FINAL REPORT

Rhode Island PY2020 Custom Electric Installations

RICE2020

Date: October 31, 2022

Table of contents

List of figures

List of tables

List of acronyms used in this report

BMS	building management system
CDA	comprehensive design assistance
CHP	combined heat and power
C&I	commercial and industrial
EMS	Energy monitoring system
EUL	effective useful life
FCM	forward capacity market
HVAC	heating, ventilating, and air-conditioning
ISP	industry standard practice
LSAF	Lifetime saving adjustment factor
M&V	measurement and verification
MBSS	model-based statistical sampling
ML	measure life
Non-Ops	Non-Operational Parameters
PY	program year
PYR	plan year report
RR	realization rate
SCADA	supervisory control and data acquisition
TMY3	typical meteorological year 3
TA study	technical Assistance study
MRD	minimum requirements document

1 INTRODUCTION

1.1 Study purpose, objectives, and research questions

This document is the final report for DNV's Impact Evaluation of Program Year (PY) 2020 Custom Electric Installations, conducted for RI Energy, carried out from November 2021 to August 2022. The DNV team includes expertise from our partner firm DMI.

The primary objective of the impact evaluation was to provide verification and re-estimation of energy and demand savings for a sample of statistically selected custom electric projects through site-specific verification, monitoring, and analysis. The results of this study, combined with those from previous years, were used to determine the gross realization rates to be used for custom electric energy efficiency projects implemented in 2023 and will be updated annually as subsequent impact evaluations are completed.

The key objectives of this evaluation were as follows:

1. **Evaluate savings impacts of PY2020 custom electric projects** to be pooled with the results of the recently completed PY2018 and PY2019 studies. This study will aim to quantify:
    - Achieved electric energy savings for custom non-lighting projects, with a targeted combined sampling precision of ±15% at 90% confidence when pooled with the results from the PY2018 and PY2019 studies.
    - Summer and winter on-peak demand realization rates will also be calculated at 80% confidence for custom non-lighting when pooled with the results from the PY2018 and PY2019 studies.
2. **Evaluate lifetime savings adjustment factors (LSAF)** for PY2020 using the results for the sites included in the study and the sampling weights calculated for Objective 1 above. LSAF was not calculated in the previous two evaluations. Therefore, PY2020 (considered Year-1) cannot be applied to future programs but would require combining LSAFs from three years (rolling/staged; PY2020+PY2021+PY2022) for program planning purposes.

Realization rates for this study were based on a combination of verified parameters of this current sample, historical operation adjustments from the PY2018 and PY2019 impact evaluations, and pooling with RI PY2020 results to produce three-year average rolling results.

1.2 Organization of report

The rest of the report is organized as follows:

- Section 2: Methodology and Approach
- Section 3: Data Sources
- Section 4: Analysis and Results
- Section 5: Conclusions and Recommendations
- Appendices

2 METHODOLOGY AND APPROACH

This study is the fourth annual C&I custom electric impact evaluation in Rhode Island using the rolling average approach. Like the 2018 and 2019 studies, this year's study was modified to adapt to limitations associated with the COVID-19 pandemic. The one major change from last year's study is that this year's study calculated savings and realization rates for non-lighting projects only.

Other key changes include:

- A portion of customers continued to face a reduction in the building- or measure-level operation, so on-site verification, M&V planning, or meter installs were not included at every site.

- Both virtual visits and an onsite without metering will generate Non-Ops adjustment factors only, while a Full M&V site visit will include metering to generate both Non-Ops and site-specific operational adjustment factors. And a site will have a Full M&V only when the following conditions are met:
  - Condition 1: Site contact is on-site, and it is safe to do site visits.
  - Condition 2: Customer operation is not affected by the pandemic (like, change in hours of operation, lower building occupancy, reduced loads, etc., due to the Pandemic).
  - Condition 3: The metering window is not affected by seasonality.

If only Condition 1 is satisfied, the evaluator and site contact may use an on-the-premises site visit in lieu of a virtual site visit but may not install metering. If conditions 1, 2, and 3 are satisfied, the evaluator has the option of installing metering to generate operational adjustment factors.

7 out of 10 sampled sites were considered Full M&V, and 3 sites were Non-Ops. DNV completed a site visit for 9 sites, while one site had a virtual visit.

Realization rates were based on a combination of verified parameters of this current sample, historical operation adjustments developed from the past two impact evaluation cycles, as well as M&V sites from this study and pooling with PY2018 and PY2019 results to produce three-year rolling average results.

Custom non-lighting projects include HVAC systems and controls, industrial process systems, and other non-lighting energy-using equipment. The decision to exclude lighting projects was made due to the relatively stable realization rates for custom lighting projects throughout the last three custom evaluation rounds.

The primary objective of the Impact Evaluation of PY2020 Custom Electric Installations was to provide verification and re-estimation of energy and demand savings for a sample of statistically selected non-lighting custom electric projects through site-specific verification, monitoring, and analysis. The results of this study were used to determine the gross realization rates for custom electric energy efficiency projects implemented in 2020 and were combined with the previous two studies to provide rolling results based on the most recent three years of study.

The goals of this study were to quantify the following:

1. Achieve electric energy savings for custom non-lighting segments statewide, with a targeted combined sampling precision of ±15% at 90% confidence when pooled with the results from the PY2018 and PY2019 studies.

2. Calculate summer and winter on-peak demand realization rates at 80% confidence at ±10% relative precision for custom non-lighting when pooled with the results from the PY2018 and PY2019 studies.
3. Calculate lifetime savings adjustment factors (LSAFs) for custom electric projects statewide for PY2020.
4. Percent on-peak realization rates will also be calculated for custom non-lighting for the three-year rolling average.

2.1 Sample development

2.1.1 Tracking data review

DNV reviewed project parameters found in the raw tracking data files received from RI Energy to uniformly classify measures as lighting or non-lighting projects to prepare the data for the sample design process.

The data included a total of 91 non-lighting applications at 79 unique sites. As mentioned earlier, the scope excluded Lighting projects in this round of evaluation. PY2020 claimed 10.7 million in annual energy (kWh) savings, which is nearly 20% less than each of the previous two years (see Table 2-3). Note that the population frame included applications completed in the calendar year 2020 and did not include Comprehensive Design Assistance (CDA)[1], CHP, or SEM applications.

Table 2-1. PY2020 Gross annual energy and peak demand savings

Total Unique Accounts (Sampling Unit)	Total Energy Savings (kWh)	Total Peak Summer Savings (kW)	Total Peak Winter Savings (kW)
79	10,676,671	1,441.1	1,167.6

2.1.2 Sampling plan

Model-based statistical sampling (MBSS) techniques have been used to develop the sample design. The sample design's general principle is that each year's results would need to achieve ±26% precision at the 90% confidence interval to maintain a three-year pooled result of ±15% precision at 90% confidence for non-lighting gross energy realization rates. Since the sampling was done individually for PY2018 and PY2019, two sections are presented individually per the respective study's workplans. The error ratios[2] (ER) for PY2020 were calculated using the actual ER from PY2018 and PY2019, presented below in Table 2-2.

Table 2-2. Sampling targets

Annual Sampling Target	3-Year Pooled Sampling Target	Error Ratio
±26% on Non-Lighting Energy (kWh) at the 90% confidence interval	±15% on Non-Lighting Energy (kWh) at the 90% confidence interval	PY2020 = 0.45

Table 2-3 presents the sample design for PY2020. The accumulated RI sample for the first three years in the staging evaluation resulted in very reasonable projected relative precision (RP) estimates of ±11% RP @ 90% for non-lighting.

[1] CHP and CDA programs are studies separately and get their own individual realization rates, therefore excluded from this study.

[2] Error ratio is a measure of the population variability between the x (known for population) and y (known only for the sample) variables. The error ratio is defined as the ratio between (a) the sum or average of the residual standard deviations of all customers, and (b) the sum or average of the expected values of y.

Table 2-3. 2020 project sample design and estimated relative precisions

End-use	Program year	Energy Savings (kWh)	Sample Size	RP @90% CI
Non-Lighting	2018	12,910,679	14	±12.3% (actual)
	2019	12,804,067	15	±18.4% (actual)
	2020	10,676,671	10	±26.0%
Non-Lighting (3-year rolling)	**2018+2019+2020**	**36,391,417**	**39**	**±11.0%**

2.1.3 Sample changes and final sample

For various reasons, some primary sampled sites were replaced with backup ones. Replacement sites were always sourced in order of priority within the same stratum when available. A summary of the replaced sites is shown in Table 2-4. The categories of replacements are:

Unresponsive: The most common reason for site replacement was unresponsive sites. A site was classified as unresponsive after the steps outlined in the customer outreach protocol had been exhausted. These steps are:

- Step 1: Send an initial outreach email to the site contact describing the reason and objectives for reaching out.
- Step 2: If the contact did not reply 48 hours after the initial contact, the evaluators followed up with a phone call. If the contact answered the call, a RI Energy-approved phone script was used to guide the conversation. If the contact did not answer the call, the evaluators left a brief voicemail referring to the initial email and requesting a callback.
- Step 3: Without any responses from steps 1 and 2, the evaluators contacted the RI Energy lead for recruiting assistance. The customers are considered unresponsive if there is no response after RI Energy's recruitment efforts.

Two sites (RICE20N069 and RICE20N001) were unresponsive in this round of evaluation.

In all cases, backups sites were selected for sites in the same strata with available backups.

Refusals: One site (RICE20N075) refused to participate in the evaluation. This category represents customers who responded to the outreach but refused or asked not to participate in the study.

Table 2-4. Summary of replaced sites

End Use	Pandemic related closure	Unresponsive	Refusal	Total Replaced Sites
Total	**0**	**2**	**1**	**3**

2.2 Description of methodology

Due to the continued restrictions of the COVID-19 pandemic limiting site work, this study's methodology was modified from typical years, which is consistent with last year's study. The key changes that remained are:

- The use of virtual audits in some cases to verify technology, assess HVAC interaction, and validate measure installation
- The use of historical operation adjustments from the last two custom electric studies combined with operation adjustments derived from this study. 7 of 10 sample projects in this study had operation adjustments. These were combined with operation adjustments from the past two custom electric rounds and used as substitutes for samples

where metering and M&V were not in scope due to the pandemic or the inability to recruit the site in time to meter in the right season.

The team has updated the realization rates yearly as part of this custom electric evaluation framework. The evaluation also generated lifetime savings adjustment factors (LSAFs) in this round.

2.2.1.1 Customer Outreach

Project engineers reached out to customer site contacts using an updated COVID-19-compliant, RI Energy-approved communication protocol and the information provided in the project files. During this initial outreach, the engineers discussed the purpose of the outreach, the effects of COVID on the facilities' operation and usage, the scope of measures installed, the availability of onsite trend/SCADA/production data, and any other applicable parameters relevant to the evaluation, and confirmed the site's ability and willingness to participate in the evaluation. When the fieldwork restarted in early 2021, RI Energy provided pandemic-specific guidelines for qualifying site visit participants, including:

- Evaluation will not conduct any outreach to healthcare facilities, such as hospitals, nursing homes, or assisted living facilities, without special permission from RI Energy.
- Evaluation will not ask anyone to go into their facility if they are not already there or create a situation where a customer feels compelled to make a separate trip to their facility to provide data.
- Evaluation will be mindful that response rates could differ from normal circumstances, and the current COVID-19 situation may influence any data we collect. We will use our best judgment about what data types would be meaningful to collect.

Efforts were made to minimize pre-recruitment evaluation activities until the customer site contact indicated they would accommodate the evaluation process. However, to communicate effectively with the customer during the initial site contact, the evaluators had to develop a strong understanding of the installed measures before customer outreach, in some cases resulting in extra work for customers that ultimately did not end up being evaluated. A backup site was selected if the site contact was unresponsive or refused to participate in the evaluation.

2.2.2 Operational and Non-Operational Impacts using Onsite Visit

The site evaluation process consisted of three phases: 1) Planning, 2) Customer Outreach, and 3) Site Evaluation.

RI Energy consulted with their internal account managers regarding customer outreach of all sampled and backup sites to determine if evaluators could proceed with the recruitment. Every site that was ready for recruitment then followed one of the three following evaluation types:

1. Onsite Site Visit with only non-operational impacts: The site is open to an onsite visit. However, the COVID-19 pandemic impacts the installed measure's operation, and little meaningful data would be obtained from onsite metering. Evaluators could use virtual visits to reduce the time spent onsite and prepare an onsite plan before the visit. Evaluators will only collect non-operational impacts for this option.

2. Onsite visit with non-operational and operational impacts: The site is open for an onsite visit, and the COVID-19 pandemic does not impact the customer. In this case, virtual site visits can also be used to collect non-operational data and make a meter installation plan before completing the onsite visit. The virtual visit would allow the evaluator to reduce prolonged exposure from time spent onsite (if the customer permits or is hesitant to do a physical visit).

3. Virtual Visit with Operational and Non-Operational impacts for non-lighting measures. Virtual inspection to verify technology and quantity.

All evaluation types listed above included an M&V plan for each site. Each site plan included the following sections:

Project description – A description of how the project saves energy.

Tracking savings – A short description of how the tracking savings were estimated and their source, including:

– Analysis method was used.

– Identification of the key baseline assumptions.

– Identification of the key proposed assumptions.

– Evaluator assessment of tracking savings methods or assumptions, including program-reported baseline.

COVID-19 impacts – A description, if any, of impacts from the current health emergency.

– Suggested site evaluation method taking into account COVID-19 Impacts.

– Reasoning for the chosen site evaluation method.

Project (site) evaluation – A short description of the methods to be used to evaluate the project, including, but not limited to:

– Methods for verifying the measure installation and current operation.

– Methods for observing and/or assessing building use and occupancy.

– Identification of the tracking and expected evaluator baseline of each measure.

– The data to be collected by DNV; where several similar items have been installed or are being controlled, the site evaluation plan described and justified the sampling rate of the equipment to be monitored.

– Site staff interview questions (to understand the baseline operation and determine if any changes in the operation of the impacted system occurred after the project was installed).

– The data provided or to be provided by the site (e.g., EMS trends, production, pre-metering) and/or RI Energy.

– The expected site evaluation analysis method to be used, including any deviations from the implementer savings estimation method. In general, the same methodology used to estimate tracking savings was used to estimate evaluated savings. DNV presented an alternative methodology only if the tracking methodology was flawed, unfeasible, or a more accurate methodology that utilized post-installation data was available.

– Key parameters that are determined through the site evaluation preparation to compare to those used in the original savings estimate.

– Measurement verification equipment to install on select equipment and quantity of devices intended for installation.

DNV updated the M&V plan, responding to RI Energy comments, and in most cases, submitted a revised M&V plan before the site visit. For some sites, the initial visit was scheduled within a couple of days or less, and RI Energy reviewers did not have the chance to approve the entire M&V plan before the site visit. For those sites, DNV evaluators emailed the plan for a quick review and response specifically for the tasks to be conducted onsite and the metering approach.

2.2.2.1 Data collection

With RI Energy's input on the site evaluation plan, the DNV team contacted the customer to schedule an onsite audit at a day and time convenient for the customer site contact.

The DNV team conducted audits to collect the data listed in the site evaluation plan for each site. In general, each data collection audit consisted of verifying the installed technology and quantities and a discussion with facility personnel regarding installed measure(s) and the baseline conditions that existed before the measure(s) installation.

2.2.3 Onsite M&V

Onsite visits were performed with RI Energy approval when the site contact was onsite. Additionally, M&V was performed when customer operation was not affected by the pandemic, and the metering window for the measures evaluated was not affected by seasonality.

Onsite M&V data collection included physical inspection, an interview with facility personnel, observation of site operating conditions and equipment, metering of equipment usage, and collection of facility-provided data. The physical inspection focused on verifying measure installation and expected operation. In some cases, multiple facility interviews and/or equipment vendor interviews were completed to ensure an accurate understanding of the operating practice.

For sites qualifying for M&V, instrumentation such as power recorders, TOU current loggers, plug load monitors, and temperature loggers were installed to monitor the usage of operating equipment and conditions of the associated affected spaces. Production data and EMS trends were also collected when available. Each site report includes a full description of the data collected and received and, where applicable, data from installed meters.

A unique savings analysis was created for each sampled project. When required, a typical meteorological year (TMY3 for Providence, RI) dataset of ambient temperatures was used for temperature-sensitive calculations. Energy savings were either calculated by the hour in an 8,760-hour spreadsheet or allocated to each hour in the year to estimate on-peak kW and kWh savings impacts. Each analysis provided estimates for annual kWh savings, on-peak kWh savings, and on-peak demand (kW) savings at the times of the winter and summer peaks, as defined by the ISO New England Forward Capacity Market (FCM). All coincident summer and winter peak reductions were calculated using the following FCM definitions:

- Coincident Summer On-Peak kW Reduction is the average demand reduction that occurs overall hours between 1 PM and 5 PM on non-holiday weekdays in June, July, and August.
- Coincident Winter On-Peak kW Reduction is the average demand reduction that occurs overall hours between 5 PM and 7 PM on non-holiday weekdays in December and January.

Each site report details the specific analysis methods used for each project, including algorithms, assumptions, and calibration methods where applicable.

Engineers submitted draft site reports to RI Energy upon completion of each site evaluation. The DNV team responded to the comments received and submitted revised reports for comment. A sample of reports was also submitted to the EERMC Consultant Team for review. The final site reports are included in 0. The body of this report provides an overview of the evaluation methods and findings only.

3 DATA SOURCES

To support the findings of the study, the DNV team used the following data sources:

- PY2020 tracking data provided by RI Energy
- PY2018 and PY2019 impact evaluation results and historical operation adjustment factors
- Project files, which typically include the following: applications, BCR screenings, invoices, technical assistance studies, applicant savings calculations, and post-installation reports
- Onsite audit observations and data collection, including inspection and verifications of equipment, nameplate data, staff interviews, vendor interviews
- For sites qualifying for M&V or sites with a customer or vendor-supplied operational data that metered or trend data

4 ANALYSIS AND RESULTS

4.1 Introduction

A total of 10 sites were evaluated in this study within the PY2020 population. These sites were classified into three evaluation categories listed below:

1) Onsite visit with non-operational and operational impacts (Full M&V)

2) Onsite visit with non-operational impacts only (Non-Ops)

3) Virtual[3] visit with Operation and Non-Operational Impacts (Full M&V)

Full M&V is considered a traditional measurement and verification (M&V) that involves onsite measurements using power, time-of-use meters or validated trend data and measure verification. Non-Ops sites were introduced in the study based on the change in scope in the spring of 2020 due to the pandemic, and they do not include any measurement or calculation of any operational characteristics of the installed measures but include verification of technology and quantities through virtual or onsite visits. Desk reviews do not include verifications or measurement but involve an in-depth assessment of tracking analysis for parameters such as baselines, methodology and checking of any tracking or administrative errors. Essentially, both Non-Ops and Desk review sites do not involve evaluating the operational characteristics of the measures.

To keep the integrity of the randomly selected sample, the study team collected as much information as possible with minimal changes to the primary sample. If COVID impacted a recruited site, the site was not dropped from the sample, but at minimum, non-operational information was collected (like measure installation verification, quantity and technology verification, assessment of baseline equipment and analysis methodology, and tracking and administrative corrections).

