energy Savings	8,314,897

A summary of the ex post savings can be found in Table 14.

Table 14: Summary of ex post savings

	kW	kWh	Therms
Ex Ante	1,507.42	13,205,002	0
Ex Post	999.15	8,314,897	0
Realization Rate	66.3%	63.0%	N/A

700016 Project Information

Project ID#:	700016
Project:	New Construction Refrigerated Warehouse
Ex Ante Savings:	5,511,827.752 kWh; 720.724 kW, 0 Therms
Facility Type:	Warehouse

Project Description

This project was completed at a refrigerated warehouse facility that consisted of 163,300 square feet of cold storage, 7,680 square feet of maintenance area, 44,000 square feet of dock space, and 6,300 square feet of office space. It should be noted that this facility is a new construction facility and therefore has a new construction baseline.

The measures involved in this project fall under six categories:

1) Single stage refrigeration system upgrades
    a. Install thermosiphon oil cooling rather than liquid injection oil cooling.
    b. Lowering the design condensing temperature from 95°F to 90°F.
2) Enhanced controls
    a. Demand defrost controls rather than timed defrost.
    b. VFD controlled condenser fan rather than cycling condenser fans.
3) LED lighting & occupancy sensor controls
4) Insulation
    a. Install R-42 wall insulation rather than R-34 wall insulation.
    b. Install R-34 dock insulation rather than R-26 dock insulation.
    c. Install R-48 roof insulation rather than R-36 roof insulation.
5) Freezer floor heating – Provide heating via an ammonia heat exchanger rather than electric heat, which prevents freezer floor frost heave.
6) Dock door design – Install vertical dock levelers that are stored vertically above the floor and have no leveler pit rather than folding the truck connector flap down into the leveler pit when the door is not being used. This reduces infiltration into the space by removing the leveler pit altogether.

Summary of the Ex Ante Calculations

The ex ante savings for this project are 5,511,827.752 kWh, 720.724 kW, and 0 therms.

A summary of the ex ante custom calculations were included with the project documentation.

The single stage refrigeration system upgrades are calculated by multiplying a pre and post-case compressor load efficiency by the annual operating hours, tons being supplied, and a load factor of 80% and dividing the resulting value by the motor efficiency. The calculation breaks up the compressor operation into a high temperature system and a low temperature system, using two systems to model the compressor system operation.

The system enhanced controls were calculated by assuming a reduction of 11.04% of the annual energy usage. The pre-case annual energy usage was estimated at 14,712,670 kWh; though this value was hard-coded and no explanation of how it was estimated was provided.

The LED lighting savings were calculated by multiplying the pre and post-case fixture quantities by their respective wattages and then multiplying these values by 6,730 hours of operation a year, with the difference in the resulting pre and post-case usages being the savings. It should be noted that this results in a baseline wattage of 0.89 watts per square foot, when the code permitted baseline is 0.6 watts per square foot.

The insulation savings were calculated by taking the area of insulation, assuming the interior space temperature according to the space type (being held constant all year) and calculating the heat transfer through each individual wall for both the baseline case and the post-case.

The freezer floor glycol loop heat recover measure savings were calculated by assuming 1.67 btu/ft^2 of heating load for 122,993.8 ft^2 of freezer floor. The post-case calculated a compressor load of 21.8 tons of additional load due to the heat exchanger. Why there would be an additional load on the compressor system is not clear.

The vertical dock door design savings were calculated by assuming 1.5 ft^2 of space to be infiltrated with an average wind speed over the course of 8,760 hours of the year at 5 mph. The amount of heat loss was calculated using the standard equation of the heatloss (btu/hr) being equal to $1.08 * CFM * [Temp_{Outside} - Temp_{Inside\ Dock}]$.

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

Table 15: Ex Ante Claimed Savings

Project	kWh	kW	Therms
New Construction Refrigerated Warehouse	5,511,828	720.724	0

Measurement and Verification Plan

IPMVP Option A, Partially Measured Retrofit Isolation, was used to establish savings for this project. A site visit was completed and each measure was verified and evaluated based on equipment inspections, gathered setpoints and functionality of the equipment, interviews with the site representatives concerning control strategies and equipment specifications, and metered data as applicable.

For the evaluation of the refrigeration system measures, the equipment was inspected, setpoints were collected, and the site representative was interviewed concerning control strategies and specifications. Make and model number of each of the compressors was collected. The refrigeration compressors were metered to determine the refrigeration load along with the outdoor weather conditions. The compressors were confirmed to use thermosiphon oil cooling rather than liquid injection oil cooling. The refrigeration system was confirmed to be a single stage ammonia refrigeration system with suction temperature of -30°F and a condensing temperature of 90°F, rather than 95°F. Blueprints for the system were collected, if available. If blueprints are not available, the site representative was asked to provide a list of evaporators and their capacities per space. Space temperature setpoints were collected, the site representative was interviewed concerning the defrost demand controls and specifically how often the evaporators defrost and for how long. The site representative was also interviewed concerning the condenser, its capacity, and how its controls are integrated into the system.

In order to verify the savings associated with the LED lighting measure, a list of the spaces including the square footage, space temperatures, lighting fixture quantity, and lighting fixture wattage was collected. The installed lighting was inspected and occupancy sensor controls confirmed to have been installed. The site representative was asked to provide any available manufacture specification sheets and the facility's lighting EMS was inspected and lighting trends or lighting usage were collected.

The insulation savings were verified by confirming the dimensions of each wall, collecting the R-value of each wall via interviews with the site representative, and collecting the space temperature setpoint of each space.

The site representative was interviewed to determine which areas of the facility were serviced by the ammonia heat recovery glycol loop system to prevent the ground from freezing and to determine the area of floor associated with each space. Additionally, the site representative was also interviewed concerning what the ground temperature setpoint is maintained.

The evaluation of the dock door design measure consisted of visually confirming the quantity of doors, confirming the vertical dock leveler design has been installed and that no leveler pits have been installed, confirming that the doors are installed on the west side of the building, and collecting the dock temperature setpoint.

Description of Verification

A site visit was completed on 08/26/2015. The site representatives were interviewed and the equipment was inspected. The site representatives that were able to meet the field engineer onsite consisted of the local facility's head of maintenance and the regional manager. After the site inspections were completed and the logging equipment was installed, a conference call was made where the field engineer interviewed the regional manager, the greater regional manager/ project contact, and the refrigeration contractor. It should be noted that the refrigerated warehouse was confirmed to have been newly constructed and to have only been in use for a few months during the time of the site visit.

The refrigeration system was inspected and the site representatives were interviewed concerning its operation. The compressors were confirmed to consist of (3) GEA 675GLX ammonia compressors and (1) GEA 400GLX ammonia compressor. During the time of the site visit, the site representatives could not provide a list of evaporators or their capacities, or the capacity of evaporators by space. Also, during the time of the site visit, the site representatives were not able to provide design or as-built drawings of the refrigeration system. The refrigeration system was confirmed to be a single-stage refrigeration system that serves each refrigerated space. The suction temperature was confirmed to be -30°F. The facility was confirmed to utilize a 90°F condensing temperature system, rather than a 95°F condensing temperature. The compressors were confirmed to be thermosiphon oil cooled compressors rather than liquid injection oil cooled compressors. Demand defrost controls were confirmed to have been installed, but none of the site representatives could provide any information on the evaporators or how often defrost occurs. The condenser fans were also confirmed to be VFD controlled with the fan speed being controlled to maintain the condenser temperature rather than cycling the fans. Fan HP and condenser information was also not available at the time of the site visit. In order to help determine the refrigeration load that the refrigeration system is required to provide, DENT Elite Pro True RMS power loggers were installed on (2) of the compressors and amp loggers were installed on the remaining (2) compressors. Additionally, an outdoor air logger was installed to record the outdoor air temperature and relative humidity at the facility during the logging period.