Operational adjustment factors were not collected from a site for two reasons: 1) the location was affected at the time of evaluation by COVID-19 restriction measures that caused occupancy or energy consumption to deviate from what was typical, or 2) meter installation, trend data collection, or physical access by evaluators to the installed measure for direct observation was impossible due to the COVID-19 restriction regulations. Restrictions came from the business itself or another governing entity. For sites where the pandemic does not impact operations, the DNV team collected operational data.

As shown in Table 4-1, seven of the 10 sample projects in this study had site-specific operation adjustments. The remaining 3 sites did not meet the qualifying criteria for metering outlined in the section above, and the evaluators assessed them for non-operation (Non-Ops) adjustments only. Table 4-2 presents the adjustment factors used in the evaluation. To compensate, the study made use of operation factors derived from the previous two custom electric sample results. These historical operation factors were combined with those from the 7 sample projects with M&V in this study to produce the operation factors used to generate the results from this study and involved the following steps:

- The evaluated results from the 2018 and 2019 studies were separated into operation and non-operation factors.
- The operation results were then combined with the operation results from this study using total population-level first-year tracking savings from each study to establish the weights each study had on the combined results.

[3] Typically, a virtual inspection is used to verify quantities and technology but we were able to confirm the operating hours for a Cannabis site using virtually verified lighting control schedule settings.

- The combined operation factors were then expanded to the population based on the case weights.

Table 4-1. Sampled Site Classification

Program Year	Evaluation Type	Sample Size
2020	Onsite visits with non-operational and operational impacts (Or full M&V)	6
	Onsite Audit with only Non-Operational Impacts (Or Non-Ops only)	3
	Virtual visit with Operation and Non-Operational Impacts (Full M&V)	1
	Total	**10**

Non-Ops sites included Baseline, methodology, tracking and administrative corrections, technology and quantity correction factors. And a Full M&V site will include Operational and HVAC interactive effects (if any).

Table 4-2. Adjustment factors for site evaluation

	Adjustment Factors						
Ratio Name:	Non-Operational Adjustments or Non-Ops Site					Operational Adjustments or Full M&V site	
Obtain During:	In-depth desk review			1st site visit (onsite or virtual)		Logger Installation	
Factor:	Baseline	Methodology	Tracking & Admin	Technology	Quantity	Operational	HVAC Interactive

4.2 PY2020 results

This section presents the expansion analysis methodology for PY2020 sites.

4.2.1.1 PY2020 Site weight calculation

Case weights have been created for each of the 10 sites by determining the total number of observations in the stratum and dividing by the number of evaluated observations.

Table 4-3. Stratification and Weighting

Strata#	Population (N)	Sample (n)	Weight (Non-Ops and Full M&V)
1	66	5	13.2
2	13	5	2.6

For the PY2020 annual evaluation, each site has a single case weight that was consistent across Full M&V and Non-Ops. And, for the portion of the sample without Full M&V, results were imputed using results from PY2018, PY2019 and PY2020 as described in APPENDIX C.

4.2.2 PY2020 Site-level discrepancies and RR

Historical operational adjustment results were used from the PY2018, PY2019, and PY2020 samples. Table 4-4 details the number of sites used from each program year that were used to calculate the imputed historical operational adjustment for this study that was used for operation adjustments for the 2020 sample sites that did not have operation data. The total number of operational adjusted sites from each program year is included, along with the total number of sites the program year contained. PY2018 used 10 out of 14, PY2019 used 10 out of 15 sampled sites, and 7 out of 10 have been used from PY2020, as shown below.

Table 4-4. Sites used for Imputed Historical Operational Adjustment Calculations (non-lighting)

Program Year	Number of Sites in Imputed Ops Adjustments	Number of Sites in Program Year
PY2018	10	14
PY2019	10	15
PY2020	7	10

Adjustment percentages found in Table 4-5 present the magnitude of changes from tracking for each site and are reported at the site level. The combination of non-operational and operational discrepancies sums up the change from tracking to evaluation (realization rate). The percentages are the total operational and non-operational adjustments compared to site-level savings.

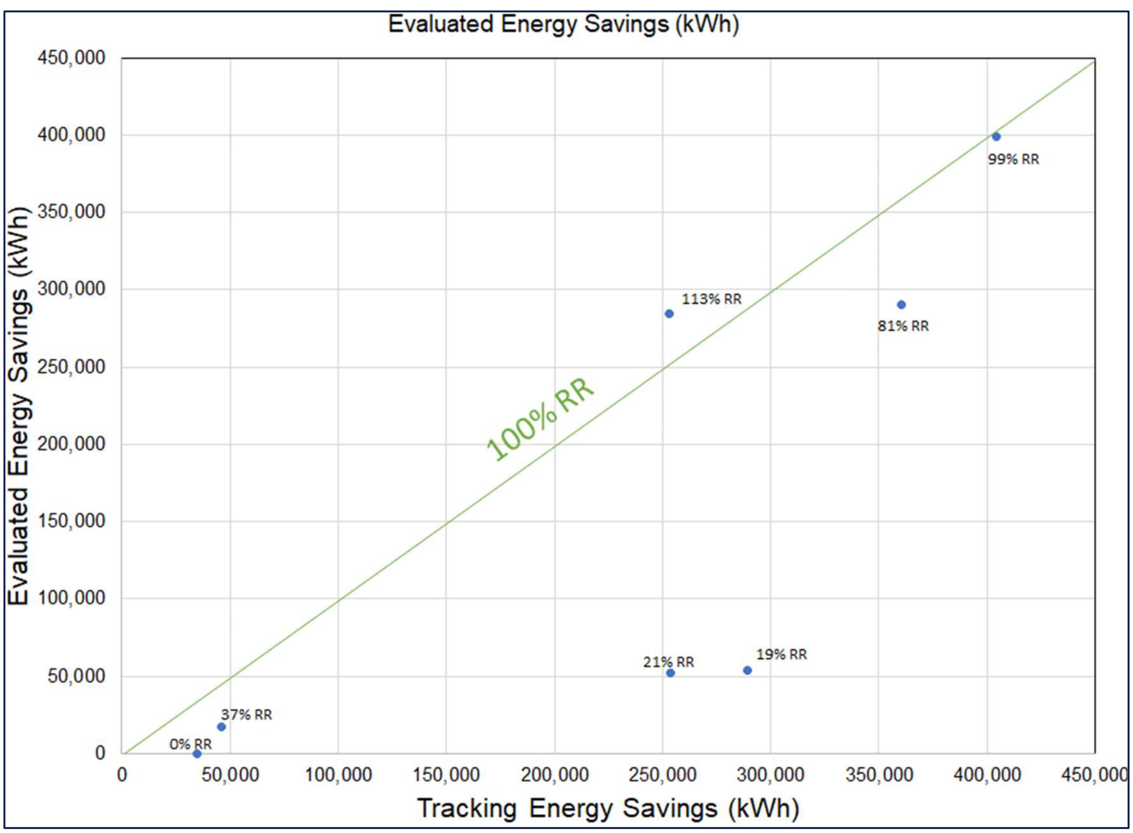
Table 4-5. Non-operational and operational weighted discrepancies – PY2020

Site ID	Tracking Savings (kWh)	Evaluated Savings (kWh)	Site Level Discrepancies		Realization Rate (%)
			Non-Operational	Operational	
RICE20N002	53,851	55,362	3%	N.A.	N.A.
RICE20N068	34,508	-	-100%	0%	0%
RICE20N076	46,221	17,241	0%	-63%	37%
RICE20N070	9,728	9,323	-4%	N.A.	N.A.

RICE20N032	121,191	121,191	0%	N.A.	N.A.
RICE20N036	360,240	290,465	0%	-19%	81%
RICE20N041	404,164	399,179	0%	-1%	99%
RICE20S009	289,016	53,792	0%	-81%	19%
RICE20N006	252,928	284,777	-0.8%	13.4%	113%
RICE20N047	253,411	52,090	-74%	-5%	21%

Figure 4-1 below presents bar charts of evaluated annual energy RRs for all PY2020 with Full M&V site evaluations. The figure below shows only 1 site that had realized energy savings greater than 100%, and one site realized zero energy savings in the evaluation.

Figure 4-1: Energy realization rates for Full M&V completed sites in the PY2020 sample (unweighted)



4.2.3 PY2020 Site-level findings

This section provides an overview of the results from PY2020 site-level tracking and evaluated results. The top six savings discrepancy changes (full M&V only) in the RI sample include the following. More details on each site can be found in the individual site writeups in 0.

RICE20N068: *Baseline Adjustment*: Deviations from the tracked savings result from changing the baseline from a retrofit to new construction. The change to a new construction baseline results in the controls added by the EMS system being considered baseline, with no savings resulting (-100%). The site had an Energy (kWh) RR of 0%.

RICE20N006 Operational*:* The evaluated savings are more than the applicant-reported savings primarily due to adjustments to dimming factors used in the analysis (which the evaluators applied identically in baseline and as-built calculations). The site had a 113% energy (kWh) RR.

RICE20S009 Quantity & *Operational*: The evaluated savings are less than the tracking savings. One of the largest contributing factors was the number of controllers being utilized. The total installed quantity was less than assumed in the tracking analysis, and not all of the installed controllers were being used at the time of the evaluation. In addition, the AC unit cooling load and the plug load standby demand were lower than predicted. The final Energy (kWh) RR for the site is 19%.

RICE20N070 *Technology*: The evaluated savings are less than the applicant-reported savings due to a discrepancy in piping material between the applicant-reported piping and the piping observed by the evaluators while on site. The site had an overall energy (kWh) RR of 96.5%.

RICE20N047 *Operational & Methodology:* The evaluated savings are lower than the applicant-reported savings because the applicant savings assumed a less efficient baseline system, i.e., load/no-load with 1 gallon/cfm of receiver storage, whereas the evaluators used a more efficient baseline system, a VFD system at 125 psi, based on the guidance from the Massachusetts baseline framework document, which states that for replace on failure measures, the baseline efficiency selected should be no less efficient than the baseline efficiency found on site, even if the industry standard practice is less efficient than what is found on site. Because the system's original design was VFD control, and that system was in place and operating 2-3 years prior to when this project was installed, the evaluators selected a VFD system for the baseline system. The Massachusetts baseline framework document allows for several exceptions to this guidance, such as if the efficiency program incentivized the original equipment, but none of the exceptions were found to be applicable to this project. The overall energy (kWh) RR for the site is 21%.

4.2.4 PY2020 RR & Combined Program RR calculation methodology

This section discusses the methodology to calculate Combined program level and the PY2020 realization rates.

$RR_{1\text{-}3} = (S_1RR_1 + S_2RR_2 + S_3RR_3)/S_T = q_1RR_1 + q_2RR_2 + q_3RR_3$

That is, the three-program year (PY) RR is the savings-weighted average of the three separately estimated RRs.

Where,

1- represents PY2018, 2 is PY2019, 3 is PY2020 and T is total (2018+2019+2020)

S_y - Population tracked savings of PY-y

S_T- population tracked savings for all three PYs combined ($S_T = S_1 + S_2 + S_3$)

RR- Realization Rate

RR_1 and RR_2 have been calculated in previous studies.

q_y = PY_y savings as a fraction of the three-program years total = S_y/S_T

<u>Calculation of RR_3 calculation</u>

The non-operational realization rate RR_{N3} is calculated from the full sample using the full sample weights and the non-operational adjusted savings for the sample via the usual formulas.

The Overall RR is the product of the operational and non-operational RR

$RR_3 = RR_{o3}\ RR_{N3}$

Where,

$RR_{o3} = f_{g3}\ RR_{og3} + (1\text{-}f_{g3})\ RRob_3$

That is, the operational adjustment for the directly represented portions of the population and the remainder are combined in proportion to their shares of PY-3 tracked savings. This formula can be expanded as

$RR_{03} = f_{g3}\ RR_{og3} + (1\text{-}f_{g3})\ (S_1RR_{o1} + S_2RR_{og2} + f_{g3}\ S_3RR_{og3})/S_{Tg}$

$= (1 + (1\text{-}f_{g3})\ S_3/S_{Tg})\ fg_3RR_{og3} + (1\text{-}f_{g3})(S_1/S_{Tg})RR_{o1} + (1\text{-}f_{g3})(S_2/S_{Tg})RR_{o2})$

$= a_{og3}\ RR_{og3} + a_1RR_{o1} + a_2RR_{o2}$,

Where,

f_{g3} = fraction of PY3 savings represented by “good” sites, i.e., those with operational data

= (full-sample-weighted savings of PY3 sample sites with operational data)/(total full-sample weighted savings for PY3)

S_{Tg} = total savings for population represented by sites with operational data, across all samples

$= f_{g1}\ S_1 + f_{g1}\ S_1 + f_{g3}\ S_3$

And S1 = fg2s2

RR_{oy} = operational-only realization rate for the PY-y sample

RR_{Ny} = non-operational-only realization rate for the PY-y sample

RR_{og3} = operational-only realization rate for the population represented by good sites in the PY-3 sample, those with operational data

RR_{ob3} = imputed operational-only realization rate for the population represented by bad sites in the PY-3 sample, those without operational data

$a_{og3} = (1 + (1-f_{g3})\ S_3/S_{Tg})\ fg_3$

$a_1 = (1-f_{g3})\ (S_1/S_{Tg})$

$a_2 = (1-f_{g3})(S_2/S_{Tg})$

The standard error calculation methodology for PY2020 is presented in APPENDIX C. Table 4-6 below presents the final PY2020 Realization by taking a product of Non-ops and operational adjustment factors. Non-Ops factor includes evaluated results from 10 PY2020 sites, while the operational adjustment factor includes 7 Full M&V sites from PY2020 and 10 Full M&V sites each from PY2018 and PY2019 samples as shown in Table 4-6.

Table 4-6. PY2020 Impact Evaluation Program Realization Rate

PY	Non-Operational Adjustment factor	Operational Adjustment factor (with Historic adjustment)	Program RR
PY2020	90% PY2020 (n=10)	79% PY2020 (n=7) + PY2019 (n=10) + PY2018 (n=10)	68.9%

Similarly, other metrics for PY2020 are calculated and presented in Table 4-7 below.

Table 4-7. Statewide non-lighting prospective realization rates PY2020

Statewide Results (n=10)	Annual	Summer On-Peak	Winter On-Peak	%On-Peak Energy
	MWh	kW	kW	MWh
Total Tracking Savings	10,677	1,441	1,168	10,677
Total Evaluated Savings	7,328	832	756	73,277
Realization Rate	**68.9%**	**51.2%**	**68.3%**	**89.8%**
Confidence Interval	90%	80%	80%	90%
Relative Precision	±28.4%	±32.3%	±26.8%	±9.7%

4.2.4.1 Combined Program Level Results

This section presents rolled-up/program-level realization rates by combining PY2018, PY2019 and PY2020 evaluated sample results.

The site-level evaluation results were aggregated using the final case weights for each respective year. The realization rates for each year were calculated by taking a product of Operational and Non-Operational Adjustment factors and then applied to total tracking savings to determine their total evaluated savings for that year. Table 4-8 presents the non-lighting realization rates for each year and the combined prospective realization rate for the custom electric program in RI to be used to calculate 2023 savings. The combined RR for non-lighting meets the targeted relative precision (RP) of ±15% at a 90% confidence interval (CI) with a value of ±12% rolling-based RR of 83.2%. The lower RRs at the site level (see six Full M&V sites <100%) have driven the RRs below 100%. The higher relative precision for PY2020 is due to high variability in site-level results (see Figure 4-1). 6 out of 7 sites that included full M&V reported savings below 100%, with major discrepancies in Operational and Technology changes. Additional reasons for discrepancies at site-level are discussed in section 4.2.3 and individual site reports in 0.

As previously stated, the variability of the combined results could increase when the evaluation includes full M&V at all the sampled sites in future evaluations.

Table 4-8. Combined Non-lighting realization rates

Non-Lighting			RI	Combined Results
	PY2018	PY 2019	PY 2020	PY2018+ PY2019+PY2020
Tracking Energy Savings (kWh)	12,910,679	12,804,067	10,676,671	36,391,417
Sample Size (n)	14	15	10	39
RR	77.6%	104.1%	68.9%	83.3%
Relative precision @ 90% CI	±12.3%	±18.4%	±28.4%	±12.0%

Table 4-9 and Table 4-10 present prospective realization rates for Summer and Winter peak demand (kW) savings, and Table 4-11 presents prospective realization rates for %On-peak energy savings. Both Summer and Winter peak demand (kW) savings RR has decreased from the previous two rounds. The relative precision has gotten worse compared to the previous one as well. This could be due to the variance in site-level realization rates. The three-year rolling/combined results for both Summer and Winter peak demands met the target precision of ±20% at 80% CI.

Table 4-9. Prospective realization rates from Evaluated Summer Peak Demand (kW) Savings for Non-Lighting Measures

Non-Lighting	RI			Combined Results
	PY2018	PY2019	PY2020	PY2018+PY2019+PY2020
Tracking Summer Demand (kW)	1,634	1,754	1,441	4,829
Sample Size (n)	14	15	10	39
RR	69.0%	72.4%	51.2%	65.1%
Relative precision@ 80% CI	±12.1%	±24.5%	±32.3%	±13.8%

Table 4-10. Prospective realization rates from Evaluated Winter Peak Demand (kW) Savings for Non-Lighting Measures

Non-Lighting	RI			Combined Results
	PY2018	PY2019	PY2020	PY2018+PY2019+PY2020
Tracking Winter Demand (kW)	1,404	1,713	1,168	4,285
Sample Size (n)	14	15	10	39
RR	86.5%	98.4%	68.3%	85.7%
Relative precision@ 80% CI	±12.8%	±44.3%	±26.8%	±18.9%

Table 4-11. Prospective realization rates from Evaluated %On-Peak Energy Savings for Non-Lighting Measures

Non-Lighting	RI			Combined Results
	PY2018	PY2019	PY2020	PY2018+PY2019+PY2020
%On Peak Energy	12,910,679	12,804,067	10,676,671	36,391,417
Sample Size (n)	14	15	10	39
RR	84.1%	68.4%	89.8%	82.7%
Relative precision@ 80% CI	±13.0%	±40.4%	±9.7%	±13.9%

4.2.5 Lifetime savings adjustment factors (LSAFs)

Lifetime savings adjustment factors were developed for the first time in this study. The LSAFs for non-lighting are provided in Table 4-12. As shown below, the LSAF RR for PY2020 is 100%, as all 10 sampled sites had no change in measure life. The methodology for these calculations can be found in APPENDIX D.

Table 4-12. Custom non-lighting LSAFs

LSAF	Statewide
PY2020 RR	100%
Three-year pooled RR	To be calculated after PY2021 and PY2022 evaluations are completed.

5 CONCLUSIONS, RECOMMENDATIONS, AND CONSIDERATIONS

5.1 Conclusions

This study's scope and approach were similar to the last round of evaluations (PY2018 and PY2019) in handling operational factors. Due to the Pandemic, the study had to rely on PY2018 and PY2019 historical operation adjustment factors combined with the PY2020 operation-adjusted sampled sites in this study. This study's historical adjustment factors were calculated using ten PY2018, ten PY2019 and seven PY2020 Full M&V sites.