A walkthrough of the entire warehouse, excluding the office and maintenance area, which was not part of the project, was completed, during which all of the lighting was inspected and counted. Of the claimed (88) LED fixtures in the dock, the dock was found to contain (75) LED fixtures. The claimed cooler quantity consisted of (72) LED fixtures, while the claimed freezer quantity consisted of (52) LED fixtures. Of the claimed quantities, (38) LED fixtures were found in the cooler, (52) LED fixtures in the freezer, (12) LED fixtures in the deep chill area, and (22) LED fixtures in the blast freezer. The site representative was asked to provide any fixture wattage information and any lighting floorplan designs; however, this information was not available at the time. The facility did have a lighting control system, which included a tracking system stating what percentage of the time the fixtures were on during the entire day. On average, the fixtures were found to be on 46% of the time. Occupancy schedules were not available.

While onsite, the interior and exterior insulated structural wall panels themselves were not able to be directly measured or inspected because of their construction; however, according to the site representative, the entire wall is constructed only from the insulated panels with the exception of the building frame. Space temperatures and space temperature setpoints were recorded for the dock, freezer, blast freezer, deep chill area, and cooler. The setpoint temperatures for each space were 40°F, -10°F, -20°F, 28°F, and 28°F, respectively. The site representative was asked what the installed R-value of each wall was; however, the site representative was not able to explicitly state what the R-value of the insulation was for each wall and could only generally say that the submitted information for the R-values of the walls and ceiling was correct. The site representative was asked to provide the dimensions of each wall and ceiling section, but was unable to provide this level of detail during the site visit. The overall building drawing was confirmed to be the same dimensions as the building as it was constructed via interviews with the site representative, with the exception of the interior wall between the freezer and the cooler. According to the drawings, the freezer consisted of (10) aisles and the cooler consisted of (4) aisles, when in reality, the freezer consists of (8) aisles and the cooler consists of (6) aisles. Note that each aisle is the same dimensions in both scenarios.

The site representative was interviewed regarding the freezer floor heating. According to the site representative, the entire floor of the warehouse area (not including the dock) is maintained to prevent the ground from freezing. The ground temperature according to the site representative is maintained at 50°F. The floor heating is recovered from the compressors using a heat exchanger transferring heat from the compressed hot refrigerant to the glycol floor heating loop.

During the site visit, the dock doors were inspected. The doors were found to all be on the west side of the building. The dock levelers were confirmed to be stored vertically, pivoting upward away from the door and floor, rather than folding a portion of the leveler underneath itself into a leveler pit. The installed dock design was also confirmed to have no leveler pits at all. The dock itself was found to maintain a set point of 40 degrees according to the maintenance personnel.

Calculation Description

The savings for the measures were broken up by the equipment system and calculated separately.

The savings for the refrigeration system measures, with the exception of the demand defrost controls, were calculated using an ASHRAE bin analysis, which calculates the load on the compressors based on the enthalpy of the refrigerant at each point in the single stage refrigeration cycle, dependent on the refrigeration load and the oil cooling required for each temperature bin. The compressor energy usage is calculated based on the calculated compressor system kW at each temperature bin, determined from the metered data, multiplied by the annual hours of operation at each compressor bin. Likewise, the condenser power is calculated for each temperature bin based on the heat rejection from the compressor system, which includes the refrigeration load and the compressor oil cooling heat load. The condenser energy is also calculated based on multiplying the condenser kW for each temperature bin by the annual hours of operation at each temperature bin.

In the pre-case, (2) liquid injection oil cooled GEA 675GLX ammonia compressors would be required to meet the refrigeration load for the baseline single stage refrigeration system with a -30°F suction temperature and a 95°F condensing temperature. The baseline condenser fans were assumed to be cycling fans of the same capacity based on standard business practices. The post-case system was found to consist of (2) thermosiphon GEA 675GLX ammonia compressors being used to meet the refrigeration load with a -30°F suction temperature and a 90°F condensing temperature. The condenser fan speed in this case is reduced via VFDs to maintain the condensing temperature. The resulting savings are 998,064 kWh and 44.0 kW.

The refrigeration system was verified to have a constant load of approximately 390 tons of refrigeration based on the metered data, which only showed (2) of the thermosiphon GEA 675GLX ammonia compressors ever operating during the entire meter period with no noticeable dependence on outdoor air conditions. Similarly, the bills for the facility support approximately 10 million kWh of annual energy usage, while the refrigeration model accounts for 8.63 million kWh of annual usage and the other facility systems account for the remaining energy usage according to the models for those systems. In particular, it should be noted that the estimated high efficiency case usage for the facility, according to the ex ante documents is 23.9 million kWh. This over estimation of the facility's refrigeration system accounts for the vast majority of the reduction in savings.

The demand defrost controls were calculated separately from the refrigeration system savings and condenser control savings. The demand defrost control savings were also calculated using an ASHRAE bin analysis where the baseline was assumed to be time-clock hot gas defrost providing defrost (2) times per day at 30 minutes per defrost. The post-case defrost is still hot gas defrost, but sensor controlled rather than time clock controlled. The calculation is based on assuming the same evaporator capacity as compressor capacity and using the same suction and condenser temperatures. Additionally, the warehouse air was assumed to have a relative humidity of 50% in the summer and 27% in the winter. The resulting savings are 546,739 kWh and 48.0 kW. It is not clear if there is a reduction in savings for this measure due to the fact that the ex ante calculations are included with other refrigeration measures that were overestimated based on the annual usage of the facility.

The pre-case LED lighting power (kW) was calculated based on the code permitted wattage of 0.6 watts/ square foot of floor area, multiplied by the floor areas of the spaces involved in the measure to determine the lighting power consumption. The pre-case lighting demand is equal to the lighting power due to the fact that all the lighting would have been expected to be on during peak demand periods. The pre-case energy usage (kWh) was calculated by multiplying the total lighting power by 8,760 hours of operation a year. The post-case lighting power was calculated based on the number of lights per each space counted, multiplied by the fixture wattage for each fixture according to the ex ante calculations due to the site representative not being able to provide more detailed information. The post-case demand is equal to the post-case lighting power multiplied by 46% due to only 46% of the lighting being expected to operate during peak hours based on the facility's lighting control system tracking capabilities and installed occupancy sensors. The post-case energy consumption (kWh) is equal to the post-case lighting power consumption multiplied by 8,760 hour per year and multiplied by 46% because the lights are only expected to be on 46% of the day. The reduction in savings is due to the ex ante calculations assuming an equal quantity of metal halide fixtures would have been installed. This cannot be considered the baseline because it surpasses the code required minimum of 0.6 watts per square foot.

The improved insulation savings were calculated using standard heat transfer "$Q=UA\Delta T$" equations. The wall and ceiling dimensions were adjusted based on a supplied mini-map of the facility, the total dimensions of the facility as found in the project documentation, and the transfer of (2) aisles from the freezer space to the cooler space to reflect how the interior spaces were actually constructed. The internal space temperature was subtracted from the ambient temperature and multiplied by the appropriate amount of wall/celling space for each space and also multiplied by the code U-value of the baseline insulation and by the actual installed insulation U-value for the post-case. The majority of the reduction for this measure is due to the fact that the ex ante calculations assumed that the west wall of the freezer and cooler was exposed to only ambient conditions when the majority of those actual walls are connected to the dock and not exposed to ambient conditions.

The freezer floor heat recovery savings were calculated using a freezer floor U-value of 0.064, as required by code, and calculating the conduction through the floor into the specific refrigerated spaces. The conduction through the floor was calculated using standard heat transfer "$Q=UA\Delta T$" equations. It should be noted that the limiting factor for how much heat can be transferred to the space is the conduction through the insulated floor from the heated ground, and not the convection off of the freezer floor which is effectively the same surface temperature as the space temperature. Based on the site representative provided information, the ground was assumed to be maintained at 50°F. It is not clear what the difference in savings is due to for this measure.

In order to calculate the dock door savings, the Ex Ante calculation was modified to reflect the actual environment. The space temperature was adjusted from 35°F to 40°F according to the actual space temperature set point. The infiltration wind speed was adjusted from 5 mph to 9.9 mph based on the TMY3 weather data for the region and the hours were reduced from 8,760 hours per year to 1,135 hours per year based on the TMY3 weather data showing wind blowing from a western direction toward the east. The savings reduction for this measure is due primarily to the reduction in effective infiltration hours.