For custom non-lighting, the gross annual energy savings RRs saw a net loss in RR over the study from 104.10% to 68.6% from PY2019, 77.6% in PY2018, but a net increase to 83.2% for the combined rolling three-year value from 81.1% in the last report to lower 2016 values being replaced by the low 2020 values and new weighting. RRs for summer and winter on-peak demand followed the same path as energy, i.e., a decrease in RR non-lighting summer and winter peak demand RRs.

5.2 Recommendations

The DNV team makes the following recommendations based on the data collected, conclusions, results, and process of this impact evaluation.

Recommendation 1: This study's RI three year rolling non-lighting (83.3%) realization rate results shall replace the previous realization rates used by RI Energy beginning in PY2023. RI Energy should continue using 95.4% (from previous evaluation) RR for lighting. The results from this study should be combined with the next round of custom electric impact evaluation, which will evaluate PY2021 applications and is expected to be applied to the PY2024 tracking savings.

Recommendation 2: We recommend the Rhode Island Energy Implementation team conduct a more rigorous review of engineering calculations for measures involving building management systems or controls measures. Review should include the baselines, control sequences and other relevant assumptions used in the applicant savings calculation. Any trend data and supporting files and post-installation verification documentation like screenshots, photographs etc., should be included in the tracking documentation. The evaluators have found several measures in this and previous studies where measure components, especially controls features, are found to have been installed or programmed in a manner inconsistent with the proposed savings application.

For example, site RICE20N076 included VFDs on two pump motors. The evaluation findings indicated that the lead pump is predominantly fully loaded while the lag pump kicks on only occasionally. This contrasts with the applicant's estimation that the lead and lag pumps will have more evenly distributed operating speed profiles. The RI team should verify the VFD operation during post-installation inspection to avoid significant savings discrepancies.

Recommendation 3: The evaluators recommend the implementation team to collect clear documentation for the basis of the measure event type (retrofit vs new construction) in the project files. The measure event description should note if the measure is a standalone project or part of a larger project, the age of any existing equipment being modified, and the reason that the project is being implemented.

An EMS application measure event type was modified by the evaluators from retrofit to new construction, which resulted in zero savings. The evaluator believes that if the application had included the project background in the application, the project would have been screened out during the application process.

Recommendation 4. The evaluators recommend that program designers and implementers become familiar with the approach evaluators use for Replace On Failure (ROF) projects in cases where the industry standard practice baseline has a lower efficiency than the existing equipment baseline. Per MA Baseline Framework Document[4], for any site-specific evaluation of ROF measures, a regressive baseline generally is not allowed, i.e., the installed measure's baseline should be at least as efficient as the efficiency of the system it replaces, even if ISP indicates a lower baseline.

Recommendation 5. The evaluator continues to note issues related to proper measure commissioning, which has been a driver for discrepancies in this study. We recommend that RI Energy ensure proper commissioning protocols are followed to ensure that key measure components are installed and are generating savings. There have also been instances where facilities adjust control measures after implementation, which reduces savings potential. It is also recommended that proper training or knowledge sharing is provided to the customer, so program savings are consistent and maintained. Also, consider educating the customer on maintaining unique or non-typical control measures such as plug load management systems etc.

Site RICE20S009, where many plug loads and AC units were plugged into uncontrolled outlets despite a controlled outlet being available, the site has indicated that they will conduct an inventory of the plug load controllers on campus and make an effort to improve the utilization rate of the controllers.

Recommendation 6. DNV recommends RI Energy continue evaluating lifetime savings and reporting them at the site level in all future custom electric evaluations. PY2020 results will be considered year 1 of the rolling-based sample, including future evaluations completed for PY2021 and PY2022. Then a standard 3-year rolling reporting cycle would be available after the PY2022 (year 3) evaluation.

[4] https://ma-eeac.org/wp-content/uploads/MA-Commercial-and-Industrial-Baseline-Framework-1.pdf

APPENDIX A. SUMMARY OF SAMPLED PROJECTS

The following table summarizes the tracking and evaluation savings estimates, site weights by site, measure and evaluation type.

Site ID	App	Tracking kWh	Weight 1	Evaluation Type	Measure	Market Event
RICE20N002	11624671	53,851	13.2	NON-OPS	HVAC (Equip or Systems)	Retrofit
RICE20N068	11759508	34,508	13.2	Full M&V	EMS / HVAC Controls	NC
RICE20N076	11404547	46,221	13.2	Full M&V	Drives on non-HVAC Systems	Add-on retrofit
RICE20N070	10251545	9,728	13.2	NON-OPS	Process Cooling	Add-on single
RICE20N032	9816848	121,191	13.2	NON-OPS	EMS / HVAC Controls	Retrofit
RICE20N036	11620396	360,240	2.6	Full M&V	Operation / Maintenance for CAIR	Retrofit
RICE20N041	10566704	404,164	2.6	Full M&V	Operation / Maintenance for CAIR	Retrofit
RICE20S009	8044397	289,016	2.6	Full M&V	Other	Retrofit
RICE20N006	10174829, 11787180	252,928	2.6	Full M&V	Process Equipment/Controls	NC

APPENDIX B. SITE SAVINGS SUMMARY

Site ID	RI Energy Application #	TRACKING DATA				EVALUATED RESULTS				Energy Realization Rate
		Annual Energy Savings (kWh)	% On-Peak Savings	Summer On-Peak Demand Savings (kW)	Winter On-Peak Demand Savings (kW)	Annual Energy Savings (kWh)	% On-Peak Savings	Summer On-Peak Demand Savings (kW)	Winter On-Peak Demand Savings (kW)	
RICE20N002	11624671	53,851	0%	18.7	9.2	55,362	58%	0.0	0.0	Non-Ops
RICE20N068	11759508	34,508	13%	3.2	0.0	0	0%	0.0	0.0	0%
RICE20N076	11404547	46,221	47%	10.4	10.4	17,241	42%	1.8	1.8	37%
RICE20N070	10251545	9,728	46%	1.1	1.1	9,323	46%	1.1	1.1	Non-Ops
RICE20N032	9816848	121,191	0%	0.0	0.0	121,191	0%	0.0	0.0	Non-Ops
RICE20N036	11620396	360,240	48%	42.8	42.8	290,465	48%	33.2	33.2	81%
RICE20N041	10566704	404,164	56%	56.1	56.1	399,179	53%	51.6	50.9	99%
RICE20S009	8044397	289,016	15%	8.3	15.7	53,792	19%	1.6	2.2	19%
RICE20N006	10174829, 11787180	252,928	68%	54.2	54.2	284,777	68%	62.4	62.4	113%
RICE20N047	10356221	253,411	44%	25.6	22.9	52,090	54%	7.0	6.5	21%

APPENDIX C. ADJUSTING GROSS REALIZATION RATE STANDARD ERRORS FOR IMPUTED OPERATING ADJUSTMENT

This appendix explains the process for calculating the current and three-year realization rates incorporating imputed operational adjustment for part of the third-year sample.

1. Basic structure

We have samples for three successive periods: 1, 2, and 3. In this evaluation, these samples are 1) PY2017/18 (P88), 2) PY2018/19 (MA20C04), and 3) PY2019/20 (MA21C04). Sample 1 is a full sample. Samples 2 and 3 have non-operational results for all sites and operational results for only a subset of sites.

Full-sample weights for period 3 are calculated in the usual way, as the ratio of population count to sample count within the sampling cell that contains a particular site, where the sample count is for all sites in the sample.

2. Notation

w_j = full-sample weight for sample site j in the Period 3 sample

S_y = population tracked savings of period y

S_T = population tracked savings for all three periods combined

= $S_1 + S_2 + S_3$

q_y = period-y savings as a fraction of the three-period total

= S_y/S_T

f_{g3} = fraction of Period-3 savings represented by “good” sites, ie those with operational data

= (full-sample-weighted savings of Period 3 sample sites with operational data)/(total full-sample weighted savings for Period 3)

S_{Tg} = total savings for population represented by sites with operational data, across all samples

= $S_1 + S_2 + f_{g3} S_3$

RR_{oy} = operational-only realization rate for the period-y sample

RR_{Ny} = non-operational-only realization rate for the period-y sample

RR_{og3} = operational-only realization rate for the population represented by good sites in the period-3 sample, those with operational data

RR_{ob3} = imputed operational-only realization rate for the population represented by bad sites in the period-3 sample, those without operational data

SE(X) = standard error of estimate X

RSE(X) = relative standard error of estimate X

=SE(X)/X

3. Period 3 operational realization rate RR_{o3}

- For the portion of the population represented by sampled sites with operational adjustments (“good” sites g), RR_{og3} is directly calculated from the sample, using the full sample weights w_j. That is, RR_{og3} is the weighted sum of verified gross savings, divided by the weighted sum of tracked gross savings.
- For sampled sites without operational adjustment (“bad” sites b), RR_{ob3} is imputed as

  $RR_{ob3} = (S_1RR_{o1} + S_2RR_{o2} + f_{g3}\ S_3RR_{og3})/S_{Tg}$

  That is, all available sites with operational data are used to impute the RR for the uncovered portion of the period-3 population, with the RR from different periods weighted by the savings it represented.
- Overall Operational Adjustment for Period 3 is calculated as

  $RR_{o3} = f_{g3}\ RR_{og3} + (1-f_{g3})RR_{ob3}$.

  That is, the operational adjustment for the directly represented portions of the population and the remainder are combined in proportion to their shares of period-3 tracked savings. This formula can be expanded as

  $RR_{o3} = f_{g3}\ RR_{og3} + (1-f_{g3})\ (S_1RR_{o1} + S_2RR_{o2} + f_{g3}\ S_3RR_{og3})/S_{Tg}$
  $= (1 + (1-f_{g3})\ S_3/S_{Tg})f_{g3}RR_{og3} + (1-f_{g3})(S_1/S_{Tg})RR_{o1} + (1-f_{g3})(S_2/S_{Tg})RR_{o2})$
  $= a_{og3}\ RR_{og3} + a_1RR_{o1} + a_2RR_{o2}$,

  Where

  $a_{og3} = (1 + (1-f_{g3})\ S_3/S_{Tg})f_{g3}$
  $a_1 = (1-f_{g3})(S_1/S_{Tg})$
  $a_2 = (1-f_{g3})(S_2/S_{Tg})$

  This expansion expresses the overall Period 3 operational realization rate as a weighted average of three independently estimated terms, the directly observed operational realization rate from each period. The factors multiplying the three realization rates have the property that

  $a_{og3} + a_1 + a_2 = 1$.

- Standard error of Period 3 realization rate: The standard error is calculated from the individual standard errors as

  $SE(RR_{o3}) = sqrt[a_{og3}^2 \, SE^2(RR_{og3}) + a_1^2 \, SE^2(RR_{o1}) + a_2^2 \, SE^2(RR_{o2})]$

  This is true because the three RRs at step 3 are from independent samples.

4. Period 3 combined RR

1. **The non-operational realization rate** RR_{N3} is calculated from the full sample using the full sample weights and the non-operational adjusted savings for the sample, via the usual formulas.

2. **The Overall RR** is the product of the operational and non-operational RR

   $RR_3 = RR_{o3} \, RR_{N3}$

3. **Standard error:** First calculate the relative standard error
   a. $RSE(RR_3) = sqrt[RSE^2(RR_{o3}) + RSE^2(RR_{N3})]$

   This formula is approximately correct, assuming that even though RR_o and RR_N are from a common sample, they are essentially unrelated so can be treated as independent.

   The standard error is then calculated from the RSE.

   b. $SE(RR_3) = RR_3 \, RSE(RR_3)$

5. Three-year combined RR

Preferred calculation

$RR_{1\text{-}3} = (S_1RR_1 + S_2RR_2 + S_3RR_3)/S_T$
$\quad = q_1RR_1 + q_2RR_2 + q_3RR_3$

That is, the three-year RR is the savings-weighted average of the three separately estimated RRs.

This calculation produces an overall realization rate for each period, then combines these across periods. This approach is the natural one, combining the historical overall results with the most recent, consistent with our general method for three-year rolling realization rate calculation, and is therefore the preferred way to produce the three-year value.

However, because the third term RR_3 is determined in part from the operational portions of RR_1 and RR_2, the three are not independent estimates. Moreover, there's no obvious way to express the calculation as the sum of independent estimates, as would be needed to produce the standard error. We therefore look at an alternative calculation for purposes of standard error calculation only.

SE calculation

We use the standard error of an alternative calculation as an approximate to the standard error of the preferred calculation. The alternative calculation would be to calculate separate operational and non-operational realization rates for the three-year period and multiply them. We calculate this SE. We can check how different the results are, but the SEs or inflation of SE ought to be ballpark the same.

6. Alternative RR calculation for SE calculation only

1. 3-year operational realization rate
   $RR_{o1\text{-}3} = q_1 RR_{o1} + q_2 RR_{o2} + q_3 RR_{o3}$
2. 3-year non-operational realization rate
   $RR_{N1\text{-}3} = q_1 RR_{N1} + q_2 RR_{N2} + q_3 RR_{N3}$
3. Combined 3-year realization rate
   $RR_{1\text{-}3} = RR_{o1\text{-}3}\, RR_{N1\text{-}3}$

Standard error calculations for the alternative RR calculation

Non-operational three-period realization rate SE

The non-operational three-period realization rate is the savings-weighted average of the separate period realization rates. Since these are all independent, we can use the formula for combinations of independent estimates to produce the standard error.

$SE(RR_{N1\text{-}3}) = \mathrm{sqrt}[q_1^2\, SE^2(RR_{N1}) + q_2^2\, SE^2(RR_{N2}) + q_3^2\, SE^2(RR_{N3})]$

Operational three-period realization rate SE

The operational realization rate is also the savings-weighted average of the three periods' operational realization rates, but these aren't all independent. We rearrange the formula to express the operational realization rate as a combination of independent estimates.

$RR_{o1\text{-}3} = q_1\, RR_{o1} + q_2\, RR_{o2} + q_3 RR_{o3}$
$\quad = (q_1 + a_1\, q_3)\, RR_{o1} + (q_2 + a_2\, q_3)\, RR_{o2} + q_3\, a_{og3}\, RR_{og3}$

where the factors a_x are as defined above. With this expression of the three-period operational realization rate as a combination of independent estimates, is standard error is calculated as

$SE(RR_{o1\text{-}3}) = \mathrm{sqrt}[(q_1 + a_1\, q_3)^2\, SE^2(RR_{O1}) + (q_2 + a_2\, q_3)^2\, SE^2(RR_{O2}) + (q_3\, a_{og3})^2\, SE^2(RR_{O3})]$.

Relative standard error of overall three-period realization rate

By the same argument as above, the relative standard errors of the two realization rate factors are combined as if they were independent estimates. This is approximately correct, assuming that even though RR_o and RR_N are from a common sample, they are essentially unrelated so can be treated as independent.

$RSE(RR_{1\text{-}3}) = \mathrm{sqrt}[RSE^2(RR_{o1\text{-}3}) + RSE^2(RR_{N1\text{-}3})]$

Standard error of the three-year realization rate

$SE(RR_{1\text{-}3}) = RR_3\, RSE(RR_{1\text{-}3})$

Level of aggregation for applying the formulas

Calculating Period 3 and three-period realization rates

The formulas for calculating the Period 3 operational realization rate RR_{o3}, the Period 3 overall realization rate RR_o, and the preferred three-period overall realization rate RR_{1-3} are applied separately for each reporting category of realization rate. Typically, each reporting category includes sample points from multiple sampling cells.

For reporting categories with no Period 3 sample that has operational data the same formulas are used, with Period 3 contributing nothing to the three-period operational realization rate. For this study all of the reporting categories used had at least one sample point with operational data.

APPENDIX D. LIFETIME SAVINGS ADJUSTMENT FACTORS (LSAFS) METHODOLOGY

Evaluation lifetime savings findings should be captured in a lifetime savings adjustment factor (LSAF), which is applied to the tracking **measure life** in the BC Tool used to report PA evaluated savings in the Annual Report. The LSAF is intended to account for the following evaluation findings:

4. Incorrect applicant effective useful life (EUL) measure life assumptions
5. Reduced life from equipment removed after a year or more of operation
6. Change in measure application type impacting measure life
7. Change in measure application type impacting dual versus single baseline status[5]
8. Incorrect applicant outyear factor (OYF) assumption

First-Year Saving Realization Rate. As a starting point, the annual savings realization rate is calculated as the weighted sample verified annual savings divided by the weighted sample tracked savings.

$$RR\% = \frac{\sum w_i \times FYS_i^{Evaluated}}{\sum w_i \times FYS_i^{Tracking}}$$

where:

$RR\%$ = first-year savings realization rate

w_i = site weight

$FYS_i^{Evaluated}$ = site evaluated first-year savings (kWh)

$FYS_i^{Tracking}$ = site tracking first-year savings (kWh)

Measure-level lifetime savings. For each evaluated measure, the evaluators calculated an evaluated lifetime savings using the following formula:

$$LS_{Savings} = FYS_{Evaluated} \times [RUL_{Evaluated} + \text{OYF} \times (EUL_{Evaluated} - RUL_{Evaluated})]$$

where:

$LS_{Savings}$ = evaluated lifetime savings (kWh)

$FYS_{Evaluated}$ = evaluated first year savings (kWh)

$EUL_{Evaluated}$ = evaluated measure life (years in decimal form) Reflects revisions to measure life due to alignments with eTRM measure lives or other adjustments or to account for equipment removal after one year.

[5] For non-lighting measures only. The LSAF published for lighting measures does not incorporate the impacts of dual baseline as the PAs at the time did not have the ability in their BCR models to track dual baseline. These dual baseline impacts are covered when applying AMLs published through the LMC study for PAs that have been able to adjust tracking measure lives to use the AMLs, and through the LMC adjustment factor discussed later in this section for PAs that have not been able to make that adjustment, or only partially did.

$RUL_{Evaluated}$ = 1/3 of $EUL_{Evaluated}$ (years)

OYF = 100% for single-baseline measures. 90% for non-lighting dual-baseline measures.

Program lifetime savings realization rate (LSRR%). The LSRR is calculated in similar fashion to the annual savings RR. To calculate LSRR, the weighted evaluated lifetime savings is divided by the weighted tracked lifetime savings. The team calculated LSRR using the following formula:

$$LSRR\% = \frac{\sum w_i \times LS_i^{Evaluated}}{\sum w_i \times FYS_i^{Tracking} \times EUL_i^{Tracking}}$$

where:

$LSRR\%$ = program lifetime savings realization rate

w_i = site weight

$LS_i^{Evaluated}$ = site evaluated lifetime savings (kWh)

$FYS_i^{Tracking}$ = site tracking first-year savings (kWh)

$EUL_i^{Tracking}$ = tracking measure life

Program LSAF. The LSAF accounts for differences noted in items 1 to 5 above and the different distribution of savings for both first-year and lifetime savings at sites included in the sample. To avoid double counting the impacts of both the FYS RR and the LS RR, we need to calculate both RRs. The LSAF can now be backed out by calculating the ratio of the lifetime savings RR over the first-year savings RR.

$$LSAF = \frac{LSRR\%}{RR\%}$$

where:

$LSAF$ = lifetime savings adjustment factor

$RR\%$ = program first-year savings realization rate

$LSRR\%$ = program lifetime savings realization rate

The program-level LSAF can be used by PAs for reporting lifetime savings and will incrementally impact the lifetime savings after the annual savings realization rate (RR) is applied. To calculate lifetime adjusted gross savings (LAGI), PAs will use the following formula:

$$LAGI = \left(Annual\ Gross\ Savings_{Tracking} \times Annual\ RR\%\right) \times \left(Measure\ life_{Tracking} \times LSAF\right)$$

where:

$LAGI$ = lifetime adjusted gross impact savings (kWh)

$Annual\ gross\ savings_{Tracking}$ = tracking annual gross savings (kWh)

$Measure\ life_{\ Tracking}$ = tracking measure life (years)

$RR\%$ = program realization rate

$LSAF$ = lifetime savings adjustment factor

The BC Model requires as input PA gross annual tracking savings and tracking measure life and does not accept as input tracking lifetime savings. The tracking measure life reflects project level applicant effective useful measure life selections and in the future dual baseline effects. The BC Model specifies evaluation factors that are required to report evaluated savings. Due to the calculation methods employed by the BC Model, the LSAF will be applied to tracking measure life.

Lighting Market Characterization (LMC) Adjustment Factor. The LMC adjustment factor accounts for the difference in tracked lighting AMLs compared to recommended AMLs provided by the lighting market characterization study. The lighting AMLs published are reflections on dual baseline adjustments as well as projected LED market saturation. Decisions made by the PA and EEAC team directed the PAs to use LMC suggested lighting AMLs moving forward, and to update previously tracked projects. This factor will adjust the published LSAF to account for projects that have not been updated with lighting AMLs. As such, the following methodology should only be applied to retrospective PYs where AMLs have either not been updated, or only partially updated. DNV created the following algorithms to determine this factor which should be applied to the LSAF for each PA:

$$LMC\ Adjustment\ Factor_{sample} = \frac{AML_{PY}}{Tracking\ ML_{sample}}$$

$$LMC\ Adjustment\ Factor_{population} = \sum LMC\ Adjustment\ Factor_{sample} * \frac{Weighted\ Tracking\ Savings_{sample}}{Weighted\ Tracking\ Savings_{population}}$$

Where,

AML_{PY} = AMLs provided in the most recent LMC memo for the respective program year

$Tracking\ ML_{sample}$ = ML that was used in tracking

$Weighted\ Tracking\ Savings_{sample}$ = Tracking savings for the sample multiplied by the site weight

$Weighted\ Tracking\ Savings_{population}$ = The sum of weighted tracking savings per PA

As mentioned before, PA calculated LMC adjustment factors should be applied to the published lighting LSAF in **Error! Reference source not found.**.

APPENDIX E. INDIVIDUAL EVALUATION SITE REPORTS

RICE20N002

Report Date: 8/1/2022

Program Administrator	National Grid
Application ID(s)	11624671
Project Type	Non Ops, On-Site
Program Year	2020
Evaluation Firm	DMI
Evaluation Engineer	Brian Paonessa
Senior Engineer	Jay Robbins

Evaluated Site Summary and Results

This retrofit project consisted of a new energy management system (EMS) at a 120,350 ft² high school. The new EMS controls the existing HVAC system as the site, including 5 rooftop units (RTUs) and 65 variable air volume (VAV) terminal boxes. Electric savings associated with the new EMS were claimed based on the following control strategies:

- 7-day scheduling
- Optimal start/stop
- Night setback
- DDC temperature controls
- Demand control ventilation (DCV)

This evaluation is considered non-ops because the evaluated measures are heavily impacted by COVID. The majority of savings for this project are derived from demand control ventilation controls. However, these controls are overwritten for health and safety purposes. The site contact indicated that the school is running with as much outside air as possible for ventilation purposes. From approximately April through mid-November the school operates with 100% outside air unless required to turn down for dehumidification. Over the winter the outside air is lowered to the maximum possible point necessary to keep the building warm. The site indicated that these control adjustments were temporary and normal operation would resume following the end of the pandemic.

The evaluators conducted an in-person visit to observe the EMS and HVAC system and learn more about the control strategies present. The evaluators observed 7-day scheduling, optimal start/stop, night setbacks, and demand control ventilation strategies possible in the EMS. The Demand Control Ventilation strategy was overwritten as expected to increase ventilation. “DDC temperature controls” refers to the installation of DDC controls themselves to enable tighter controls. The evaluators did not observe installed controls that would support claiming savings for these controls. The evaluators therefore removed this control strategy from the custom-express tool savings.

This measure is classified as a single baseline retrofit. The evaluated savings are 102.8% of the tracked savings. The savings claimed by the applicant for this project are 51,582 kWh.

The evaluation results are presented in Table 5-1.

Table 5-1. Evaluation Results Summary

PA Application ID	Measure Name		Annual Electric Energy (kWh)	% of Energy Savings On-Peak	Summer On-Peak Demand (kW)	Winter On-Peak Demand (kW)
11624671	New EMS	Tracked	53,851	63.7%	7.8	0.0
		Evaluated	55,362	57.8%	0.0	0.0
		Realization Rate	102.8%	90.7%	0%	-

5.2.1 Explanation of Deviations from Tracking

Deviations from the tracked savings are a result of the evaluator finding 10 RTUs connected to the EMS that should have been considered for supply fan savings, versus the 5 indicated by the customer in the ex-ante estimate. This increase in savings was partially offset by the removal of the "DDC Temp Controls" input from the EMS Custom-express tool. No controls were observed on site that supported claiming savings for that strategy.

5.2.2 Recommendations for Program Designers & Implementers

There are no recommendations at this time.

5.2.3 Customer Alert

There is no relevant customer alert.

Evaluated Measures

The project consisted of the installation of an EMS system to add control systems to five existing RTUs and 65 VAV boxes throughout a high school. The applicant claims that the new EMS includes a 7-day schedule, optimal start/stop, night setbacks, DDC temperature control, and demand control ventilation.

5.2.4 Application Information and Applicant Savings Methodology

This section describes the applicant's application information, savings methodology, and the evaluation assessment of the savings calculation algorithm used by the applicant.

5.2.5 Applicant Description of Baseline

The applicant describes the measure as a retrofit with a single baseline. The applicant identified 5 RTUs being connected to the EMS system. The pre-installation site condition is the existing HVAC equipment (5 RTUs and 65 VAV boxes) with no EMS system installed.

Table 5-2 summarizes the key baseline parameters assumed by the applicant.

Table 5-2. Applicant baseline summary

Measure	Parameter	Value(s)	Source of Parameter Value
ECM 1	DX compressors connected kW	194.0	Applicant savings analysis (custom express tool)
	DX compressors annual operating hours	600 (50 hours per week for 12 weeks per year)	Applicant savings analysis (custom express tool)
	RTU supply fan connected kW	6.0	Applicant savings analysis (custom express tool)

	RTU supply fan annual operating hours	2,100 (50 hours per week for 42 weeks per year)	Applicant savings analysis (custom express tool)

The inputs (kW and hours) used in the custom express tool should reflect the appropriate rooftop units and operating schedules. This application included only the total values for all units; no additional calculations were provided showing how the total was calculated.

5.2.5.1 Applicant Description of Installed Equipment and Operation

This section describes the proposed condition assumed in the applicant analysis. The proposed case includes the following control strategies: 7-day scheduling, optimized start/stop, night time setbacks, DDC temperature control, and demand control ventilation. Table 5-3 summarizes the key proposed case inputs used in the applicant savings analysis.

Table 5-3. Application Proposed Case Key Parameters

Measure	Parameter	Value(s)	Source of Parameter Values
ECM 1	DX compressors connected kW	194.0	Applicant savings analysis (custom express tool)
	DX compressors annual operating hours	468 (12 hours per week for 39 weeks per year)	Applicant savings analysis (custom express tool)
	Supply fans connected kW	6.0	Applicant savings analysis (custom express tool)
	Supply fans annual operating hours	1,470 (35 hours per week for 42 weeks per year)	Applicant savings analysis (custom express tool)

5.2.5.2 Applicant Energy Savings Algorithm

The applicant used the prescriptive EMS tool with built-in savings factors to calculate the measure savings. The applicant entered the key parameters from Table 5-2 and Table 5-3 into the tool and selected 5 EMS control strategies: 7-day scheduling, optimized start/stop, night time setbacks, DDC temperature controls, and demand control ventilation to calculate the savings. Enabling these control strategies in the prescriptive tool implies that the existing/baseline case did not include these control strategies. The addition of demand control ventilation to control the DX RTU compressors has the largest savings impact (79.3% of the total).

The table below provides a breakdown of the savings source for each control strategy for both the DX RTU compressors and the RTU supply fans. Please note, the EMS tool uses 7-day Scheduling, Optimal Start/Stop, and Night time Setbacks to determine if equipment runtime savings can be calculated. Theses these 3 controls strategies enable the tool to calculate savings, but the actual savings are calculated based on the key parameters (i.e., kW demand and the reduction annual hours).

Table 5-4. Applicant savings breakdown based on control strategy

EMS Control Strategy	Applicant Savings		
	kWh Saving	% Of Claimed Savings	Note
DX RTU Compressors			
Reduction in Annual Hours	5,122 kWh	9.5%	7-day Scheduling, Optimal Start/Stop, or Night time Setbacks must be enabled in the prescriptive EMS tool for it to calculate savings from equipment runtime. Toggling between these 3 control strategies does not affect the calculated kWh Savings.
7-day Schedule	-	-	Included in annual hours reduction
Optimal Start/ Stop	-	-	Included in annual hours reduction
Night time Setbacks	-	-	Included in annual hours reduction
DDC Controls	2,270 kWh	4.2%	
Demand Control Ventilation	42,680 kWh	79.3%	
RTU supply fans			
Reduction in Annual Hours	8,902 kWh	7.0%	7-day Scheduling, Optimal Start/Stop, or Night time Setbacks must be enabled in the prescriptive EMS tool for it to calculate savings from equipment runtime. Toggling between these 3 control strategies does not affect the calculated kWh Savings.
7-day Schedule	-	-	Included in annual hours reduction
Optimal Start/ Stop	-	-	Included in annual hours reduction
Night time Setbacks	-	-	Included in annual hours reduction

5.2.5.3 Evaluation Assessment of Applicant Methodology

The applicant used the EMS custom-express tool to calculate savings. The sources of savings that the applicant identified could be defined as scheduling, DDC controls, and demand control ventilation. The total savings from the tool are represented as:

$$E_{Total} = E_{Compressors} + E_{Supply\ Fans}$$

where,

E_{Total} = Total electric energy saved from the EMS system installation

$E_{Compressors}$ = Energy saved from RTU DX compressors

$E_{Supply\ Fans}$ = Energy saved from RTU and VAV supply fans

The compressor and supply fan savings can then be individually calculated:

$$\mathrm{E_{Compressors}} = \mathrm{E_{Run\ Time}} + \mathrm{E_{DDC\ Controls}} + \mathrm{E_{DCV}}$$

$$\mathrm{E_{Supply\ Fans}} = \mathrm{E_{Run\ Time}}$$

The energy saved from the run time reduction, DDC temperature controls, and DCV are then calculated as:

$$E_{Run\ Time} = kW \times Hours\ Saved \times SF_{Run\ Time}$$

$$E_{DDC\ Controls} = kW \times Post\ Hours \times SF_{DDC\ Controls}$$

$$E_{DCV} = kW \times SF_{DCV}$$

where,

kW = The full load connected kW for the DX compressors or supply fans

Hours Saved = Reduction in hours between the base case (no EMS) and proposed case (installed EMS)

Post Hours = Proposed case hours with the EMS installed

SF = the savings factors for each of the run time, DDC controls, and DCV.

The savings factor change based on if the DX compressors or supply fans are being analyzed. The savings factors for the different parameters used in the applicant's analysis are summarized in Table 5-5 and explained in more detail below.

Table 5-5. Savings factors summary

Equipment	Savings Factors		
	Run Time	DDC Controls	DCV
DX Compressors	0.2	0.025	220 kWh/compressor kW
Supply Fans	1.0	N.A.	N.A.

N.A. = Not Applicable

The evaluators agree with the methodology the custom express tool uses for the run time calculation. The 0.2 run time savings factor on the DX compressor is assumed to represent an average duty cycle. The Rhode Island TRM indicates that there is a default of 855 effective full load cooling hours in Rhode Island, and there are 3,813 hours above 55°F according to TMY-3 weather data in Providence RI. This represents a calculated 22.4% duty cycle, similar to the 20% factor used by the EMS tool.

The DCV savings factor of 220 kWh per compressor kW was determined to be reasonable. A demand control ventilation measure is not included in the most recent Rhode Island TRM, but the 2019-2021 MA TRM lists a savings factor of 170 kWh per compressor ton, which is about equivalent to the custom express tool factor when considering a performance factor of 1.3 kW/ton. The evaluators have also researched different demand control ventilation calculators for implementation purposes, and found these factors to generally align with their research.

5.2.6 On-Site Inspection and Metering

This section provides details on the tasks performed during the site visit and the date it was conducted, and how it was conducted.

5.2.6.1 Summary of On-site Findings

The evaluators conducted a site-visit on June 1, 2022. During the site visit, the evaluators interviewed the site contact and observed the EMS system. The evaluators were also given remote access to the EMS system.

A summary of the information ascertained during the site visit is as follows:

- The EMS system is operational and communicating with RTUs and associated VAV terminal boxes
- There are 10 RTUs serving the space and communicating with the EMS (as opposed to 5 listed in the ex-ante estimate).
- The EMS system commands the HVAC equipment to occupied mode depending on the space in the building. These schedules are:
    - Classrooms and general building areas: 6:30AM-2:30PM on weekdays (8 hours/day)
    - Gym: 7:00AM-2:30PM on weekdays (7.5 hours/day). RTU-7 and RTU-8.
    - Auditorium: 7:00AM-9:00AM on weekdays (2 hours/day).
- The mixed air damper control was manually overwritten to 80% open. The site contact indicated that this is to maximize outside air for COVID prevention purposes. The site manually changes the outside air quantity to the highest possible amount while still being able to sufficiently condition the building.
- An additional “COVID Purge” control schedule was added to the EMS system to run from 5:00AM-7:00AM and 3:00PM-5:00PM. The site contact is unsure of the exact performance of this function.
- Optimal start/stop is disabled on the RTUs.
- The VAV terminal boxes have differing occupied/unoccupied heat/cool setpoints, but are setback during unoccupied hours.
- Last summer the school was occupied but it will not be this summer. The RTUs still have to run for dehumidification even if the school is closed for the summer.

Table 5-6. Measure verification

Measure Name	Verification Method	Verification Result
New EMS	Verify the EMS controllers are installed and communicating with the new EMS system via a site visit.	The EMS is operational and communicating with operational HVAC equipment (10 RTUs and various VAV boxes)

5.2.7 Evaluation Methods and Findings

This section describes the evaluator methods and findings.

5.2.7.1 Evaluation Description of Baseline

The evaluator reviewed the project files and interviewed the site contact to gather information on the baseline. The site had an existing control system (Johnson FX controls) which were limited and unable to perform the functions of the current EMS system. The evaluator classifies this measure as a retrofit with a single baseline.

5.2.7.2 Evaluation Calculation Method

The evaluator used the same custom express tool as the applicant to update the electric savings for this project. The evaluators found that there were 10 RTUs in the space connected to the EMS system. The evaluators found that the 10 RTUs should all have fan scheduling savings. However, 5 of the 10 RTUs appeared in the EMS to be make-up air units with only economizer cooling and no DCV controls, making them ineligible for DX compressor scheduling or DCV savings, as summarized in Table 5-7.

Table 5-7. RTU Summary

RTU Number	Space Served	Note
RTU-1	Classrooms	DCV Control
RTU-2	Hallways	MAU – No DX Compressors or DCV
RTU-3	Classrooms	DCV Control
RTU-4a	Cafeteria/Kitchen	DCV Control
RTU-4b	Cafeteria	DCV Control
RTU-5	Classrooms/Library	DCV Control
RTU-6	Hallways	MAU – No DX Compressors or DCV
RTU-7	Gym	MAU – No DX Compressors or DCV
RTU-8	Gym	MAU – No DX Compressors or DCV
RTU-9	Hallways	MAU – No DX Compressors or DCV

The evaluators did not observe any controls in the EMS system that would support claiming savings for "DDC Temperature Controls". Therefore, the evaluators opted to include only scheduling savings from the DX compressors and supply fans as well as demand control ventilation savings from the DX compressors.

The site did not have mechanical drawings available and the majority of RTU nameplates were illegible due to being weathered. RTU-5 had a nameplate that indicated a supply fan load of 2 hp, which indicates that the 6-kW connected supply fan load is reasonable for the five RTUs considered by the applicant. Fans were not metered as would be done for a full M&V evaluation.

The evaluators adjusted the supply fan kW to be double the applicant's input in order to account for double the amount of RTUs being eligible for scheduling savings than initially considered. It is likely that the supply fan kW is not exactly double, however, the spaces served by the additional RTUs (hallways, gyms), would likely include similarly sized units and more conclusive information is not available.

The schedule observed in the EMS and discussed in Section 5.2.6.1 indicated that the units serving the classrooms, hallways, and cafeteria operate for 8 hours per day, from either 6:30AM-2:30PM or 6:00AM-2:00PM. RTU-7 and RTU-8 serving the gym are in occupied mode from 7:00AM-2:30PM, for a total of 7.5 hours per day.

The DX compressor input in the custom express tool only considers RTU-1, 3, 4a, 4b, and 5, which all have an 8 hour per day occupied schedule. This equates to 40 hours per week (5 school days per week). The supply fan input considers all ten RTUs, equating to an average of 7.9 occupied hours per day or 39.5 occupied hours per week. The proposed case run times are considered operational adjustments and are not accounted for in the savings adjustment by the evaluators. The weeks per year was not adjusted from what is indicated by the applicant. The baseline hours of operation were considered to be reasonable by the evaluators and also not adjusted. The DX compressor and supply fan inputs are summarized in Table 5-8. A sequence of operations provided by the applicant indicated that the units would shut off during unoccupied hours.

Table 5-8. Evaluator description of Dx Compressors and Supply Fans

Parameter	Description	
	kW	Occupied Schedule
DX Compressor	194 connected kW from 5 RTUs	40 hours/week, 12 weeks/year
Supply Fans	12 connected kW from 10 RTUs	39.5 hours/week, 42 weeks/year

Final Results

The project consisted of the installation of a new energy management system (EMS) at a 120,350 ft² high school. The applicant considered scheduling savings from the supply fans and scheduling, DDC temperature control, and DCV savings from the DX compressors. The evaluators adjusted the savings to only consider scheduling and DCV savings. Table 5-9 summarizes the key parameters used to calculate the energy savings for the measure.