It should be noted that the 83.6% of the reduction in savings is due to the reduction in the refrigeration savings, which includes the defrost demand control savings. Of the remaining 16.4% of the reduction, 7.6% is due to the lighting reduction, 1.0% is due to the insulation savings reduction, 5.0 % is due to the freezer floor heating savings reduction, and 2.8% is due to the dock door design reduction.

Based on a TMY3 normalized bill regression of April through July of 2015, the facility is expected to use approximately 10 million kWh on an annual basis. In comparison, the ex post case models the facility usage as being 9.65 million kWh which is comparable. A summary of the ex post savings can be found in Table 16.

Table 16: Summary of Ex Post Savings

	kW	kWh	Therms
Ex Ante	720.72	5,511,828	0
Ex Post	209.58	2,517,216	0
Realization Rate	29%	46%	N/A

700020 Project Information

Project ID#:	700020
Measure:	Lighting: Fixture replacement and occ. sensor installation
Ex Ante Savings:	4,099,073.8 kWh; 442.774 kW, 0 Therms
Facility Type:	Warehouse

Measure Description

This project consisted of replacing the existing T12 fluorescent fixtures, metal halide fixtures, and high pressure sodium fixtures in several areas of a facility with T8 and T5 fluorescent fixtures. The project also included installing occupancy sensors to control approximately 30% of the fixtures that were being replaced/ retrofitted.

Summary of the Ex Ante Calculations

The ex ante savings for this project are 4,099,073.8 kWh, 442.7 kW, and 0 therms. Custom calculations were included with the project documentation. A list of the fixtures involved in the project can be seen in Table 17 and Table 18.

Table 17: Pre-Case Fixture Overview

Pre-Case Fixture Type	Pre-Case Fixture Quantity
STRIP 8' 2 LAMP T12 HO	1,691
HIGH BAY MH 400	147
HIGH BAY MH 1000	120
HIGH BAY HPS 400	153
TROFFER 4' 4 LAMP T12	340
TROFFER 4' 2 LAMP T12	34
Total	**2,485**

Table 18: Post-Case Fixture Overview

Post-Case Fixtures	Post-Case Fixture Quantity	# of Occ. Controlled Fixtures
Z254	67	67
IBZ454	606	266
IBZ654	70	16
IBZ854	6	6
TZ254	18	18
IBL36L	120	0
2SP8 BIHP	340	0
2SP8 BILP	34	0
Total	**1,261**	**373**

The savings were calculated by first determining the pre and post-case total fixture wattages, which were determined by multiplying the pre and post-case fixture quantity by the input wattage of the specific fixture type. The pre and post-case total kWh was determined by multiplying the fixture wattages by the associated quantity and associated operating hours, which consists of 8,760 annual operating hours for each of the fixtures, except for the occupancy controlled fixtures which were assumed to have a 30% reduced operating level in the post-case, resulting in 6,132 annual hours of operation.

Typical fixture wattages were assumed for the pre-case fixtures according to their type, while actual fixture wattages were used in the savings calculations for the post-case fixtures according to their manufacture listed input power.

The resulting usage is approximately 703.8 kW and 6,165,358.1 kWh in the pre-case and 261.0 kW and 2,066,284.3 kWh in the post case. The ex ante savings for this measure are presented in Table 18.

Table 19: Ex Ante Claimed Savings

Measure	kWh	kW	Therms
Lighting: Fixture replacement and occ. sensor installation	4,099,073.8	442.774	0

Measurement and Verification Plan

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

The onsite measurement and verification of this project consisted of inspecting the equipment, interviewing the site representative, and possible metering of the equipment.

During the site visit, a list of all spaces and their associated pre and post-case light fixtures was collected from the site representative. This list was spot checked to verify its accuracy. If this was not possible, the spaces where the fixtures were installed were examined and their quantities and fixture types were recorded to determine the accuracy of the project documented list of fixtures shown in Table 17. If possible, the equipment and/ or spare parts was examined in order to collect fixture wattage, lamp wattage, and ballast information. Fixture controls was also examined while examining the different spaces.

The site representative was interviewed concerning the pre and post-case fixture types, quantities, fixture wattages, ballast factors, lamp wattages, fixture controls, operating hours, holiday operation, and any seasonal influences on the usage of the fixtures or spaces. The site representative was specifically asked if the lighting is on continuously, if time clocks are used, or if the fixtures are simply manually controlled. In addition, the site representative was on what line voltage the fixtures operated.

If the lighting operated 8,760 hours or utilize time clocks or other timing controls, then no loggers would have been installed, but the on/off times would have been recorded. If the lighting is not controlled, the customer was interviewed and lighting level loggers were installed to monitor the operating hours, unless the lighting in the specific space is kept to a strict operating schedule. Logging of the fixtures was completed using Hobo U12-12 light level loggers and Hobo UX90 lighting state loggers.

Description of Verification

A site visit was completed on 07/14/2015, the fixtures were inspected and counted, and the site representative was interviewed.

The site representative only had a basic knowledge of which fixtures were replaced and other employees that were present during the site visit could not give more detailed information. There were no detailed lists of fixtures that were replaced. Based on this, the fixtures that the site representative thought were part of the project were surveyed along with the vast majority of the fixtures in the facility.

The project that was completed consisted of a majority of the fixtures in the facility. There were some slight discrepancies between what was observed onsite and what was listed in the project documentation; however, due to the site representative's limited knowledge of the project, it was not clear if the fixtures were part of a different project, were pre-existing fixtures, or were part of this project. The number of fixtures that were observed that could be attributed to the project with certainty accounted for approximately 88% of the project claimed fixtures. The remaining observed fixtures accounted for more than the missing 12% of fixtures. Based on the available information, the claimed types and quantities are reasonable, but an exact number could not be verified other than via project invoices, which are consistent with the project documentation.

Due to the lack of detailed fixture and space descriptions and the lack of the site representative's knowledge of the project, loggers were installed to meter the occupancy controlled fixtures that were believed to be part of the project. The non-occupancy controlled fixtures are expected to operate continuously based on interviews with the site representative.

Calculation Description

Based on the site visit collected information, the ex ante calculations were found to be reasonable with the only adjustment made to the ex post operating hours for occupancy sensor controlled fixtures.

Similar to the ex ante calculations, the savings were calculated by first determining the pre and post-case total fixture wattages, which were determined by multiplying the pre and post-case fixture quantity by the input wattage of the specific fixture type. These assumptions were taken from the ex ante calculations because more detailed information was not available. The pre and post-case total kWh was determined by multiplying the fixture wattages by the associated quantity and associated operating hours, which consists of 8,760 annual operating hours for each of the fixtures, except for the post-case occupancy controlled fixtures where the metered data was used to determine the annual operating hours for each occupancy sensor controlled space. The summarized logger data showing the impact of the occupancy sensors can be seen in Table 19 and Table 20.

Table 20: Logger Analysis

Logger ID	Area	Hours	CF
00154	High Bay Area	1,150	30%
00175	Mezzanine Area	108	1%
00320	High Bay Area	5,090	88%
00463	High Bay Area	4,500	88%
00549	Small Item Storage Shelf Area	2,130	21%
02548	Small Item Storage Shelf Area	1,307	31%
02582	Small Item Storage Shelf Area	2,435	22%

Logger ID	Area	Hours	CF
02634	Mezzanine Area	189	1%
02769	Small Item Storage Shelf Area	1,818	15%
02878	Mezzanine Area	305	2%

Table 21: Logger Analysis by Space Type

Area	Average Op. Hours	Average CF
Mezzanine Area	201	1%
Small Item Storage Shelf Area	1,923	22%
High Bay Area	3,580	69%

The savings adjustment is due to the occupancy sensor controlled fixtures operating a different number of hours than expected. A summary of the ex post savings can be found in Table 21.