Table 5-9. Summary of Key Parameters

Parameter	Applicant	Evaluator
DX Compressors		
Baseline occupied schedule	50 hours/week, 12 weeks/year	50 hours/week, 12 weeks/year
Proposed occupied schedule	39 hours/week, 12 weeks/year	40 hours/week, 12 weeks/year*
Connected RTUs	5	5
Connected kW	194.0	194.0
Savings strategies	Scheduling, DDC Temp Controls, DCV	Scheduling, DCV
Supply Fans		
Baseline occupied schedule	50 hours/week, 42 weeks/year	50 hours/week, 42 weeks/year
Proposed occupied schedule	35 hours/week, 42 weeks/year	39.5 hours/week, 42 weeks/year*
Connected RTUs	5	10
Connected kW	6.0	12.0
Savings strategies	Scheduling	Scheduling
Savings		
Annual electric savings (kWh)	53,851	55,362
Electric realization rate (%)	102.8%	

*Evaluated savings are calculated with the same schedule as the applicant due to non-ops nature of the site.

5.2.8 Explanation of Differences

The evaluated savings are more than the applicant savings due to the increase in connected supply fan kW. This adjustment is partially offset by the removal of the DDC temperature control strategy. Table 5-10 provides a summary of the differences between tracking and evaluated values.

Table 5-10. Summary of Deviations

End-use	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
HVAC	Pre-project errors (inputs or calculations)	Additional Connected RTUs (Supply Fan kW)	7.0%	**Increased Savings-** The evaluators increased the connected supply fan kW from 6kW to 12kW due to an additional 5 RTUs being connected to the EMS than noted by the applicant.
HVAC	Pre-project errors (inputs or calculations)	Remove DDC Temperature Controls Input	-4.2%	**Decreased Savings-** The evaluators removed the DDC Temperature Control inputs from the savings tool.

5.2.9 Lifetime Savings

The evaluators classified the measure as an add-on with a single baseline. The evaluators calculated applicant and evaluated lifetime savings values using the following formula:

$$\mathrm{LAGI} = \mathrm{FYS} \times \mathrm{EUL}$$

where:

LAGI = lifetime adjusted gross impact (kWh)

FYS = first year savings (kWh)

EUL = measure life (years)

The evaluated lifetime savings are greater than the tracking lifetime savings because the evaluated first year savings are greater than the tracking first year savings. Table 5-11 provides a summary of key factors that influence the lifetime savings.

Table 5-11. Measure 11624671- Lifetime Savings Summary

Factor	Tracking	Evaluator
Lifetime savings (kWh)	538,510	553,620
First year savings (kWh)	53,851	55,362
Measure lifetime (years)	10	10
Measure life reference	Tracking	Screening Tool
Measure event type	Retrofit	Retrofit
Baseline classification	Single – Pre existing	Single – Pre existing
Measure status (operational or removed)	N/A	Operational

N/A = Not Applicable

The evaluation uses the same 10-year measure life as the applicant. Since the first-year savings are similar, the lifetime savings are similar as well.

5.2.9.1 Ancillary impacts

The project included gas savings of 3,451 therms from connecting a hydronic boiler to the EMS system. The changes addressed in this report would not affect the calculated gas savings from the EMS tool. However, a change in ventilation rates as a result of decreasing the RTU runtimes would result in less outside air needing to be conditioned by the boilers, decreasing the heating load in the facility.

RICE20N006

Report Date: 7/28/2022

Application ID(s)	10174829, 11787183
Project Type	New Buildings & Major Renovation
Program Year	2020
Evaluation Firm	DNV
Evaluation Engineer	Max Ma
Senior Engineer	Joseph St John

5.3 Evaluated Site Summary and Results

The evaluated project consists of the installation of LED process lighting fixtures in a new-construction agricultural indoor growth facility. The impacted facility operates with a consistent schedule throughout the year. Both the baseline and proposed fixtures are tuned (dimmed) to the same required output to meet process needs. This evaluated project includes two measures:

Measure 10174829: This measure was Phase I of the lighting project at this facility. Phase I installed 8 LED fixtures in the vegetation room operating 18 hours per day, dimmed to an average of 55%; and 120 LED fixtures in the flower rooms operating 12 hours per day, dimmed to an average of 78%. All installed fixtures have rated inputs of 645W each. All baseline fixtures have high-pressure sodium (HPS) lamps with rated inputs of 1,067W each. Baseline and installed fixtures have identical average dimming and provide similar photosynthetically active radiation (PAR) output. Energy savings result from the reduced lighting fixture wattage as well as interactive cooling savings. Because of the high insulation, no outdoor air (to minimize biohazard contamination) and high humidity load, cooling is required year-round at an estimated efficiency of 0.85 kW/ton. The tracking savings for this measure is 230,185 kWh/yr.

Measure 11787183: This measure was Phase II of the lighting project at this facility. Phase II installed 12 LED fixtures in the vegetation room operating 18 hours per day, dimmed to an average of 55%. All installed fixtures have rated inputs of 645W each. All baseline fixtures have high-pressure sodium (HPS) lamps with rated inputs of 1,067W each Baseline and installed fixtures have identical average dimming and provide similar photosynthetically active radiation (PAR) output. Energy savings result from the reduced lighting fixture wattage as well as interactive cooling savings. Because of the high insulation, no outdoor air (to minimize biohazard contamination) and high humidity load, cooling is required year-round at an estimated efficiency of 0.85 kW/ton using packaged DX units. The dehumidification units are also DX located within the production spaces, where heat is rejected directly into the space to be removed by the space cooling system. The tracking savings for this measure is 22,743 kWh/yr.

The site contact indicated that the site's operations were not changed since the project's completion and will remain the same in the future, without any impacts from Covid-19. However, the site contact did not allow in-person site visits because of the concern for biological contamination (introducing fungus, mold, bacteria etc. into the growth areas). The evaluators determined that the virtual site visit can sufficiently document relevant operational parameters (lighting on/off schedules, percentage dimming in each space) which the site contact confirmed to remain constant. Therefore, the evaluators performed a full M&V with operational and non-operational parameters updated from virtual site visit findings.

The evaluation results are presented in Table 1-1.

Table 5-12. Evaluation results summary

PA Application ID	Measure Name		Annual Electric Energy (kWh)	% of Energy Savings On-Peak	Summer On-Peak Demand (kW)	Winter On-Peak Demand (kW)
10174829	LED Fixtures Phase I	Tracked	230,185	68%	51.40	51.40
		Evaluated - ops	264,339	68%	59.31	59.31
		Realization Rate	115%	100%	115%	115%
11787183	LED Fixtures Phase II	Tracked	22,743	61%	3.46	3.46
		Evaluated - ops	20,439	61%	3.11	3.11
		Realization Rate	90%	100%	90%	90%
Totals		**Tracked**	**252,928**	**68%**	**54.86**	**54.86**
		Evaluated - ops	**284,777**	**68%**	**62.43**	**62.43**
		Realization Rate	**113%**	**100%**	**114%**	**114%**

5.3.1 Explanation of Deviations from Tracking

The evaluated savings are more than the applicant-reported savings primarily due to adjustments to dimming factors (which the evaluators applied identically in baseline and as-built calculations). Further details regarding deviations from the tracked savings are presented in Section 3.1.

5.3.2 Recommendations for Program Designers & Implementers

There are no recommendations currently.

5.3.3 Customer Alert

There were no customer alerts.

5.4 Evaluated Measures

The following sections present the evaluation procedure, including the findings from an in-depth review of the supplied applicant calculations and the evaluation methodology determined to be the best fit for the site and the information available.

The evaluated project consists of the installation of a total of 140 LED process lighting fixtures in a new-construction agricultural indoor growth facility over two phases.

5.4.1 Application Information and Applicant Savings Methodology

This section describes the applicant's application information, savings methodology, and the evaluation assessment of the savings calculation algorithm used by the applicant.

5.4.1.1 Applicant Description of Baseline

The applicant classified the project as new construction with an industry standard practice (ISP) baseline. The applicant described the baseline as high-pressure sodium (HPS) fixtures of the same quantity and rated lumens output as the installed fixtures. The applicant assigned baseline percentage dimming to the desired output (assuming input wattage is also proportional to the percentage dimming). Table 5-13 provides a summary of applicant's baseline key parameters.

Table 5-13. Applicant baseline key parameters

		BASELINE		
Measure	**Parameter**	**Value(s)**	**Source of Parameter Value**	**Note**
10174829 – LED Phase I	Fixture quantity in flower room	120	TA study	Same as installed
10174829 – LED Phase I	Fixture quantity in vegetation room	8	TA study	Same as installed
11787183 – LED Phase II	Fixture quantity in vegetation room	12	TA study	Same as installed
LED for both phases	Fixture technology	HPS	TA study	
LED for both phases	Fixture wattage	1,067W	TA study	
LED for both phases	Fixture discharge PAR	1,722 mmol/s	TA study	Marginally higher than installed
LED for both phases	Flower room dimming	78%	TA study	Same as installed
LED for both phases	Flower room daily hours	12	TA study	Same as installed
LED for both phases	Vegetation room dimming	55%	TA study	Same as installed
LED for both phases	Vegetation room daily hours	18	TA study	Same as installed
LED for both phases	Annual operating days for all fixtures	365	TA study	Same as installed
LED for both phases	HVAC cooling efficiency	0.85 kW/ton	TA study	Same as installed

5.4.1.2 Applicant Description of Installed Equipment and Operation

The applicant described the installed LED fixtures as the same locations, quantities, operating hours and percentage dimming as the baseline HPS fixtures. Table 5-14 provides a summary of the applicant proposed key parameters.

Table 5-14. Applicant proposed key parameters

		INSTALLED		
Measure	**Parameter**	**Value(s)**	**Source of Parameter Value**	**Note**
10174829 – LED Phase I	Fixture quantity in flower room	120	TA study	Same as baseline
10174829 – LED Phase I	Fixture quantity in vegetation room	8	TA study	Same as baseline
11787183 – LED Phase II	Fixture quantity in vegetation room	12	TA study	Same as baseline
LED for both phases	Fixture technology	LED	TA study	
LED for both phases	Fixture wattage	645W	TA study	
LED for both phases	Fixture discharge PAR	1,700 mmol/s	TA study	
LED for both phases	Flower room dimming	78%	TA study	Same as baseline
LED for both phases	Flower room daily hours	12	TA study	Same as baseline
LED for both phases	Vegetation room dimming	55%	TA study	Same as baseline
LED for both phases	Vegetation room daily hours	18	TA study	Same as baseline
LED for both phases	Annual operating days for all fixtures	365	TA study	Same as baseline
LED for both phases	HVAC cooling efficiency	0.85 kW/ton	TA study	Same as baseline

5.4.1.3 Applicant Energy Savings Algorithm

The applicant used a custom spreadsheet-based analysis to calculate energy savings for each measure. For all calculations, the applicant applied the same average dimming factor to both the baseline and installed fixtures, because the baseline and installed fixtures have similar nameplate discharge PAR values, so are estimated to achieve the same discharge PAR values when dimmed to the same levels.

Measure 10174829 – LED Phase I

The applicant used the following formulas to quantify the energy savings for this measure:

$$kWh_{save} = kWh_{Flower} + kWh_{Veg}$$

where,

kWh_{save} = energy savings for this measure, 230,185 kWh/yr

kWh_{Flower} = energy savings for the flower rooms, 215,023 kWh/yr

kWh_{Veg} = energy savings for the vegetation rooms, 15,162 kWh/yr

For the flower rooms:

$$kWh_{Flower} = \left(kW_{Ltg-F} + kW_{clg-}\ \right) \times \frac{12\ hr}{day} \times \frac{365\ day}{yr}$$

where,

kW_{Ltg-F} = kW reduction from flower room lighting

kW_{clg-F} = kW reduction from flower room cooling

$$kW_{Ltg-F} = (kW_{Base} - kW_{Installed}) \times Dim_F \times Qty_F$$

where,

kW_{Base} = baseline HPS fixture input power, 1.067 kW/fixture

$kW_{Installed}$ = installed LED fixture input power, 0.645 kW/fixture

Dim_F = average dimming factor in the flower rooms, 78%

Qty_F = fixture quantity in the flower rooms in scope, 120

$$kW_{Clg-}\ = kW_{Ltg-F} \times \frac{3.142\ ton}{12\ kW} \times \frac{0.85\ kW}{ton}$$

For the vegetation rooms:

$$kWh_{Veg} = \left(kW_{Ltg-V} + kW_{clg-V}\right) \times \frac{18\ hr}{day} \times \frac{365\ day}{yr}$$

where,

kW_{Ltg-} = kW reduction from vegetation room lighting

kW_{clg-F} = kW reduction from vegetation room cooling

$$kW_{Ltg-V} = (kW_{Base} - kW_{Installed}) \times Dim_V \times Qty_V$$

where,

kW_{Base} = baseline HPS fixture input power, 1.067 kW/fixture

$kW_{Installed}$ = installed LED fixture input power, 0.645 kW/fixture

Dim_V = average dimming factor in the vegetation rooms, 55%

Qty_V = fixture quantity in the vegetation rooms in scope, 8

Cooling savings is calculated as:

$$kW_{Clg-V} = kW_{Ltg-V} \times \frac{3.142\ ton}{12\ kW} \times \frac{0.85\ kW}{ton}$$

The applicant claimed that 100% of the lighting fixture wattage reduction contribute to interactive cooling savings, because the space has restricted outside air flow (for controlling contaminants) as well as an atypically high internal load due to the density of plants, fixtures and dehumidification units that reject heat into the space. Therefore, the impacted spaces require mechanical cooling 24/7, all year round.

Measure 11787183 – LED Phase II

The applicant used the following formulas to quantify the energy savings for this measure:

$$kWh_{Veg} = \left(kW_{Ltg-V} + kW_{clg-V}\right) \times \frac{18\ hr}{day} \times \frac{365\ day}{yr}$$

where,

kW_{Ltg-F} = kW reduction from vegetation room lighting

kW_{clg-F} = kW reduction from flower vegetation cooling

$$kW_{Ltg-V} = (kW_{Base} - kW_{Installed}) \times Dim_V \times Qty_V$$

where,

kW_{Base} = baseline HPS fixture input power, 1.067 kW/fixture

$kW_{Installed}$ = installed LED fixture input power, 0.645 kW/fixture

Dim_V = average dimming factor in the vegetation rooms, 55%

Qty_V = fixture quantity in the vegetation rooms in scope, 12

$$kW_{Clg-V} = kW_{Ltg-} \times \frac{3.142\ ton}{12\ kW} \times \frac{0.85\ kW}{ton}$$

Additional details on the applicant algorithm could be found in the project files.

5.4.1.4 Evaluation Assessment of Applicant Methodology

The evaluators found the applicant's analysis methodology appropriate and well substantiated given the information available at the time of the savings development during this new construction.

5.4.2 Virtual Inspection

Because the site contact did not permit in-person site visit due to concerns of biological contamination to the agricultural products, the evaluators conducted virtual inspections by requesting pictures of the relevant systems to verify measure installation and used screen shots of the lighting controls outputs to update the evaluator's analysis. The site supplied the requested information on July 26, 2022.

5.4.2.1 Summary of Virtual Findings

The evaluators interviewed the owner of the facility who was the most knowledgeable at this site about the installed project as well as the general operations of the facility. During the phone interview, the site contact confirmed the project as a new construction, confirmed that all listed LED fixtures in the invoices were installed and operational, and that all controls were installed and functional as reported in the application. Table 5-15 provides a summary of the virtual site visit findings.

Table 5-15. Measure verification

Measure Name	Verification Method	Verification Result
Both measures	Verify the fixture count through invoices and spot photo verification.	All fixtures on the invoices were installed and operational, as reported in the application.
Both measures	Interview the site contact for typical operations.	The site operates all days of the year and requires mechanical cooling year-round with a high heat load and no outside air.
Both measures	Inspect photos of the lighting control panels to update the percentage dimming.	Flower rooms were dimmed to 92% (higher lighting level than the applicant-estimated 78%); vegetation rooms were dimmed to 50% (lower lighting level than the applicant-estimated 55%). The site contact indicated that dimming levels, once optimized, do not change.
Both measures	Inspect photos of the lighting control panels to update the daily lighting hours.	Flower rooms' fixtures operate from 6:00 a.m. to 5:59 p.m. (12 hours per day, same as applicant-reported). Vegetation rooms' fixtures operate from 6:00 a.m. to 11:59 p.m. (18 hours per day, same as applicant-reported).

Measure Name	Verification Method	Verification Result
Both measures	Review HVAC units' nameplate to determine the cooling efficiency.	The nameplate cooling efficiency is 15 SEER, which equates 0.80 kW/ton, more efficient than the applicant-estimated 0.85 kW/ton.

Photo 2-1 through Photo 2-6 present example findings from the virtual site visit.

Photo 5-1. Fixtures in vegetation room

Photo 5-2. Lighting controller in vegetation room – showing dimming percentage

Photo 5-3. Lighting controller in vegetation room – showing schedules (6:00 am to 11:59 pm, missing digits due to interaction between camera and LCD display)

Photo 5-4. Fixtures in flower room (indoor dehumidification unit in background)

Photo 5-5. Lighting controller in flower room – showing dimming percentage

Photo 5-6. Lighting controller in vegetation room – showing schedules

5.4.3 Evaluation Methods and Findings

This section describes the evaluator methods and findings.

5.4.3.1 Evaluation Description of Baseline

The evaluator reviewed the project files and interviewed the site contact to gather information on the baseline. The evaluators determined that both measures are new construction with ISP baselines. Per ISP guidance in effect in RI, the baseline for agricultural lighting is HPS fixtures that produce equivalent PPFD (or equivalent PAR if installation locations are consistent). Therefore, the evaluators agree with the applicant's baseline characterization and used the same in the evaluations, with updated to operational parameters based on virtual site visit findings.

5.4.3.2 Evaluation Calculation Method

The evaluators used the same analysis method as the applicant did, as detailed in Section 2.2.2. The evaluators also verified that the applicant-reported space conditions which supported that 100% of the lighting fixture wattage reduction have associated interactive cooling savings. Table 5-16 and Table 5-17 detail the baseline and installed input parameters used in the evaluator's analysis.