Table 22. Summary of Ex Post Savings

	kW	kWh	Therms
Ex Ante	442.8	4,099,074	0
Ex Post	481.2	4,366,938	0
Realization Rate	109%	107%	N/A

700028 Project Information

Project ID#:	700028
Measure:	Compressed air systems
Ex Ante Savings:	9,424,815.5 kWh; 1,075.892 kW, 0 Therms
Facility Type:	Manufacturing/Industrial

Measure Description

This project consisted of Installing (1) new 400 HP compressor, re-gearing (1) 300 HP compressor, installing (4) low pressure blowers, (2) new dryers, new pressure and flow controllers, (10) no loss drains, a new header, (1) 3,000 gallon tank, (1) 1,500 gallon tank, (1) 5,000 gallon tank, a compressor automation system, and repairing leaks, as well as re-piping an existing 2,000 gallon tank to service the high pressure side of the compressed air system and removing some desiccant driers.

The post-case compressed air system consists of the following (19) compressors (Table 22, Table 23, Table 24, and Table 25):

Table 23: Low Pressure Compressors

	Low Pressure S	Low Pressure S	Low Pressure S	Low Pressure S	Low Pressure S	Low Pressure N
Compressor	QMA150 #2	25-100L #3	LS25-200 #4	QMA 100 #5	QMA 75 #6	TS32-300 #8
Equipment #	6277	6278	22293	6280	6283	6281
Rated CFM	750	480	950	475	352	1,640
Manufacturer	Quincy	Sullair	Sullair	Quincy	Quincy	Sullair
Model	QMAPWCW31A	25-100L	25-200L	QMA 100	QMA 75	TS32-300
Type	Rotary Screw	Rotary Screw	Rotary Screw	Rotary Screw	Rotary Screw	Rotary Screw
Serial Number	71596	24230 B6F	003-73387	71125	70981	003-127369
Year	n/a	n/a	n/a	n/a	n/a	n/a
Rated Pressure	110	100	100	100	100	115
Rated BHP	198	115	220.0	109	79	331
Service Factor	1.15	1.15	1.15	1.25	1.15	1.15
Power Factor	0.86	0.86	0.88	0.83	0.81	0.88
Nameplate HP	200	100	200	100	75	300
Nameplate Amps	222	111	219	116	88.4	330
Actual Amps	208	128	200	120	94	319
Motor Efficiency	95.0%	95.0%	93.0%	92.4%	92.0%	95.0%
Calculated KW	147.2	90.6	144.8	81.9	62.6	230.9

Table 24: Medium Pressure Compressors

	Medium Pressure S	Medium Pressure N
Compressor	WH 28 #2	TS-32-300
Equipment #	6262	6276
Rated CFM	990	1,240
Manufacturer	Belliss & Morcom	Sullair
Model	WH 28 H3N	TS-32-300
Type	Reciprocating	Rotary Screw
Serial Number	8071	2-00703090108
Year	n/a	2007
Rated Pressure	650	175
Rated BHP	343	335
Service Factor	1.15	1.15
Power Factor	0.84	0.84
Nameplate HP	400	300
Nameplate Amps	477	330
Actual Amps	392	330
Motor Efficiency	96.0%	95.8%
Calculated KW	273.8	228.1

Table 25: High Pressure Compressors

	High Pressure S	High Pressure S	High Pressure S	High Pressure S	High Pressure S	High Pressure S
Compressor	WH 28 #1	WH 28 #3	WH 28 #4	WH 28 #5	WH 28 #6	WH 28 #7
Equipment #	6159	6263	6264	6265	6266	6267
Rated CFM	1,011	1,025	1,025	1,011	970	1,018
Manufacturer	Belliss & Morcom	Belliss & Morcom	Belliss & Morcom	Belliss & Morcom	Belliss & Morcom	Belliss & Morcom
Model	WH 28 H3N	WH 28 H3N	WH 28 H3N	WH 28 H3N	WH 28 H3N	WH 28 H3N
Type	Reciprocating	Reciprocating	Reciprocating	Reciprocating	Reciprocating	Reciprocating
Serial Number	8116	8277	8412	8513	8555	7255
Year	n/a	n/a	n/a	n/a	n/a	n/a
Rated Pressure	650	650	650	660	660	500
Rated BHP	375.0	380	380	375	359	377
Service Factor	1.15	1.15	1.15	1.15	1.15	1.15
Power Factor	0.81	0.81	0.81	0.81	0.81	0.81
Nameplate HP	400	400	400	400	400	450
Nameplate Amps	503	487	484	465	465	482
Actual Amps	435	490	491	481	457	427
Motor Efficiency	93.5%	93.5%	93.5%	93.5%	93.5%	93.5%
Calculated KW	289.3	325.8	326.5	319.9	303.9	283.9

Table 26: High Pressure Compressors (Continued)

	High Pressure S	High Pressure N	High Pressure N	High Pressure N	High Pressure N
Compressor	WH 29 #8	WH 50 #10	WH 40 #11	WH 40 #12	WH 50 #13
Equipment #	6268	6270	6271	10814	18671
Rated CFM	1,013	1,750	1,310	1,310	1,750
Manufacturer	Belliss & Morcom	Belliss & Morcom	Belliss & Morcom	Belliss & Morcom	Belliss & Morcom
Model	WH29 H3N	WH 50 H3N	WH 40 H3N	WH40 H3N	WH 50 H3N
Type	Reciprocating	Reciprocating	Reciprocating	Reciprocating	Reciprocating
Serial Number	8773	9162	9022	9037	9552
Year	n/a	1999	1998	1998	2003
Rated Pressure	660	660	660	660	660
Rated BHP	385	737	545	545	737
Service Factor	1.15	1.15	1.15	1.15	1.15
Power Factor	0.81	0.81	0.83	0.83	0.81
Nameplate HP	400	750	550	600	750
Nameplate Amps	477	915	630	689	911
Actual Amps	422	865	520	596	870
Motor Efficiency	93.5%	93.5%	93.5%	93.5%	93.5%
Calculated KW	280.6	575.2	354.3	406.1	578.5

Summary of the Ex Ante Calculations

The ex ante savings for this project are 9,424,815.5 kWh, 1,075.892 kW, and 0 therms.

Calculations were included in the project documentation; however, the exact calculations used to calculate the ex ante savings are not clear.

The calculation that matches the claimed project savings takes the total metered kWh of the month of November (2014) for the pre-case and the total metered kWh for the month of March (2015) for the post-case, divides the total kWh for each by the number of days in that month, and multiplies it by 365 days to establish the annual pre and post-case energy consumption. It is not clear how total kWh usage for the two months were calculated because the numbers are hard-coded. Also, there are no comments provided in the calculations or project documents regarding the production levels or comparing CFM levels to the same CFM levels. Based on the provided information, it is possible that the calculated “savings” could simply be a difference in production levels; however, there is no information to corroborate whether or not this is the case.

It appears that metered data was used to establish the amp draw of the various compressors for the two meter periods and subsequently the average kW load on each of the compressors, but the values used in the other project calculations are hard-coded and do not include any discussions or comments on the production levels.

It is not clear how or if savings were calculated for the reduction in CFM levels due to the installation of no loss drains and leak repairs. In addition, it is not clear if the refrigerated dryer savings were calculated.

The ex ante savings for this measure are presented in Table 26.

Table 27: Ex Ante Claimed Savings

Measure	kWh	kW	Therms
Compressed air systems	9,424,815.5	1,075.892	0

Measurement and Verification Plan

IPMVP Option A, Partially Measured Retrofit Isolation, was used to establish savings for this project. A site visit was completed, where the following activities were conducted and information was collected:

- Compressors (Pre-case)
  - Recorded make, model & capacity for all compressors.
  - Collected CAGI Sheets for all compressors.
  - Recorded operating pressure setpoints for each compressor.
  - Recorded which compressors serve the low pressure system, the mid pressure system, and high pressure system, and the "high high" pressure system.
  - Recorded the pressure maintained for each system.
  - Interviewed the site representative concerning the sequencing of the compressors.
- Compressors (Post-Case)
  - Recorded make, model & capacity for all compressors.
  - Collected CAGI Sheets for all compressors.
  - Recorded operating pressure setpoints for each compressor.
  - Recorded which compressors serve the low pressure system, the mid pressure system, the high pressure system, and the "high high" pressure system.
  - Recorded the pressure maintained for each system.
  - Interviewed the site representative concerning the sequencing of the compressors.
- Piping adjustments
  - Interviewed the site representative concerning the pre-case compressed air pipe design.
  - Where were each of the compressors, dryers, and tanks located in the design?
- Leak Report
  - Compiled list of which leaks were repaired & capacity, as well as on what pressure system the leaks were repaired.
- Tanks

- Collected a list of all tanks that are part of the system.
- Collected a list of the new tanks.
- Determined where each of the tanks are located in the pre-case system in respect to the compressed air system design.
- Determined where each of the tanks are located in the post-case system in respect to the compressed air system design.
- Collected the pressure set point of the tanks.

- Dryers
  - Collected a list of any removed air dryers including make, model, capacity, type, and power profile.
  - Collected a list of any added air dryers including make, model, capacity, type, and power profile.
  - Determined which system (low, mid, high, or high high) the removed and added dryers serve.
- Blowers
  - Collected a list of the added blowers including make, model, and capacity.
  - Determined what function the blowers serve.
  - Determined what system the new blowers displaced and what the displaced system equipment consisted of, how it was used and controlled, as well as how it was loaded.
- Controls
  - Interviewed the site representative concerning how the pre-case compressed air system was sequenced and how it was controlled.
  - Interviewed the site representative concerning the post case compressed air system and how it was sequenced and how it is controlled.

Description of Verification

A site visit was completed on 08/31/2015. The site representative was interviewed and the equipment was inspected. The site representative could not provide any trended data and no logging was permitted.

The site representative was interviewed concerning each of the compressors at the facility. In the pre-case, the low pressure system (operating at 95 PSI) consisted of Quincy compressors #2, #3, #4, #5, #6, and #8. In the post-case, the low pressure system (operating at 90 PSI) consisted of Quincy compressors #2, #3, #4, #5, #6, and #8. The pre-case mid pressure system (operating at 140 PSI) consisted of the B&M WH28 H3N compressor and the Sullair TS-32-300 compressor. The Sullair TS-32-300 compressor was maintained as a mid-pressure compressor in the post-case (operating at 115 PSI), but the B&M WH28 H3N compressor was converted to a high pressure compressor in the post-case (operating at 460 PSI). There was no high pressure system in the pre-case, but there was a “high high” pressure system (operating at 500 PSI). The pre-case “high high” pressure compressors consisted of B&M compressors #1, #3, #4, #5, #6, #7, #8, #10, #11, #12, #13. In the post-case B&M compressors #1, #3, #4, #10, #11, #12, #13 were converted to high pressure compressors (operating at 460 PSI) while B&M compressors #5, #6, #7, #8 were kept as “high high” pressure compressors (operating at 500 PSI). The project documented make, model, and capacity for each of the compressors was found to be accurate.

It should be noted that in the pre-case, there were no connections between the different compressor system. The low, mid, and “high high” systems were each separate systems and not connected in any way. Each of the pre-case systems had tanks after the compressor dryers. The “high high” pressure system had (1) 2,000 gallon tank. In the post-case, the “high high” pressure system tank capacity was increased by adding (1) new 5,000 gallon tank to the existing (1) 2,000 gallon tank. The “high high” pressure system serviced its own product line and also now has a flow controller that connects it to the high pressure system in case the high pressure system cannot meet its demand requirements. The high pressure system is now also connected to the mid-pressure system via a flow controller in case the mid-pressure system cannot meet its flow requirements. Additionally, the mid-pressure system is now also connected to the low pressure system via a flow controller in case the low pressure system cannot meet its flow requirements. The pre and post-case diagrams can be seen in Figure 3 and Figure 4.

Figure 3: Pre-Case Compressed Air System Diagram

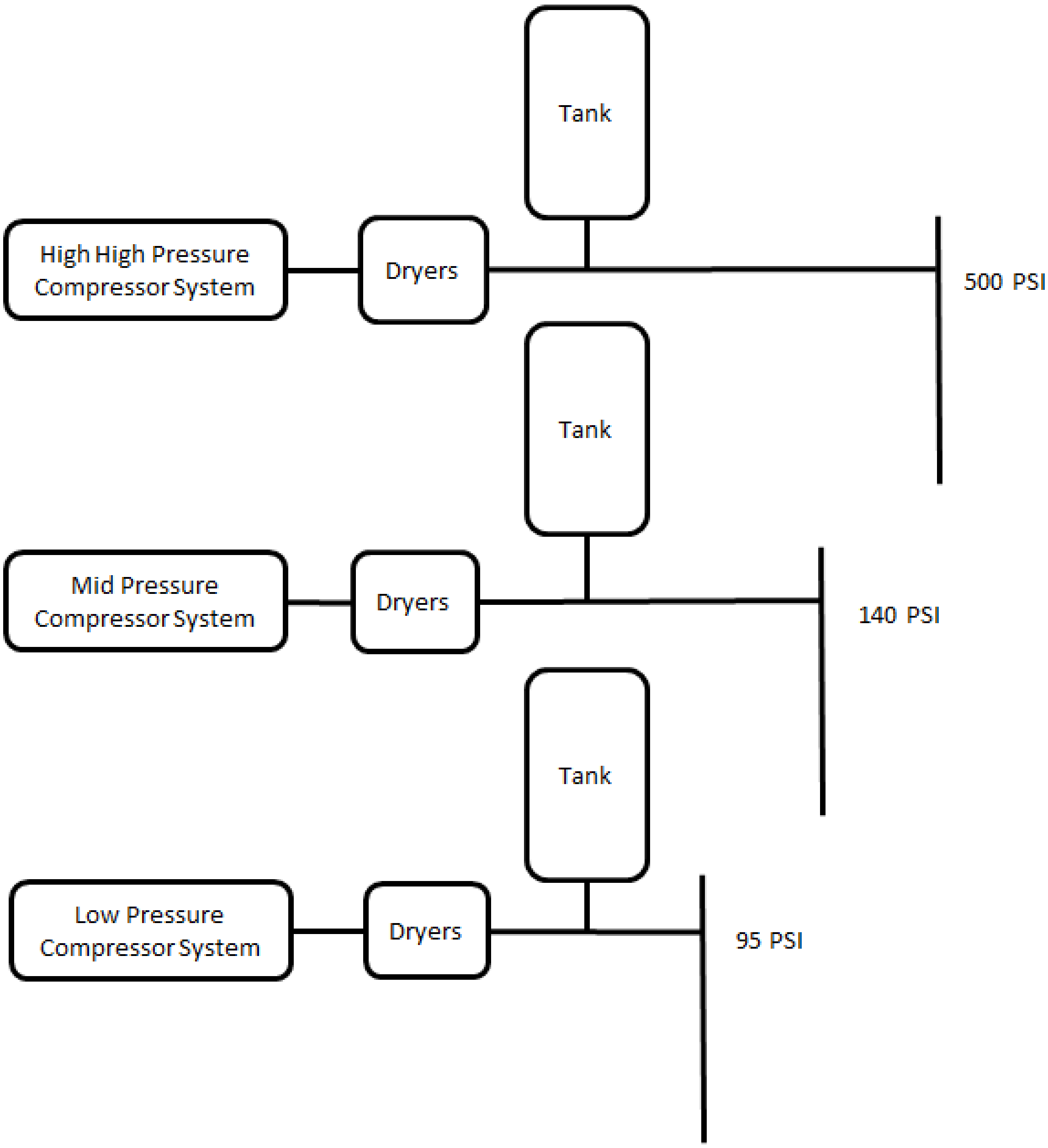
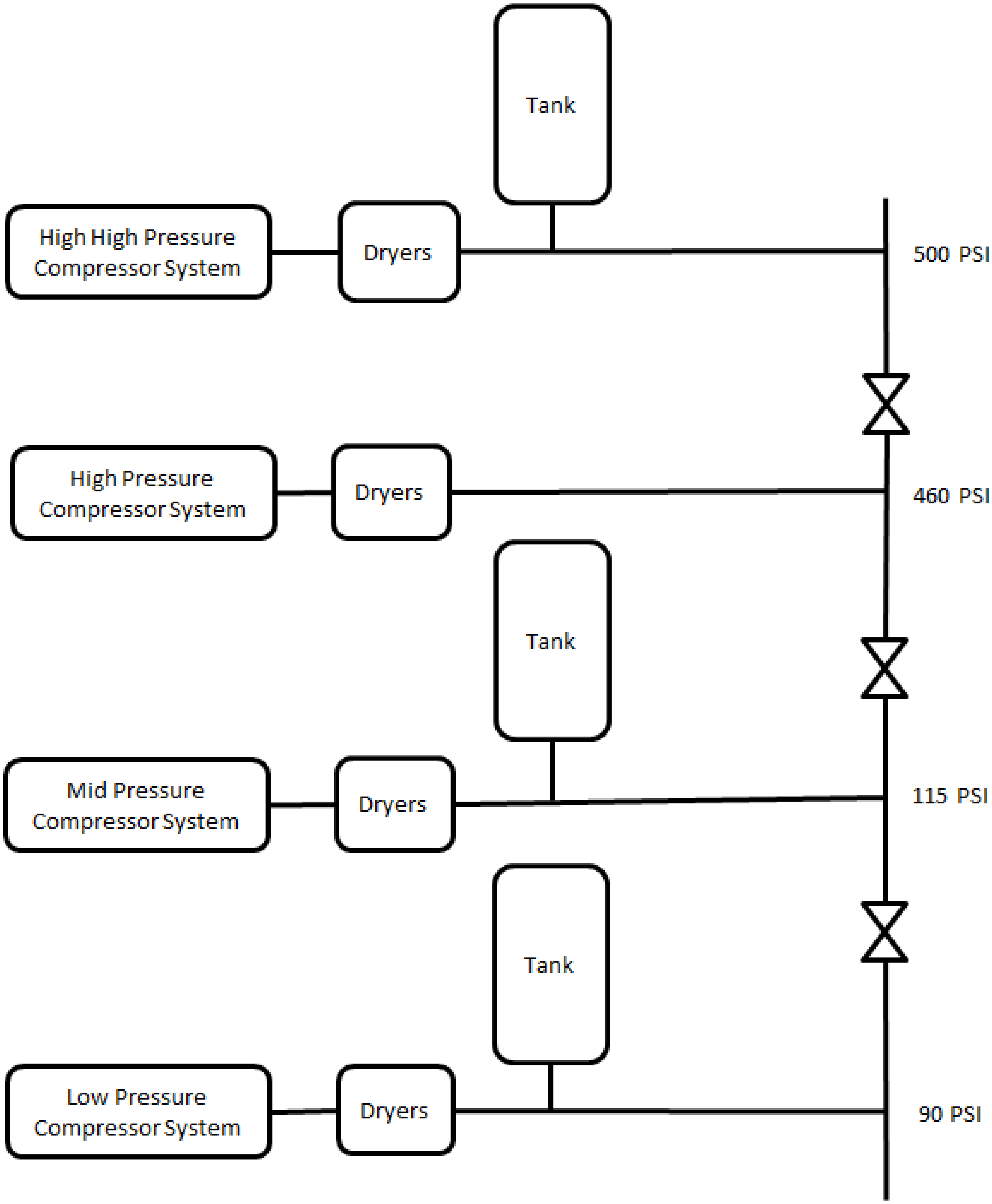