Table 5-16. Evaluator's baseline key parameters

		BASELINE		
Measure	Parameter	Value(s)	Source of Parameter Value	Note
10174829 – LED Phase I	Fixture quantity in flower room	120	Verified with invoice	Same as installed
10174829 – LED Phase I	Fixture quantity in vegetation room	8	Verified with invoice	Same as installed
11787183 – LED Phase II	Fixture quantity in vegetation room	12	Verified with invoice	Same as installed
LED for both phases	Fixture technology	HPS	Per RI ISP	Per ISP in RI
LED for both phases	Fixture wattage	1,067W	TA study	Per baseline fixture specifications
LED for both phases	Flower room dimming	92%	Updated to be same as installed	Same as installed
LED for both phases	Flower room daily hours	12	Updated to be same as installed	Same as installed
LED for both phases	Vegetation room dimming	50%	Updated to be same as installed	Same as installed
LED for both phases	Vegetation room daily hours	18	Updated to be same as installed	Same as installed
LED for both phases	Annual operating days for all fixtures	365	Verification with site contact	Verified per site contact interview
LED for both phases	HVAC cooling efficiency	0.80 kW/ton	Updated to as-built DX cooling nameplate	Updated per HVAC nameplate

Table 5-17. Evaluator's installed key parameters

		INSTALLED		
Measure	Parameter	Value(s)	Source of Parameter Value	Note
10174829 – LED Phase I	Fixture quantity in flower room	120	Verified with invoice	Verified with invoice
10174829 – LED Phase I	Fixture quantity in vegetation room	8	Verified with invoice	Verified with invoice
11787183 – LED Phase II	Fixture quantity in vegetation room	12	Verified with invoice	Verified with invoice
LED for both phases	Fixture technology	LED	Verified with photos and invoice	Verified with photos
LED for both phases	Fixture wattage	645W	Per as-built specifications	Per installed fixture specifications
LED for both phases	Flower room dimming	92%	Verified with screenshot on controller	Updated per lighting controller
LED for both phases	Flower room daily hours	12	Verified with screenshot on controller	Verified per lighting controller
LED for both phases	Vegetation room dimming	50%	Verified with screenshot on controller	Updated per lighting controller
LED for both phases	Vegetation room daily hours	18	Verified with screenshot on controller	Verified per lighting controller
LED for both phases	Annual operating days for all fixtures	365	Verification with site contact	Verified per site contact interview
LED for both phases	HVAC cooling efficiency	0.80 kW/ton	Updated to as-built DX cooling nameplate	Updated per HVAC nameplate

5.5 Final Results

The evaluated project includes two measures of LED installation (128 fixtures in Phase I, 12 fixtures in Phase II) at a new construction indoor agricultural facility. The installed LED fixtures save energy through reduced wattage for equivalent output compared to the baseline HPS fixtures, as well as the interactive cooling energy savings. Because the site does not allow in-person site visits, the evaluators performed M&V using virtual site visit methods capturing all relevant parameters to the evaluator’s custom spreadsheet savings analysis. The evaluators verified that most parameters were accurate as the applicant reported, with updates to the lighting percentage dimming and cooling efficiency. The evaluation resulted in an overall increased energy savings. Table 5-9 provides key parameters used in the evaluation.

Table 5-18. Summary of key parameters

	BASELINE	PROPOSED / INSTALLED

Parameter	Tracking Value(s)	Evaluation Value(s)	Tracking Value(s)	Evaluation Value(s)
Fixture quantity in flower room - Phase I	120	120	120	120
Fixture quantity in vegetation room - Phase I	8	8	8	8
Fixture quantity in vegetation room - Phase II	12	12	12	12
Fixture technology	HPS	HPS	LED	LED
Fixture wattage	1,067W	1,067W	645W	645W
Flower room dimming	78%	92%	78%	92%
Flower room daily hours	12	12	12	12
Vegetation room dimming	55%	50%	55%	50%
Vegetation room daily hours	18	18	18	18
Annual operating days for all fixtures	365	365	365	365
HVAC cooling efficiency	0.85 kW/ton	0.80 kW/ton	0.85 kW/ton	0.80 kW/ton

5.5.1 Explanation of Differences

This section will describe the key drivers behind any difference in the application and evaluation estimates annual kWh savings, percent on-peak kWh saving, and demand savings. The following table will be used to summarize these differences. The purpose of this table is to describe how changes to the key parameters influenced the final project savings through the end-use summary analysis. Table 3-2 provides a summary of the differences between tracking and evaluated values.

Table 5-19. Summary of deviations

Measure	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
10174829	Operations	Flower room dimming	15.3%	**Increased savings -** evaluated dimming factor of 92% is higher than applicant-reported 78% (dimming factor was applied to both baseline and installed fixtures), resulting in higher output.
10174829	Operations	Vegetation room dimming	-0.5%	**Decreased savings -** evaluated dimming factor of 50% is lower than applicant-reported 55% (dimming factor was applied to both baseline and installed fixtures), resulting in lower output.
10174829	Interactivity	HVAC cooling efficiency	-1.2%	**Decreased savings -** evaluated cooling efficiency of 0.80 kW/ton is more efficient than applicant-reported 0.85 kW/ton,

				resulting in lower interactive cooling savings.
11787183	Operations	Vegetation room dimming	-0.8%	**Decreased savings -** evaluated dimming factor of 50% is lower than applicant-reported 55% (dimming factor was applied to both baseline and installed fixtures), resulting in lower output.
11787183	Operations	Efficiency	-0.1%	**Decreased savings -** evaluated cooling efficiency of 0.80 kW/ton is more efficient than applicant-reported 0.85 kW/ton, resulting in lower interactive cooling savings.
Final RR				**113%**

5.5.2 Lifetime Savings

This new construction has a lost opportunity baseline defined by ISP. The evaluators calculated applicant and evaluated lifetime savings values using the following formula:

$$\mathrm{LAGI} = \mathrm{FYS} \times \mathrm{EUL}$$

where:

LAGI = lifetime adjusted gross impact (kWh)

FYS = first-year savings (kWh)

EUL = measure life (years)

The evaluated lifetime savings are more than the tracking lifetime savings because the evaluated first-year savings are more than the tracking first-year savings.

Table 5-20 and Table 5-21 provide a summary of key factors that influence lifetime savings.

Table 5-20. Measure 10174829 - Lifetime Savings Summary

Factor	Tracking	Application	Evaluator
Lifetime savings	2,301,850 kWh	2,301,850 kWh	2,643,387 kWh
First year savings	230,185 kWh	230,185 kWh	264,339 kWh

Factor	Tracking	Application	Evaluator
Measure lifetime	10 years (override for process equipment)	10 years (project BCR, override for process equipment)	10 years (for process equipment)
Baseline classification	New construction	New construction	New construction

Table 5-21. Measure 11787183 - Lifetime Savings Summary

Factor	Tracking	Application	Evaluator
Lifetime savings	227,430 kWh	227,430 kWh	204,386 kWh
First year savings	22,743 kWh	22,743 kWh	20,439 kWh
Measure lifetime	10 years (override for process equipment)	10 years (project BCR, override for process equipment)	10 years (for process equipment)
Baseline classification	New construction	New construction	New construction

5.5.2.1 Ancillary impacts

There no further ancillary impacts from this project.

RICE20N032

Report Date: 7/26/2022

Program	Custom Electric	
Application ID(s)	1465813	
Project Type	C&I Initial Purchase & End of Useful Life	
Program Year	2020	
Evaluation Firm	DNV	
Evaluation Engineer	Shravan Iyer	
Senior Engineer	Shaobo Feng	

5.6 Evaluated Site Summary and Results

The site is a 450,000 ft^2 warehouse and distribution center for a pharmaceutical chain. The facility operates three shifts per day six days per week between Monday and Saturday with some limited work during the weekends that pertain to maintenance, administration etc. The project installed at the facility includes the following measure:

EEM-1: Replacing existing Energy Management System (EMS) with new building EMS - The facility replaced their existing EMS that was non-functioning in many ways with a new EMS with capabilities that provided better scheduling, temperature setbacks and could turn off equipment during un-occupied hours.

The energy savings for this measure comes from the temperature setback during un-occupied hours resulting in the fans cycling less often and the reduced need to cool or heat the conditioned space.

This site was impacted significantly by COVID-19 which hit a few months after the project was installed. During the initial telephone conversations with the site contact, the evaluators were told that after the pandemic hit, the EMS was recalibrated to modify the operation of the facilty's HVAC system by adjusting outdoor air damper positions to increase fresh air intake to contain the spread of COVID and also readjusting temperature setpoints and the setback during occupied and un-occupied periods. Additionally, the ensuing labor shortage and supply chain disruptions have resulted in fluctuating occupancy and increased hours of operation sometimes with fewer staff. All of these changes have made the pre and post pandemic operations different to the point where they cannot be compared with each other. Therefore this site was evaluated using a non-operational adjustment methodology.

The evaluation results are presented in Table 5-1.

Table 5-1. Evaluation results summary

PA Application ID	Measure Name		Annual Electric Energy (kWh)	% of Energy Savings On-Peak	Summer On-Peak Demand (kW)	Winter On-Peak Demand (kW)
1465813	Replacing existing building EMS System	Tracked	121,191	0%	0.0	0.0
		Evaluated - ops	121,191	0%	0.0	0.0
		Realization Rate	100%	0%	0%	0%
Totals		**Tracked**	**121,191**	**0%**	**0.0**	**0.0**
		Evaluated - ops	**121,191**	**0%**	**0.0**	**0.0**
		Realization Rate	**100%**	**0%**	**0%**	**0%**

5.6.1 Explanation of Deviations from Tracking

The evaluated savings are the same as the applicant-reported savings primarily due to the fact that the measure was evaluated as a non-operational adjustment only, wherein only the measure installation and operation was confirmed by the evaluators. Further details regarding deviations from the tracked savings are presented in Section 3-1.

5.6.2 Recommendations for Program Designers & Implementers

There are no recommendations.

5.6.3 Customer Alert

There were no customer alerts.

5.7 Evaluated Measures

The measures installed at this site include:

EEM-1: Replacing existing EMS with new building EMS - The project consisted of the facility replacing their existing EMS that was non-functioning in many ways with a new EMS with capabilities that provided better scheduling, temperature setbacks and could turn off equipment during un-occupied hours.

5.7.1 Application Information and Applicant Savings Methodology

The site replaced their pre-existing EMS with a new EMS, because the pre-exisiting system was non-functioning in many was and did not have the functionalities that were required for its effective use. The pre-existing was unusable primarily because the different modules were inaccessible to the site staff. The site staff could not access the different settings in the system and the user-interface was not easy to work with. Additionally, multiple systems/modules were integrated such that it caused problems wherein even basic setpoints could not be controlled effectively. The applicant used multiple regression models between trend kW data and OAT to model the pre install and post install operating profiles for both occupied and unoccupied periods during the weekdays and weekends. The results were annualized using an 8760 spreadsheet. The site did not claim energy savigs for occupied periods in either case and only calculated the difference in kW between pre and post install case for unoccupied periods. The difference between the two was the annual energy savings.

5.7.2 Applicant Description of Baseline

The applicant categorized this measure as a retrofit measure. The applicant baseline consists of a pre-exisiting building EMS that was in poor working condition and had very limited controls capability. The facility's HVAC system operated continuously with no schedules while being wired to the existing non-functioning system throughout the year.

Table 5-22 shows the key inputs used in the applicant savings calculation methodology:

Table 5-22. Applicant baseline key parameters

BASELINE			
Measure	Parameter	Value(s)	Source of Parameter Value
Replacing existing building EMS System	Total OA CFM from RTUs	6,413 CFM	Applicant Documentation
Replacing existing building EMS System	Weekday HVAC Operation profile occupied Hours	7 a.m. to 10 p.m.	Applicant Documentation

Replacing existing building EMS System	Saturday HVAC Operation profile Occupied Hours	7 a.m. to 10 p.m.	Applicant Documentation
Replacing existing building EMS System	Interior space setpoints	Winter/heating – Occupied 68F; Un-Occupied 62F	Applicant Documentation
Replacing existing building EMS System	Interior space setpoints	Summer/cooling - Occupied 72F; Un-Occupied 78F	Applicant Documentation

5.7.2.1 Applicant Description of Installed Equipment and Operation

The facility proposed to replace their pre-exisiting building EMS which was non-functioning, with very limited control capabilities and the systems's modules were inaccessible due to a difficult-to-use user interface. The new EMS will provide the facility staff with the capabilities to implement temperature setbacks, turning off equipment during occupied and unoccupied hours to heat or cool the conditioned space appropriately as needed. Table 5-23 lists the key inputs in the installed case:

Table 5-23. Applicant proposed key parameters

PROPOSED			
Measure	**Parameter**	**Value(s)**	**Source of Parameter Value**
Replacing existing building EMS System	Total OA CFM from RTUs	6,413 CFM	Applicant Documentation
Replacing existing building EMS System	Weekday HVAC Operation profile occupied Hours	7 a.m. to 10 p.m.	Applicant Documentation
Replacing existing building EMS System	Saturday HVAC Operation profile Occupied Hours	7 a.m. to 10 p.m.	Applicant Documentation
Replacing existing building EMS System	Interior space setpoints	Winter/heating – Occupied 68F; Un-Occupied 62F	Applicant Documentation
Replacing existing building EMS System	Interior space setpoints	Summer/cooling - Occupied 72F; Un-Occupied 78F	Applicant Documentation

5.7.2.2 Applicant Energy Savings Algorithm

The applicant energy savings was calculated as follows:

The project was installed in June 2019. The applicant calculation used kW data (trend data at 15-minute intervals) to determine the operating kW profile of the site's HVAC system in the pre and post case. Here, the pre case was considered to be the kW data for 2018 (January to December) and the post case data used was from July to December 2019. The applicant created multiple regression models between the site's kW and OAT (dry bulb) for occupied and unoccupied periods on weekdays, and Saturdays using both pre and post install kW data. This was done to determine the operating profile of the site's HVAC systems in both the pre and post case and to determine the impact of the EMS controls that were implemented in terms of providing setback to the heating and cooling setpoints for the conditioned space during both occuipied and unoccupied periods. Some of the general assumptions used in the applicant analysis are listed below:

- The pre-install trend kW data used in the analysis is from January to December 2018.
- The post-install trend kW data used in the analysis is from July to December 2019.
- The EMS controls do not have any impact on HVAC system operation during the occupied hours.
- The savings for this measure were claimed only for the unoccupied hours.

The hours of operation used in the analysis are:

Table 5-3. Site Operating Hours

	Start	End
Weekday Occ Hours	7 a.m.	10 p.m.
Saturday Occ Hours	7 a.m.	10 p.m.
Sunday Hours	No Operation	

The applicant used pre-install trend kW data for 2018 and 2019 to create a regression model between kW and OAT for both the pre-install and post install case for occupied hours during the weekdays and Saturday. These regressions are shown below in Figure 2-1 and 2-2:

Figure 2-1 Weekday Occupied kW v/s OAT for Pre and Post Install Case

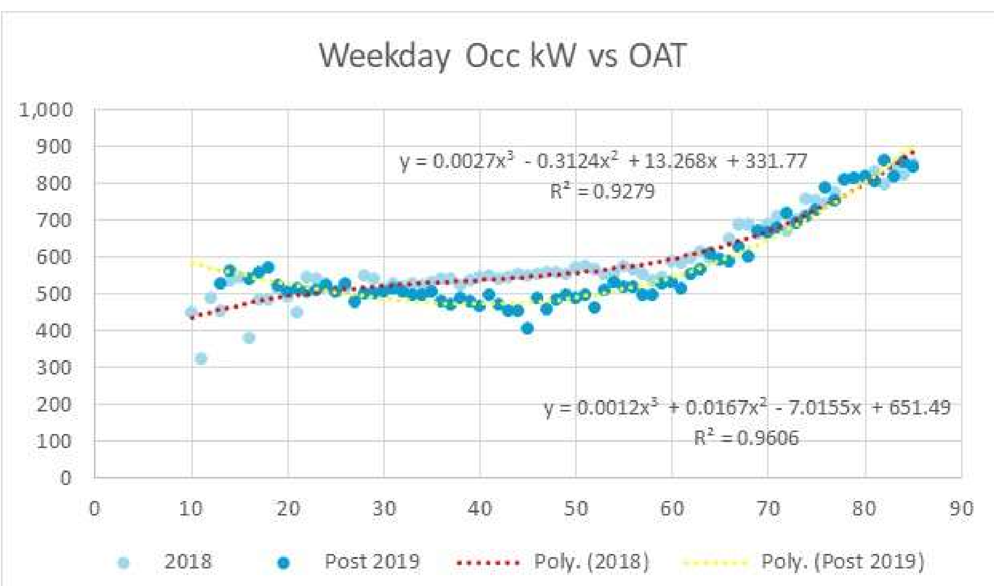
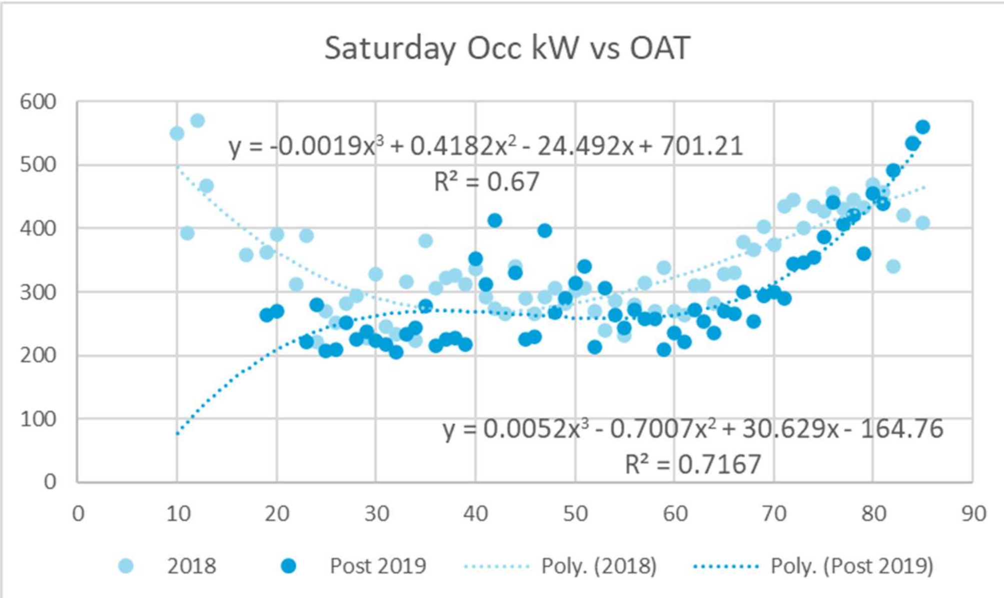


Figure 2-2 Saturday Occupied kW v/s OAT for Pre and Post Install Case



Similar regressions were created using kW and OAT for unoccupied periods for the pre and post-install periods as shown in Figure 2-3 and Figure 2-4 below:

Figure 2-3 Weekday Unoccupied kW v/s OAT for Pre and Post Install Case

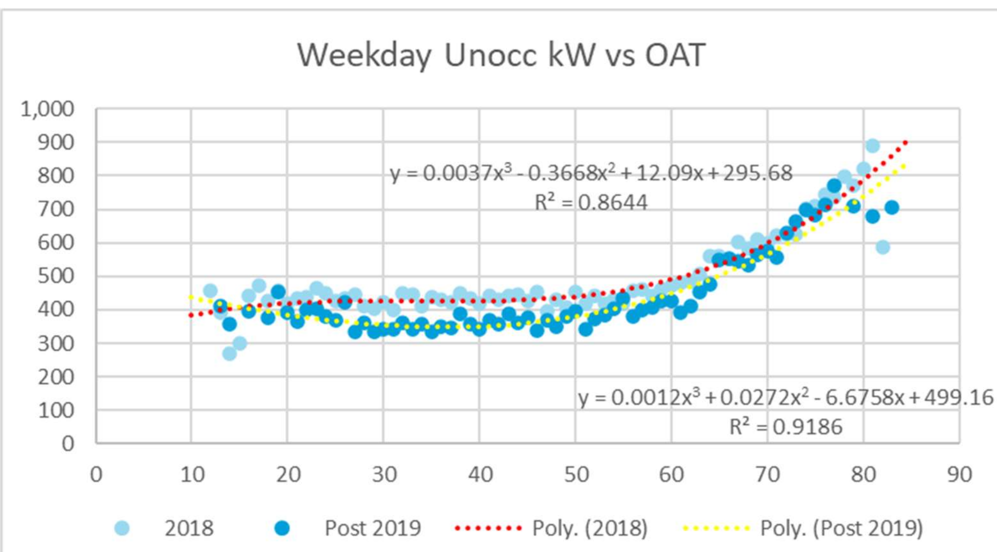
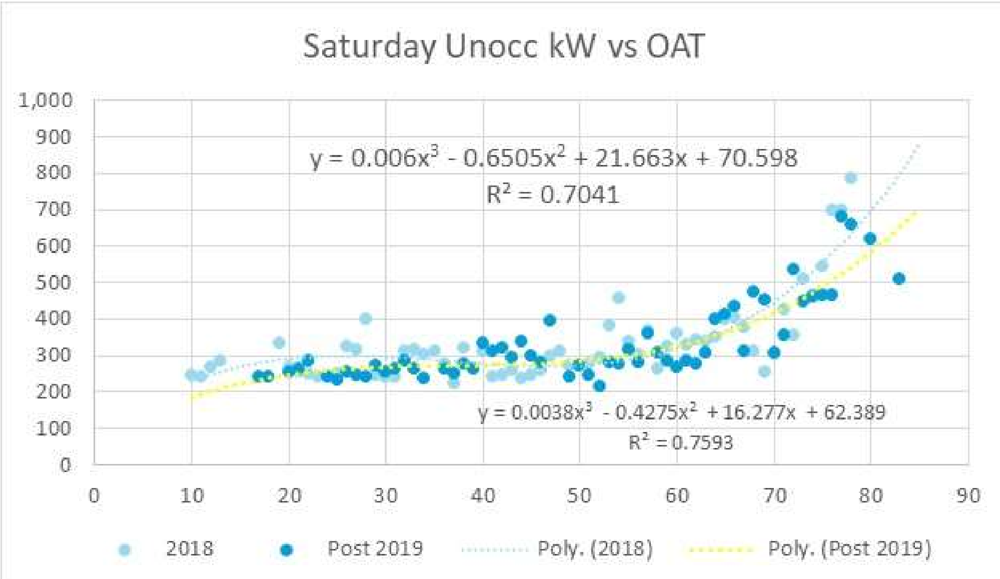


Figure 2-4 Saturday Occupied kW v/s OAT for Pre and Post Install Case



The regression coefficients obtained from the above regression models are summarized in the Table 2-4 below:

Table 2-4 Regression Coefficients for Occupied and Unoccupied Periods

			C	X	X^2	X^3
Base	Weekday	Occ	331.77	13.268	-0.3124	0.0027
Proposed	Weekday	Occ	651.49	-7.0155	0.0167	0.0012
Base	Weekday	Unocc	295.68	12.09	-0.3668	0.0037
Proposed	Weekday	Unocc	499.16	-6.6758	0.0272	0.0012
Base	Saturday	Occ	701.21	-24.492	0.4182	-0.0019
Proposed	Saturday	Occ	-164.76	30.629	-0.7007	0.0052
Base	Saturday	Unocc	70.598	21.663	-0.6505	0.006
Proposed	Saturday	Unocc	62.389	16.277	-0.4275	0.0038

The above regression models were used to estimate the annual energy consumption for the pre and post install case using an 8,760-spreadsheet. The kW consumption was calculated for unoccupied periods during the weekdays and during Saturdays annually using the 8,760 spreadsheet. No kW reduction was calculated for occupied hours either during weekdays or on Saturdays. The difference between pre and post install kW during unoccupied hours during weekdays and Saturdays is the total annual kWh savings. The measure yielded annual energy savings of 121,191 kWh.

5.7.2.3 Evaluation Assessment of Applicant Methodology

The evaluators determined that the applicant's analysis methodology was reasonable. The evaluators agree with the applicant approach to create regression models for operating kW and OAT during occupied and unoccupied periods during weekdays and during Saturdays for the years 2018 and 2019 (July through December) which were used as the pre and post case data respectively. No savings were claimed for occupied hours during the weekdays and

Saturdays since the control upgrades did not have any significant impact during occupied hours and therefore the site did not get any savings for those hours. The savings were only claimed for the unoccupied hours during the weekdays and during Saturdays since that setback was implemented during the unoccupied hours only. The evaluators find this methodology reasonable.

5.7.3 Site Inspection

The evaluators conducted a site visit on 6/15/2022 to verify the installation of the new building EMS system. The evaluators discussed the installation of the project with the Facility/Service Manager who was the site contact. The site contact informed the evaluators that the project was installed in June 2019. The site contact informed the evaluators that the pre-existing EMS system was old and was non-functioning in many ways. The site personnel had trouble accessing the different modules in the system and thereby unable to use a wide range of the system's functionalities and therefore decided to replace it with a new system.

The evaluators learned onsite that the facility had been impacted heavily by the COVID-19 pandemic. The ensuing supply chain issues, labor shortages and other pandemic related impacts resulted in the site increasing their hours of operation while working with less staff. The differences in the site's operation pre and post pandemic are described below:

When the project was installed in June 2019, the site's operating hours were between 7 a.m and 10 p.m Monday through Saturday. The site was typically occupied during these hours and did not have any temperature setback for the unoccupied hours. A few months later, after the onset of the COVID-19 pandemic, the site had to alter the operation of their HVAC system such as opening outdoor air dampers to the maximum extent to allow fresh air intake in order to reduce the spread of COVID-19. Temperature setpoints were manually overridden to change the HVAC system's operation to reflect the new hours of operation. The ensuing staffing shortages and supply chain disruptions resulted in the site operating for longer hours with fewer staff.

The operation of the site after the onset of COVID-19 is described below:

The evaluators learned onsite that the site operated 24 hours per day for six-and-a-half days. The site's operating hours were: the first shift begins at 5 a.m. and ended at 3 p.m. and the second shift would begin at 3 p.m. and ended at 5 a.m. The site's temperature setpoints are as follows: Winter - Occupied 68°F and Unoccupied - 62°F. Summer – Occupied - 72°F and Unoccupied - 78°F. The EMS was programmed to be on occupied mode between 7 a.m. and 10 p.m. Monday through Saturday.

As described above, the operation of the HVAC system at the site is considerably different post-pandemic compared to its pre-pandemic operation. The evaluators verified the installation of the EMS system and took screenshots of the system that are shown below in Figure 2-5 and Figure 2-6:

Figure 2-5 EMS display screen

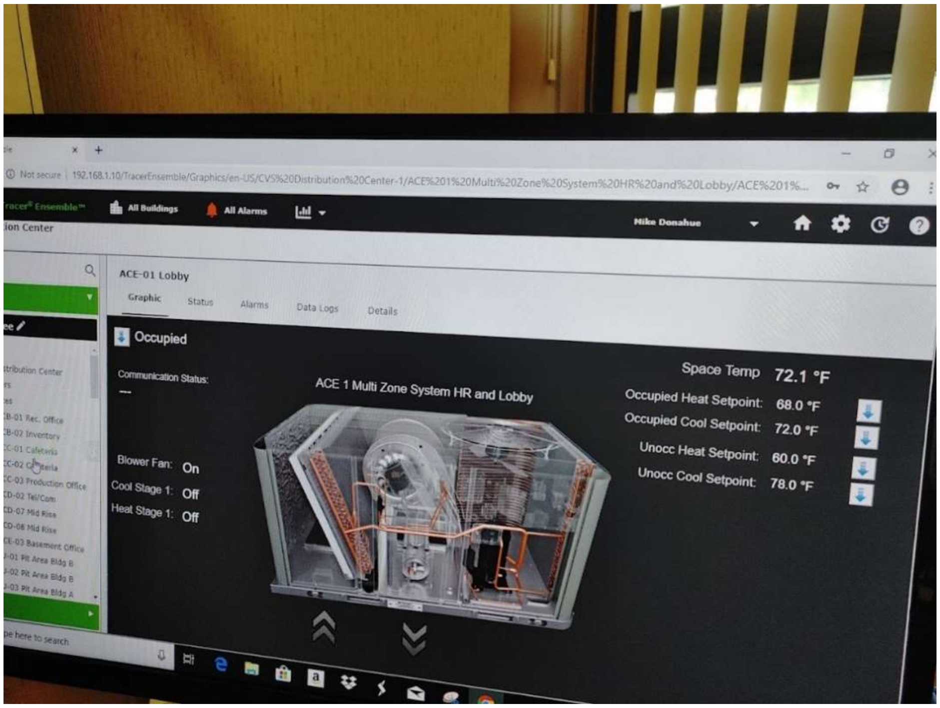
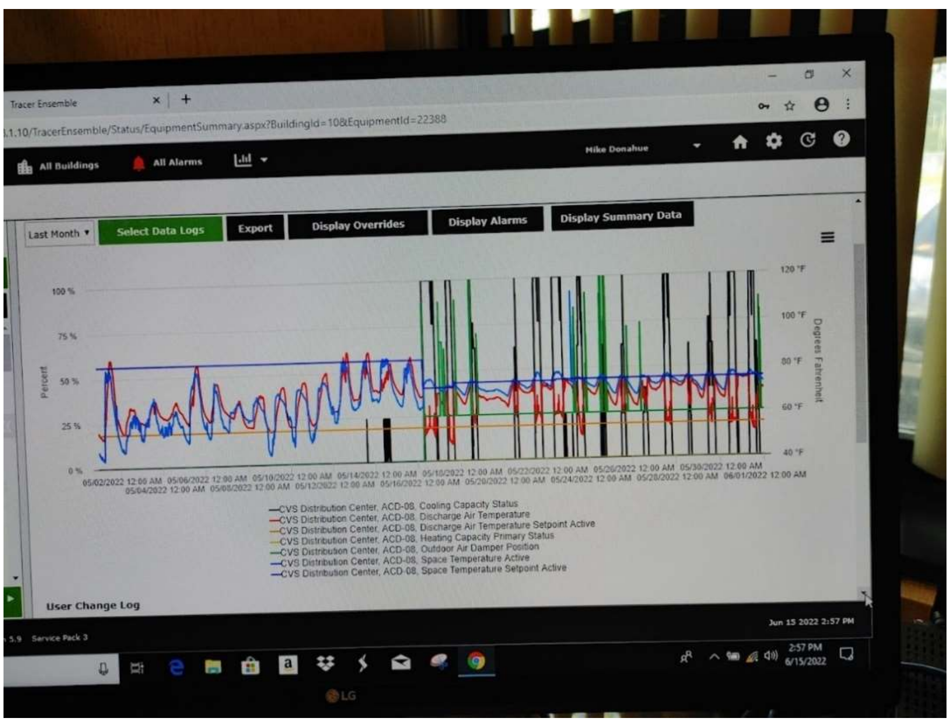


Figure 2-6 EMS display screen



As shown in the above figures, the EMS was found to be installed onsite. This site was evaluated as a non-operations adjustment owing to the significant differences in the operation of the system due to the COVID-19 pandemic. A summary of the site visit findings is listed below:

5.7.3.1 Summary of Site Visit Findings

The evaluators made the following observations on site:

- The evaluators verified the installation of the new EMS.

- The evaluators confirmed that the HVAC units claimed to be wired to the EMS were indeed wired to the building EMS.

Table 5- shows the summary of the verification methods used to verify the installation of the project and the corresponding evaluation findings:

Table 5-5. Measure verification

Measure Name	Verification Method	Verification Result
Replacing existing building EMS	Verify the installation of the EMS onsite	EMS was found to be installed.
Replacing existing building EMS	Verify that the HVAC units claimed in the application were linked to the new EMS	The units were found to be linked to the EMS.

5.7.4 Evaluation Methods and Findings

This section describes the evaluator methods and findings.

5.7.4.1 Evaluation Description of Baseline

The evaluator reviewed the project files, interviewed the site contact to gather information on the baseline for the pre-existing EMS system, which agreed with the tracking baseline. The evaluators determined this measure is a retrofit with a single baseline, and the baseline is the pre-existing condition.

5.7.4.2 Evaluation Calculation Method

Since this project was evaluated as a non-operations adjustment only, and the operating conditions onsite have changed substantially after the COVID-19 pandemic, any comparison with the pre and post install operation would not be accurate. Therefore, the evaluators agree with the applicant savings calculation methodology and give the applicant full credit for the savings that was claimed since the system was found installed and fully operational.

5.8 Final Results

The evalautors verified the installation of the project and confirmed that the system is operational. Since this site was evaluated as a non-operations adjustment only, all non-operational parameters such as measure installation and measure operation were verified and confirmed and were found to be in agreement with the tracking documentation. Additionally, since there were no non-operational adjustments involved, the evaluators give full credit to the applicant for the savings claimed. .

5.8.1 Explanation of Differences

The evaluators found no differences between the pre-and post case non-operational parameters for this measure, i.e. the measure was found to be installed, operational and all HVAC units were integrated into the system. Since, no further operational adjustments were made, there was no difference between the tracking and evaluated savings..

5.8.2 Lifetime Savings

The evaluators classified this measure as retrofit with a single baseline.

Table 5-11 provides a summary of key factors that influence lifetime savings.

Table 5-1. Measure 1465813 - Lifetime Savings Summary

Factor	Tracking	Application	Evaluator
Lifetime savings	1,211,910 kWh	1,211,910 kWh	1,211,910 kWh
First year savings	121,191 kWh	121,191 kWh	121,191kWh
Measure lifetime	10 years	10 years (project BCR)	10 years (RI TRM)
Baseline classification	Retrofit	Retrofit	Retrofit

5.8.2.1 Ancillary impacts

There are no ancillary impacts.

RICE20N036

Report Date: 7/15/2022

Program	Custom Electric	
Application ID(s)	1722075	
Project Type	C&I Initial Purchase & End of Useful Life	
Program Year	2020	
Evaluation Firm	DNV	
Evaluation Engineer	Shravan Iyer	
Senior Engineer	Joseph St.John	

1 Evaluated Site Summary and Results

This site is a roughly 3 million ft^2 (70 acres) plastic fabrication facility that manufactures PET and polypropylene films for various end-use applications. The facility uses various methods of casting to manufacture the films. Additionally, the facility manufactures food packaging material. The facility's production schedules are: The first shift begins at 8 a.m and ends at 8 p.m. The second shift begins at 8 p.m. and ends at 8 a.m. The facility runs 24/7 for 365 days per year. The facility has a heavy compressed air load and uses compressed air for controlling pneumatic actuators, cleaning debris from grinder bearings, baghouse cleaning and for powering pneumatic rolls, tools, valves and solenoids. The project installed at this site consists of a single energy efficiency measure (EEM) which is described as follows:

EEM-1: Fixing air leaks in the compressed air system- A total of (133) air leaks were identified during the compressed air-leak audit that was performed at the site, and the identified leaks were tagged and fixed, reducing the leak load from 2,821 cfm to 2,607 cfm thereby saving 214 cfm.

The energy savings for this measure come from the compressor's reduced energy use due to the reduced leak load. Air leaks in a compressed air system result in the compressor drawing more power to maintain the required pressure and cfm levels to compensate for the losses that occur due to leaks. The measure was categorized as a retrofit measure.

The evaluators performed a full M&V evaluation with a site visit and metering deployment, because the site's operations were typical during the evaluation period. Additionally, the evaluators found that the facility did not have any COVID-19 related impacts and never shut down during the pandemic. The evaluation found the measure savings to be 290,465 kWh annually, which is lower than the tracking savings listed in the applicant documentation. The evaluation results are presented in Table below.

Table 5-1. Evaluation results summary

PA Application ID	Measure Name		Annual Electric Energy (kWh)	% of Energy Savings On-Peak	Summer On-Peak Demand (kW)	Winter On-Peak Demand (kW)
1722075	Fixing Compressed Air Leaks	Tracked	360,240	48%	42.80	42.80
		Evaluated - ops	290,465	48%	33.16	33.16
		Realization Rate	81%	100%	77%	77%
Totals		**Tracked**	**360,240**	**48%**	**42.80**	**42.80**
		Evaluated - ops	**290,465**	**48%**	**33.16**	**33.16**
		Realization Rate	**81%**	**100%**	**77%**	**77%**

1.1 Explanation of Deviations from Tracking

The evaluated savings are lower than the applicant-reported savings primarily due to the higher compressor efficiency in the post case. Further details regarding deviations from the tracked savings are presented in Section 3-1.

1.2 Recommendations for Program Designers & Implementers

For the purposes of accurately quantifying impacts resulting from compressed air leak repair projects funded by utility rebate programs, it is recommended for consideration that the program develop reasonable estimates for the following key parameters:

- Rate at which new compressed air leaks develop on an annual basis, possibly expressed as a percentage of total compressed air capacity, but ideally with some sort of curve, possibly exponential. From this, a "median time until repaired leaks are nullified by new leaks" value can be determined.

For additional context, similar to the work DNV is doing for steam traps, which is a similar operation and maintenance measure, the lifetime savings associated with a program intervention like this requires knowledge of the baseline and post-case test/repair frequencies, as well as the rate at which new "failures" occur. Without incorporating some knowledge or estimate of the baseline and post-case repair frequencies, the program is implicitly assuming that the customer would perpetually forego testing and repairing without the program, which ends up overestimating lifetime impacts for steam traps. DNV is not sure if that's also true for compressed air leak repairs. Carried out to the (il)logical conclusion, this idea of implicitly assuming the customer would do nothing themselves, would mean that without the program, customers would allow their systems to reach 100% failed traps, or 100% of their compressed air CFM load going towards leaks. A NTG factor can partially address this issue, but a more direct way is to collect data on the baseline, post-case repair rates, as well as have an understanding of the rate at which new leaks develop.

- Non-program test and repair frequency

- With-program test and repair frequency

With the estimates for the above key parameters, an adjusted measure life can be developed for compressed air leak repair projects which take into account both with-program and without-program air leak test and repair frequencies.

The evaluators also recommend for consideration that the program be designed to encourage optimal test and repair frequencies for compressed air leaks that balance both energy costs and maintenance costs.

1.3 Customer Alert

There were no customer alerts.

2 Evaluated Measures

The measures installed at this site include:

EEM-1: Fixing air leaks in the compressed air system- The project consisted of fixing compressed air leaks throughout the facility to reduce the energy use of the facility's compressed air system.

2.1 Application Information and Applicant Savings Methodology

The facility conducted a compressed air leak audit to identify air leaks in the compressed air system throughout the facility. A total of (133) air leaks were tagged and fixed, reducing the leak load from 2,821 cfm to 2,607 cfm. The applicant savings calculation used a custom spreadsheet-based tool where pre-case and post-case cfm values were plugged into the savings calculator, and the calculator generated the demand, energy, and peak savings for the project based on the user-provided inputs.