Figure 4: Post-Case Compressed Air System Diagram



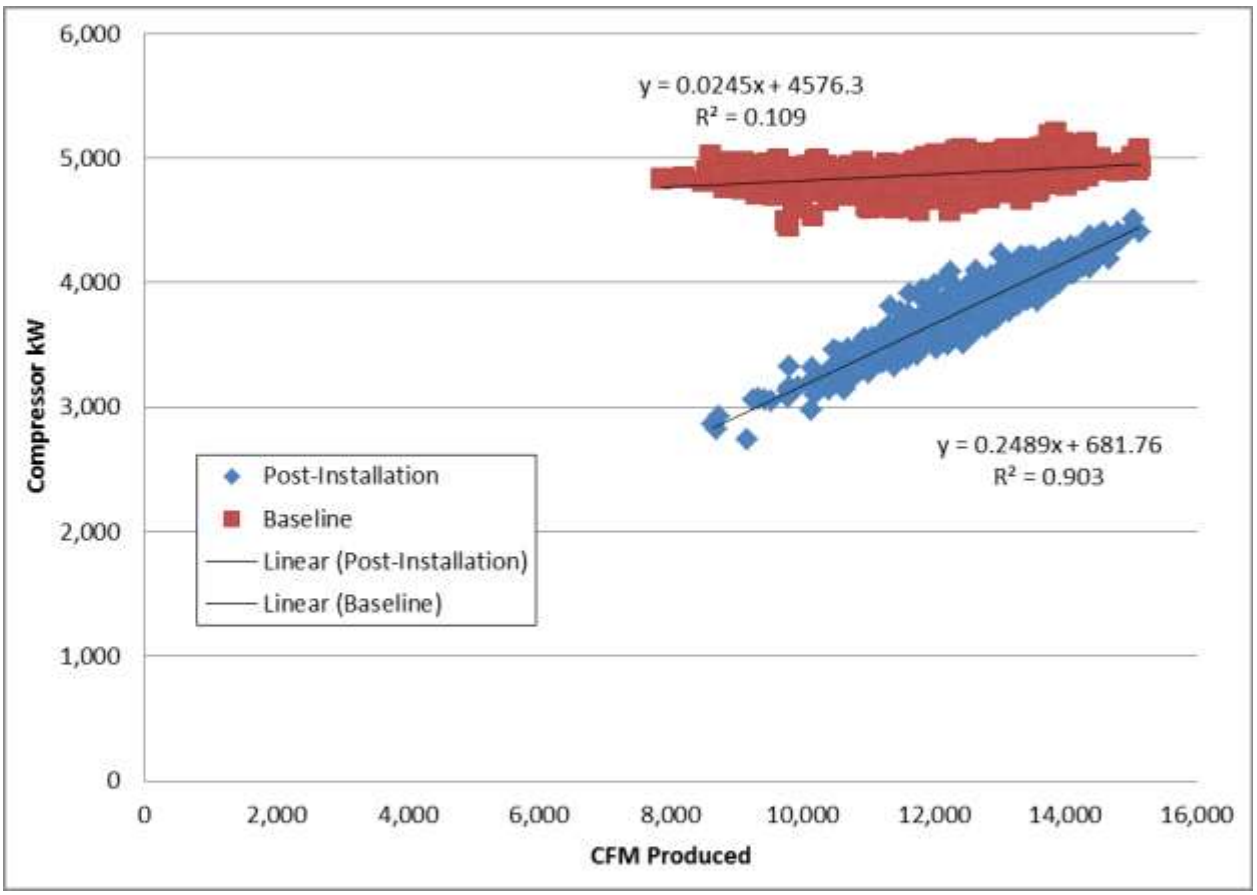
The zero loss drains were inspected and the site representative was interviewed. In the pre-case, the zero loss drains would open every 10 to 15 minutes for 10 seconds at a time, even if the compressor was not running.

In addition to the large 5,000 gallon tank that was added to the system, (22) 30 gallon tanks were added to the individual process machines to ensure that proper pressure and flow would always be maintained. The project documentation also listed a new 400 HP compressor as being installed, low pressure blowers, (2) new air dryers, (1) 3,000 gallon tank being installed, (1) 1,500 HP tank being installed, leak repairs, and the removal of some desiccant dryers. According to the site representatives, none of these measures were done as part of the project.

Calculation Description

The ex post savings for this project were determined by correlating the compressor power to CFM produced for the baseline and post-installation periods. The customer provided hourly metered data of each of the compressors in the system as well as the CFM produced during that hour for 30 days both before and after the project was completed. The baseline data was recorded in November of 2014, and the post-installation data was recorded in March of 2015. The results of the correlation are shown in Figure 5.

Figure 5: Baseline and Post-Installation Compressor kW and Flow



The figure clearly shows a significant decrease in the demand required for producing similar CFM levels. To determine the typical yearly savings, a daily profile was developed from the post-installation period data. The average CFM produced per day was determined, and the power correlation equations from Figure 5 were used to determine the power for each hour of the day. The results of the calculation can be seen in Table 27.

Table 28: Summary of Ex Post Calculation

Hour	CFM	Base kW	Proposed kW	kW Savings	kWh Savings
0	12,597	4,884.91	3,817.49	1,067.42	389,608.64
1	12,509	4,882.75	3,795.51	1,087.24	396,842.17
2	12,563	4,884.07	3,808.98	1,075.09	392,408.28
3	12,582	4,884.55	3,813.82	1,070.73	390,816.93
4	12,365	4,879.24	3,759.85	1,119.39	408,575.92
5	12,335	4,878.50	3,752.38	1,126.12	411,033.87
6	12,292	4,877.45	3,741.64	1,135.81	414,569.80
7	12,490	4,882.30	3,790.94	1,091.36	398,345.35
8	11,951	4,869.09	3,656.69	1,212.40	442,524.31
9	11,701	4,862.96	3,594.46	1,268.50	463,004.09
10	11,928	4,868.52	3,650.90	1,217.62	444,431.19
11	12,174	4,874.54	3,712.13	1,162.41	424,279.41
12	12,135	4,873.60	3,702.58	1,171.02	427,423.53
13	12,220	4,875.67	3,723.58	1,152.09	420,513.51
14	12,492	4,882.35	3,791.42	1,090.92	398,186.88
15	12,606	4,885.14	3,819.78	1,065.36	388,855.79
16	12,649	4,886.19	3,830.44	1,055.75	385,348.86
17	12,825	4,890.49	3,874.13	1,016.36	370,970.91
18	12,989	4,894.52	3,915.14	979.38	357,472.66
19	12,929	4,893.05	3,900.23	992.83	362,381.97
20	12,850	4,891.12	3,880.58	1,010.54	368,848.76
21	12,961	4,893.84	3,908.17	985.67	359,769.03
22	12,726	4,888.07	3,849.54	1,038.53	379,062.29
23	12,813	4,890.21	3,871.35	1,018.86	371,883.11

The demand (kW) savings were determined by subtracting the calculated post-installation demand from the calculated baseline demand. The energy (kWh) savings were determined by multiplying the demand savings by 365, as there are 365 of each hour of the day in a year. The peak demand savings were calculated as the average of the demand savings for the 4:00pm to 7:00pm hours of the day (hours 16, 17, and 18). A summary of the ex post savings can be found in Table 28.

Table 29: Summary of Ex Post Results

	kW	kWh	Therms
Ex Ante	1,076	9,424,816	0

Ex Post	1,018	9,567,157	0
Realization Rate	94.5%	101.5%	N/A

700069 Project Information

Project ID#:	700069
Measure:	New Construction Reduced LPD Lighting
Ex Ante Savings:	2,321,851 kWh; 150.71 kW
Facility Type:	Warehouse

Measure Description

This project was completed as part of a new facility construction. The customer installed (416) fixtures of various wattages in 42,500 square feet of office area, (79) of which are controlled by occupancy sensors. The customer also installed (825) fixtures in 717,500 square feet of warehouse space, all of which are controlled by occupancy sensors, and (157) exterior LED fixtures in 472,000 square feet of uncovered parking area and to illuminate (3) exterior windows. The fixtures installed with this project are listed in Table 29.

Table 30: Summary of Lighting Installations

Qty	Description	Wattage	Sensor Qty	Area	Area Type
150	2-lamp 4'T8	59	3	42,500 sf	Office
25	*N/A*	11	5		
167	2x4 Recessed LED	39	56		
50	2-lamp 4'T8	59	15		
24	*N/A*	192	0		
120	LED wall luminaire	109	0	472,000 sf	Uncovered Parking
32	LED pole fixture	209	0		
5	*N/A*	25	0	3 windows	Windows
825	High Bay LED	388	825	717,500 sf	Warehouse

Summary of the Ex Ante Calculations

The ex ante savings for this project are 150.71 kW and 2,321,851 kWh.

The baseline lighting energy use for this project is based on the maximum code-allowable lighting power density per ASHRAE 90.1-2010. The lighting power density values for the various areas of the facility were taken from the LPD tables for the building area method. The code-allowable lighting demand for exterior window illumination is 400 Watts per window.

The project documentation indicates that the warehouse areas of the facility are expected to be in use during all hours of the day, so the baseline lighting operation for the warehouse areas is continuous operation (8,766 hours per year). The default lighting operation specified in ASHRAE 90.1-2010 is used in the savings calculations for the lights in the offices and uncovered parking areas of the facility. The occupancy sensors installed with this project are expected to reduce the operation of the controlled lights by 30%. The lighting details are shown by space type in Table 30.

Table 31: Space Lighting Details

Space Type	Code-allowable LPD (W/sf)	Baseline Lighting Hours	Operating Hours w/Sensors
Office	0.90	4,439	3,107
Warehouse	0.66	8,766	6,136
Uncovered Parking	0.10	4,903	-

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

$$Energy\ savings\ (kWh) = Baseline\ FL\ kW \times \frac{Baseline\ hours}{year} - Installed\ FL\ kW \times \frac{installed\ hours}{year}$$

$$Demand\ savings\ (kW) = \ Baseline\ FL\ kW - Installed\ FL\ kW$$

The ex ante demand savings are only for the fixtures located in the warehouse areas, uncovered parking areas, and 12,500 square feet of the office areas. It is not known why the lights in 30,000 square feet of the office spaces were not included in the ex ante demand savings calculations.

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

Table 32: Summary of Project Savings

Measure	kWh	kW
New Construction Reduced LPD Lighting	2,321,851	150.71

Measurement and Verification Plan

IPMVP Option A, Partially Measure Retrofit Isolation, was used to establish savings for this measure.

A site visit was completed, during which the customer was interviewed about the work that was completed for this project. During the site visit the following information was collected and/or verified:

- Verified quantity, model numbers, and wattages of installed fixtures – see Table 19.
- Collected fixture model numbers not specified in project documentation.
- Determined if any areas of the facility is conditioned during the summer? If so, what is the type and efficiency of the cooling equipment, what are the space temperature setpoints, and does the system have economizer capabilities?
- Were there any seasonal variations in the use of the facility?
- Determined if the operation of the lights monitored used an energy management system? If so, does the system have trending capabilities?

If it was not possible to collect or initialize trends of lighting operation during the site visit, Hobo UX90 light on/off loggers or Hobo U12-012 lumen level loggers would be installed to monitor the operation of approximately 20 light fixtures throughout the facility. Additionally, Hobo U12-012 external channel loggers with split-core current transducers were installed to monitor at least two of the exterior lighting fixtures installed with this project.

The data collected with the installed loggers was used to develop average weekly profiles of the operation of the metered lights. The developed weekly profiles was used to determine the expected annual operation of the installed lights and their operation during peak periods. The demand of the installed fixtures was used with the developed profiles to determine the annual energy use of the installed fixtures. This energy use was compared to the baseline energy use of the facility with baseline controls (no occupancy sensors) to determine the savings for this project. The ex post energy savings calculations can be summarized with the following equation:

$$Energy\ savings\ (kWh) = Baseline\ FL\ kW \times \frac{baseline\ operating\ hours}{year} - Installed\ FL\ kW \times \frac{metered\ operating\ hours}{week} \times \frac{52.14\ weeks}{year}$$

To determine the summer peak demand savings for this project, the average operation of the installed lights was found for periods from 4-7 PM Monday thru Friday during the summer months, and compared to what the estimated operation of the lights would be if occupancy sensors had not been installed. The ex post demand savings calculations can be summarized with the following equation:

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

Description of Verification

A site visit was completed on 09/15/2015. The site representative was interviewed and the equipment was inspected. A list of lighting for the warehouse area was collected from the site representative that included fixture type and quantity. The provided list was verified to be accurate. All of the non-warehouse spaces, including office spaces, lobbies/lounges, breakrooms, locker rooms, restrooms, storage rooms, etc. were surveyed and the room fixture types and quantities were recorded. Manufacture specification sheets were not available and the site representative was not able to provide wattages of any of the fixtures.

The warehouse fixtures were verified to consist of (726) LED fixtures controlled via occupancy sensors. Light loggers were installed in the warehouse to record the operation of representative fixtures. In addition, the warehouse was confirmed to be 30,000 square feet. A total of (207) LED fixtures were found to be installed in the office spaces and light loggers were installed in representative areas to record the fixture operation, a majority of which were occupancy sensor controlled. The exterior fixtures were confirmed to consist of (152) LED fixtures.

The office was found to be fully staffed with (10) people during the daytime shifts on the weekdays, (4) people occupy the office during weekday night shifts and (2) people occupy the office during all weekend hours. The weekday day shifts consist of 6:30 AM until 6:30 PM. Similarly, the warehouse is fully staffed with (25) people for all 24 hours of the day for all week days, and fully staffed on Saturday and Sunday from 6:30 AM until 6:30 PM. During the night shifts on Saturday and Sunday (6:30 PM until 6:30 AM) the warehouse staff consists of (3) to (6) people depending on need. The parking lot lighting is believed by the site representative to be astronomic time clock controlled, though it may be a photo sensor.

Calculation Description

The ex post savings for this project were calculated by comparing the installed lighting power density to the code allowed lighting power density. Additionally, occupancy sensors were installed to determine the post-installation operating hours. Based on the site visit, all of the claimed fixtures were found to be installed. The baseline operating hours were assumed to be the customer stated hours of operation, or 7,488 hours per year. The lighting logger data can be seen in Table 32.

Table 33: Lighting Logger Analysis

	Logger ID	Hours	Peak CF	On Time (%)
Warehouse*	791	2,268	30%	30%
	2661	7,778	96%	104%
	2944	769	10%	10%
	Average	**3,605**	**45%**	**48%**
Office	905	7,535	100%	101%
	1056	493	9%	7%
	3054	1,506	18%	20%
	2588	4,037	48%	54%
	Average	**3,393**	**44%**	**45%**

*Two loggers with significant daylighting interactions were excluded.

In the ex ante analysis, the occupancy sensors were assumed to provide 30% run time savings. However, as the lighting logger data shows, they actually are providing a 55% reduction in runtime hours throughout the facility.

Decreasing the overall hours of operation from 8,760 hours per year to 7,488 hours per year reduced the savings. However, this was offset by the increase in reduced runtime provided by the occupancy sensors. Additionally, the new construction lighting calculator used to determine the ex ante savings does not include any demand savings provided by the occupancy sensors. Accounting for this increased the demand savings of this project. A summary of the ex post savings can be found in Table 33.

Table 34: Summary of Ex Post Savings

	kW	kWh	Therms
Ex Ante	150.71	2,321,851	0
Ex Post	353.65	2,213,219	0
Realization Rate	234.7%	95.3%	N/A

700396 Project Information

Project ID#:	700396
Measure:	Boiler improvements
Ex Ante Savings:	0 kWh; 0 kW, 256,029.869 Therms
Facility Type:	Manufacturing/Industrial

Measure Description

This project consisted of re-tubing a facility's existing boiler (Boiler #3), replacing the boiler's burner with a high efficiency burner, re-tubing the boiler's economizer, and connecting the economizer to a condensing heat exchanger associated with another boiler (Boiler #4). Note that Boiler #4 had been used to meet the loads prior to Boiler #3 being repaired.

Summary of the Ex Ante Calculations

The ex ante savings for this project are 0 kWh, 0 kW, and 256,030 therms. Custom calculations were included with the project documentation.

The calculations compare the savings to the apparent project savings by using a list of pounds/ steam flow compared to the gas consumption to develop and efficiency profile for both boiler #3 and boiler #4.These are then both compared to operating bins with the percent time at each bin to calculate the savings. This method results in similar savings to the claimed savings. The actual project claimed savings calculations use a hard-coded annual steam production savings multiplied by a hard-coded 11.92 therms per 1,000 lbs of steam. There are no comments on how these values were determined.

The ex ante savings for this measure are presented in Table 34.

Table 35: Ex Ante Claimed Savings

Measure	kWh	kW	Therms
Boiler improvements	0	0	256,030

Measurement and Verification Plan

IPMVP Option A, Partially Measured Retrofit Isolation, was used to establish savings for this project. A site visit was completed, where the following activities were conducted and information was collected:

- Visually verified the installation of the new equipment and confirm that boiler #3 and its associated economizer were re-tubed and connected to the condensing heat exchanger.
- Obtained the make and model number of all of the boilers and boiler burners if possible, as well as the boiler capacities.
- Collected efficiency test data from the site representative if available for each of the boilers that were part of the system, both before and after the completion of the project.
- Interviewed the site representative concerning:
  - The system operation, setpoints, etc.

- Operating hours and any lockout periods, including seasonal use
- Pre & post-case boiler sequencing
- Pre & post-case controls (hot water reset schedules)
- The demand load that the system meets, if the system is used for domestic hot water, HVAC, process, etc.
- The gas usage at the facility
- The boiler economizers, temperatures, effectives, flash steam recover, etc.
- If the system is a steam system, is it open or closed to the atmosphere

- Verified that the boiler system does not contain other boilers.
- Collected any gas records that the site representative has kept.
- Collected steam flow and gas flow if available

Description of Verification

A site visit was completed on 09/01/2015. The site representative was interviewed and the equipment was inspected.

Trended data of the steam production and gas usage per hour for the boiler system was collected while onsite. Boiler #4 was found to be the primary boiler in the pre-case and boiler #3 was not operational. Both Boiler #3 and Boiler #4 are connected to their own non-condensing economizers. Boiler #3 was confirmed to be tied into the condensing economizer that previously serviced only Boiler #4. Boiler #3 is now operated as the primary boiler because it now has a VFD fan unlike Boiler #4. Boiler #3 and its non-condensing economizers were confirmed to have been re-tubed. Combustion efficiencies for the boilers were not available and combustion tests could not be performed. The boiler system was found to supply 139 PSI steam to the facility for production purposes. The trended period was confirmed to be a period of typical operation and the boiler system was confirmed to only be shut down for (1) week a year. According to the customer, the historical boiler steam production as produced by Boiler #4 was produced at a rate of 11.9 Therms per 1,000 lbs of steam. This number could not be verified apart from the site representative.

Calculation Description

The trended data supplied was analyzed and the typical steam production was found to be 299,945 thousand pounds of steam produced annually. The trended data included the amount of steam produced by the improved Boiler #3 along with the gas consumption of Boiler #3, resulting in an average steam production rate of 10.13 therms per 1,000 lbs of steam.

Based on the steam production rate, the savings is equal to the annual steam usage multiplied by the difference between the pre-case steam production rate and the post-case steam production rate as can be seen in the equations below.

$$Therms_{saved} = SteamProduction_{Annual} * (ProductionRate_{PreCase} - ProductionRate_{PostCase})$$

$$SteamProduction_{Annual} = SteamProductionAverage_{HourlyMeteredData} * 8760 * \frac{51}{52}$$

Note: The facility is shut down (1) week out of the (52) weeks per year and the steam system is also shut down during the plant shutdown period.

$$ProctionRate = \frac{SteamProduction_{TrendedPeriod}}{GasUsage_{TrendedPeriod}}$$

Note that the facility recorded the gas usage in therms per hour and the steam production in thousands of pounds of steam per hour.

The resulting savings were compared to the facilities gas bills and were confirmed to be reasonable. In fact, there was little difference between the savings shown on the gas bills and the calculated savings based on the trended data.

The savings are greater than expected because the annual usage is slightly greater than the ex ante calculations used to calculate the savings. In addition, Boiler #3 was found to be slightly more efficient than expected.

A summary of the ex post savings can be found in Table 35.

Table 36: Summary of Ex Post Savings

	kW	kWh	Therms
Ex Ante	0	0	256,030
Ex Post	0	0	532,073
Realization Rate	N/A	N/A	208%