2.2 Applicant Description of Baseline

The applicant categorized this measure as a retrofit measure. As stated in the above section, the facility operates three shifts per day. The applicant documentation describes the facility's compressed air system as consisting of: (3) 150HP two-stage rotary screw, water cooled compressors that serve as the trim compressors. The compressors are staged using an automated sequencing controller that sequences the compressors based on compressed air loads and (2) 350HP water cooled compressors that serve as the baseloaded compressors. The 350 HP compressors run all the time and do not have any sequencing controls. The air from the compressors runs through two 1,400 cfm and one 1,800 cfm dessicant air dryer to remove the moisture content in the air before feeding the plant. The tracking documentation claims the compressors run 8,400 hours per year.

Table 5-22 shows the key inputs used in the applicant savings calculation methodology:

Table 5-24. Applicant baseline key parameters

		BASELINE	
Measure	Parameter	Value(s)	Source of Parameter Value
Fixing Compressed Air Leaks	Compressor System Efficiency	4.99 cfm/kW	Applicant Documentation
Fixing Compressed Air Leaks	Hours of Operation	8,400 Hours	Applicant Documentation
Fixing Compressed Air Leaks	Number of Leaks Fixed	133	Applicant Documentation
Fixing Compressed Air Leaks	Air Leak Load	2,821 cfm	Applicant Documentation

2.2.1 Applicant Description of Installed Equipment and Operation

The facility proposed to fix the compressed air leaks that were observed throughout the facility and identified using an ultrasonic detector. The facility was able to identify and tag (133) air leaks which were fixed. This reduced the average cfm demand from 2,821 cfm prior to fixing the air leaks to 2,607 cfm after fixing the air leaks. Since nothing else changed in their process besides this leak reduction project, the reduction in CFM demand was attributed to fixing the leaks. Table 5-23 lists the key inputs in the installed case:

Table 5-25. Applicant proposed key parameters

		PROPOSED		
Measure	**Parameter**	**Value(s)**	**Source of Parameter Value**	**Note**
Fixing Compressed Air Leaks	Compressor System Efficiency	4.99 cfm/kW	Applicant Documentation	
Fixing Compressed Air Leaks	Hours of Operation	8,400 Hours	Applicant Documentation	
Fixing Compressed Air Leaks	Number of Leaks Fixed	133	Applicant Documentation	
Fixing Compressed Air Leaks	Air Leak Load	2,607 cfm	Applicant Documentation	
Fixing Compressed Air Leaks	Air Leak load reduction	214 cfm	Applicant Documentation	

2.2.2 Applicant Energy Savings Algorithm

The applicant used a custom spreadsheet-based savings calculator to estimate savings for this project. The pre and post-repair cfm values (determined in the leak survey) were used as inputs in the calculator tool to estimate the savings as shown in the formula below:

$$kWh\ Save = \frac{(cfm_{pre} - cfm_{post})}{Eff} \times hr$$

where,

$kWh\ Save$ = *electric energy savings, in kWh/yr*
cfm_{pre} = *pre-project air leak flow, 2,821 cfm*
cfm_{post} = *post-project air leak flow, 2,607 cfm*
Eff = *compressed air system efficiency, 4.99 cfm/kW*
hr = *annual operating hours, 8,400 hr/yr*

The applicant calculated tracking savings for this project as 360,240 kWh, and the summer and winter seasonal demand as 42.80[6] kW.

[6] Winter peak duration: December and January between 5 p.m. and 7 p.m. Monday to Friday
Summer peak duration: June, July, and August between 1 p.m. and 5 p.m. Monday to Friday

From the above savings calculation, the evaluators determined that the variables that have the greatest

impact on the savings are the operational hours of the compressors, compressor efficiency and the air leak reduction amount.

2.2.3 Evaluation Assessment of Applicant Methodology

The evaluators determined that the applicant's analysis methodology was reasonable. The evaluators agree with the methodology used to calculate the savings, by estimating the pre and post case cfm to determine the leak load. The pre and post-repair cfm values were used as inputs in the custom savings calculator spreadsheet. However, the applicant's overall methodology is simplified and does not account for the effects of efficiency changes on the compressed air system as the load changes. The evaluators used an updated methodology that incorporates the performance data on each compressor in calculating the compressors' input kW.

2.3 Site Inspection

The evaluators conducted a site visit on 5/17/2022 to verify the compressed air leaks fixed as part of the project and install ElitePRO power loggers to collect data (voltage, amperage, and power factor) on the compressors in the facility. The evaluators had an initial discussion with the maintenance technician (who was the site contact) and learned that the facility runs the two 350HP compressors as the baseloaded compressors, and the three 150HP compressors serve as the trim compressors to meet load requirements of the facility. The 150 HP compressors are sequenced automatically depending on the compressed air loads.

The evaluators inspected the facility's compressed air system in the central compressed air plant. The compressed air system in the facility consists of:

- Three 150HP two-stage rotary screw, water cooled compressors with a rated capacity of 654 acfm. These compressors are the trim compressors and are automatically sequenced based on the load.
- Two 350HP water cooled compressors with a rated capacity of 1,555 acfm. They are the baseloaded compressors that run all the time and primarily serve the facility's compressed air requirement.
- Two dessicant externally heated retentive air dryers with a rated capacity of 1,400 scfm each.
- One dessicant heated blower retentive air dryer with a rated capacity of 1,800 scfm.
- The system also consists of one 200 Gallon receiver tank that is located at the lower level of the production building and two 1,060 Gallon receiver tanks in the compressor room.

The compressed air system operates at 90 psig which is the pressure required in the production area. The site contact informed the evaluators that the compressors operate for 24/7, 365 days per year since there is no downtime for the facility's production throughout the year. The compressors are water cooled by design and use water from the cooling tower to cool the compressors by drawing ambient outdoor air and use a plate and frame heat exchanger system to cool the individual compressors. The facility's compressed air system inventory is described further in the following Table 2-3 below:

Table 2-3. Compressed air system inventory

Index Number	Compressor ID	Compressor HP	Control type	Sequencing Present (Yes/No?)
1	#1	150 HP	Load/No Load	Yes
2	#2	150 HP	Load/No Load	Yes
3	#3	150 HP	Load/No Load	Yes
4	#4	350 HP	Load/No Load	No
5	#5	350 HP	Load/No Load	No

While inspecting the compressed air system, the evalautors were informed that one 350 HP compressor was down temporarily at the time because motor that had burned out was in the process of being replaced. The evalautors were also told that the operating profiles of both 350HP compressors would be identical and that they would be used all the time since they were used as the baseload compressors to meet production needs.

After inspecting the compressed air system, the evaluators verified a sample of 10 compressed air leaks that were fixed as part of the project as claimed in the applicant documentation using an ultrasonic leak detector to determine if the leaks claimed in the project were fixed. The evaluators inspected the compressed air leaks in two different buildings, i.e. the Utilities building and the Boiler building. The leaks inspected by the evaluators are listed in Table 5- below:

Table 5-4. Sample Compressed air leaks inspected using Ultrasonic Leak Detector

Index Number	Leak Tag Number	Location	Size Classification	Evaluation Finding (Leaking/Not-Leaking)
1	P211	Utilities Building- Behind Air dryer 1	S	Not Leaking
2	P212	Utilities Building- Air dryer 3	S	Not Leaking
3	P213	Utilities Building- Air dryer 2	ML	Leaking
4	P214	Utilities Building Air- dryer 2	ML	Leaking
5	P215	Utilities Building- Diamond Tank	LL	Not Leaking
6	P216	Utilities Building- Deck 1	LL	Not Leaking
7	P219	Boiler Building- Boiler 3	ML	Not Leaking
8	P220	Boiler Building- RO 2	ML	Not Leaking
9	P221	Boiler Building- R Block	LL	Leaking
10	P222	Boiler Building- Filtration System	LL	Not Leaking

During the site visit, the evaluators observed that of the ten leaks that were inspected, three were found to be leaking. For context, the project was installed around December 2020, and the site visit was conducted in May 2022. The evaluators confirmed this using the ultrasonic leak detector. On enquiring with the site contact, the evaluators learned that the site has a comprehensive preventive maintenance program that includes conducting annual compresed air leak audits, typically once per year.

The evaluators also took photos of the compressors, the nameplates on each compressor, and the respective display screens. The evaluators then installed ElitePRO power loggers in the disconnects of the 150HP compressors and the 350HP compressors. The loggers monitored kW data from 5/17/2022 to 6/24/2022 at 5-minute intervals by logging voltage, amperage, and power factor. The evaluators verified with the site contact that the metering period captured typical operations.

2.3.1 Summary of Site Visit Findings

The evaluators made the following observations on site:

- Based on conversations with the facility maintenance technician, the evaluators confirmed that the compressed air leak repair project was completed in December 2020 as claimed in the applicant documentation.

- The evaluators confirmed the presence of (5) air compressors, i.e. (3) 150 HP and (2) 350HP two-stage screw compressors as listed in the applicant documentation. The evaluators verified the compressor nameplate data and collected the compressors' make and model numbers and other related information. The production area requires an operating pressure of 90 psig.

- The 150HP compressors serve as the trim compressors and the 350HP compressors serve as the baseloaded compressors.

Table 5- shows the summary of the verification methods used to verify the installation of the project and the corresponding evaluation findings:

Table 5-5. Measure verification

Measure Name	Verification Method	Verification Result
Fixing Compressed Air Leaks	Verify the nameplate of the compressors matches the project description via. physical inspection	The nameplate of the compressor matched the project description.
Fixing Compressed Air Leaks	Verify the compressed air leaks that were fixed as part of the project using an ultrasonic leak detector	Seven compressed air leaks were found to be fixed upon inspection of a sample of ten leaks using the ultrasonic leak detector
Fixing Compressed Air Leaks	Interview site contact for typical compressed air operating hours	The compressed air system operates 24/7, The 150HP compressors are staged automatically and the 350HP units run all the time.

2.4 Evaluation Methods and Findings

This section describes the evaluator methods and findings.

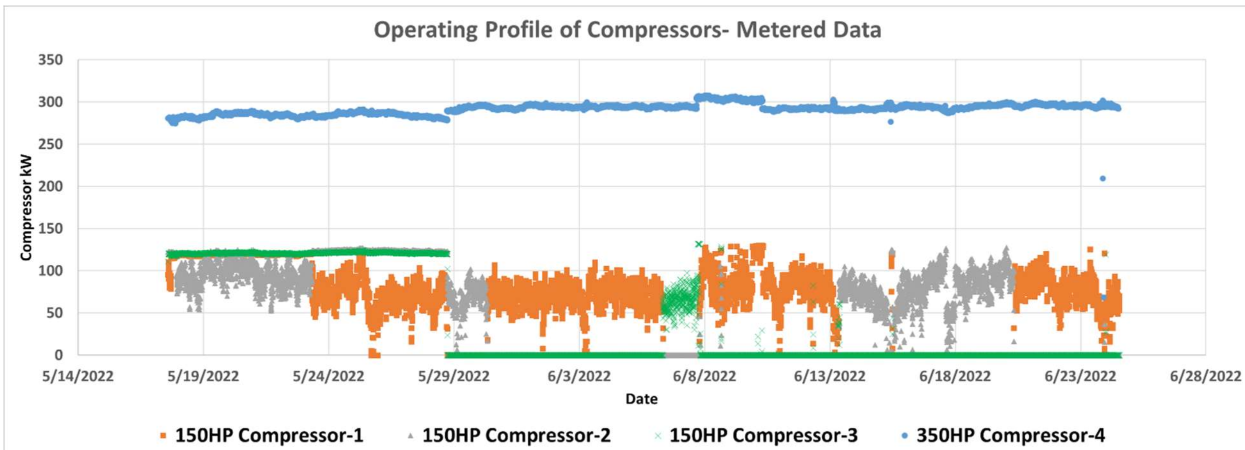
2.4.1 Evaluation Description of Baseline

The evaluator reviewed the project files, interviewed the site contact to gather information on the baseline for the compressed air leak measure, which agreed with the tracking baseline. The evaluators determined this measure is a retrofit with a single baseline, and the baseline is the pre-existing condition.

2.4.2 Evaluation Calculation Method

The evaluators used metered data obtained from the ElitePRO power loggers to understand the operating profile of the 150HP and 350HP compressors. The loggers were installed between May 16th and June 24th 2022, for six weeks. During this period, the operating profile was observed to be typical, as shown in Figure 5-1 below:

Figure 5-1. Metered compressor power for 150 and 350HP compressors



From Figure 5-1, the evaluators noted that the compressed air loads of the facility are primarily being met by the 350HP compressor that exhibits the largest kW draw among the compressors and is the primary baseloaded compressor at the facility and operates at a nearly constant load throughout the metering period. The other three 150HP compressors serve as trim compressors due to variation in the compressed air loads and are automatically sequenced by the compressor sequencing control system. The evaluators modeled the operating profile of each compressor individually over the metering period to understand the average hourly kW draw and the individual compressor's operating profile over the metering period. The following heat maps show the operating profiles of all metered compressors where the average hourly kW draw was modeled over a typical week during the metering period as shown in and below:

Figure 5-2. Average hourly kW draw of 150 HP compressor #1 (from metered data)

Typical Operating Profile of 150HP Compressor #1							
Hour/Day	Sun	Mon	Tue	Wed	Thu	Fri	Sat
0	59	58	51	77	70	73	63
1	55	51	45	73	65	69	60
2	55	49	45	74	64	73	69
3	58	49	48	71	71	75	69
4	55	38	43	71	70	68	65
5	50	42	42	76	70	65	65
6	57	48	51	79	76	66	70
7	53	43	43	73	70	58	67
8	50	47	43	78	64	67	70
9	58	50	52	79	74	76	73
10	54	40	45	73	77	69	66
11	52	38	48	76	74	72	72
12	59	46	55	83	79	77	80
13	52	45	50	59	70	74	73
14	56	50	54	65	76	78	75
15	57	54	63	74	77	80	78
16	51	49	56	65	68	75	73
17	46	46	58	61	66	67	69
18	51	51	63	67	67	70	59
19	48	41	63	60	61	62	55
20	51	44	73	66	57	66	56
21	56	49	78	68	64	67	60
22	54	46	76	66	66	64	54
23	54	45	71	66	66	61	55

Figure 5-3. Average hourly kW draw of 150 HP compressor #2 (from metered data)

Typical Operating Profile of 150HP Compressor #2							
Hour/Day	Sun	Mon	Tue	Wed	Thu	Fri	Sat
0	49	59	40	47	50	55	62
1	45	53	40	47	51	54	63
2	33	54	39	45	49	54	60
3	40	59	39	46	54	54	63
4	35	51	39	45	51	55	59
5	32	50	38	47	51	55	56
6	39	50	40	43	51	56	56
7	43	48	41	42	45	53	60
8	46	33	40	35	50	55	59
9	50	36	41	37	51	58	57
10	53	40	40	34	51	56	54
11	45	39	39	38	48	54	56
12	52	41	38	53	52	56	60
13	51	42	41	39	54	58	62
14	55	43	41	39	53	66	61
15	56	39	53	41	47	63	67
16	54	41	52	49	43	50	64
17	50	42	53	42	50	55	57
18	48	42	54	47	52	49	51
19	48	41	50	42	46	49	50
20	49	42	50	42	51	55	52
21	54	41	51	49	54	56	55
22	53	41	50	48	54	57	49
23	56	38	45	42	52	57	46

Figure 5-4. Average hourly kW draw of 150 HP compressor #3 (from metered data)

Typical Operating Profile of 150HP Compressor #3							
Hour/Day	Sun	Mon	Tue	Wed	Thu	Fri	Sat
0	24	24	38	40	40	43	49
1	24	24	40	40	40	40	49
2	24	24	35	40	40	40	48
3	24	24	37	40	40	41	48
4	24	24	39	41	40	40	48
5	24	24	38	41	40	40	48
6	24	24	38	41	40	40	48
7	24	24	38	41	40	41	48
8	27	33	38	41	40	40	48
9	24	41	37	41	40	40	48
10	24	36	38	40	41	40	48
11	24	34	37	40	40	40	48
12	24	36	39	42	40	40	48
13	24	37	38	40	41	42	48
14	24	35	39	40	40	48	48
15	24	37	52	40	40	48	48
16	24	36	51	51	40	48	48
17	24	38	55	40	40	48	48
18	24	37	57	40	40	48	32
19	24	36	60	40	40	48	24
20	24	37	41	40	40	48	24
21	24	36	40	40	40	48	24
22	24	38	40	40	40	49	24
23	24	37	40	40	40	49	24

Figure 5-5. Average hourly kW draw of 350 HP compressor #4 (from metered data)

Typical Operating Profile of 350HP Compressor #4							
Hour/Day	Sun	Mon	Tue	Wed	Thu	Fri	Sat
0	292	293	292	294	293	293	290
1	292	293	293	294	294	293	290
2	292	293	292	294	294	293	290
3	292	294	293	294	294	293	290
4	291	293	293	294	294	293	289
5	292	293	293	294	294	293	289
6	293	293	293	295	294	293	290
7	292	293	293	295	293	292	290
8	293	292	293	294	293	291	290
9	293	292	293	294	294	291	290
10	293	292	292	293	294	291	289
11	292	291	292	293	294	290	289
12	292	291	292	293	294	290	289
13	292	291	292	293	293	290	289
14	292	291	292	292	293	289	289
15	292	291	290	292	293	289	289
16	291	290	292	292	293	289	288
17	291	290	292	293	292	288	289
18	291	291	292	292	293	288	291
19	292	291	292	293	293	289	291
20	292	291	293	293	293	289	291
21	293	292	293	293	292	289	292
22	293	292	294	293	290	290	291
23	293	292	293	293	292	290	291

The above heat maps help understand the operating profiles of the four compressors. From Figure 5-2 to Figure 5-4 we observe that the three 150HP compressors are sequenced such that their operating profile is nearly-evenly distributed to meet the compressed air loads of the facility and they serve as trim compressors. The primary base loaded compressor is the 350HP unit that has a much higher kW draw compared to the other three compressors as we can observe from Figure 2-5. It is also worth noting that though the evaluators could not meter the fifth 350HP compressor due to the fact that the motor burned out and was in the process of being replaced, the evaluators have reason to believe that the operation of the compressor would be identical to that of the 350HP compressor that was metered, since both compressors run simultaneously all the time. Therefore, in summation, the 150HP compressors supplement the operation of the 350HP compressors in the facility's compressed air system and the above data and the corresponding observations made by the evaluators corroborate the information provided by the facility maintenance technician during the initial conversations the evaluators had onsite.

Based on the data shown in the above heat maps, the evaluators modelled the savings using an 8760-analysis profile. The metered kW data was aggregated into 168-hour weekly profiles as shown in the above heat maps, averaged by the hour of the day and day of week to represent the typical kW demand of the air compressor. This data was extrapolated to a year (using an 8,760 hourly spreadsheet) to model the as-built annual kWh consumption of the compressors. The installed compressor kW was modeled using metered data obtained from the loggers installed by the evaluators, which was converted to cfm using compressor performance data from CAGI sheets and factored in the motor efficiency for the compressors[7]. The evaluators calculated baseline kW using baseline air demand using the compressor performance data. The base case compressor staging strategy was modeled identically to the post case strategy. It was assumed that the entire 214 CFM was added back into only the trim compressors when calculating the addition kWh in the base case.

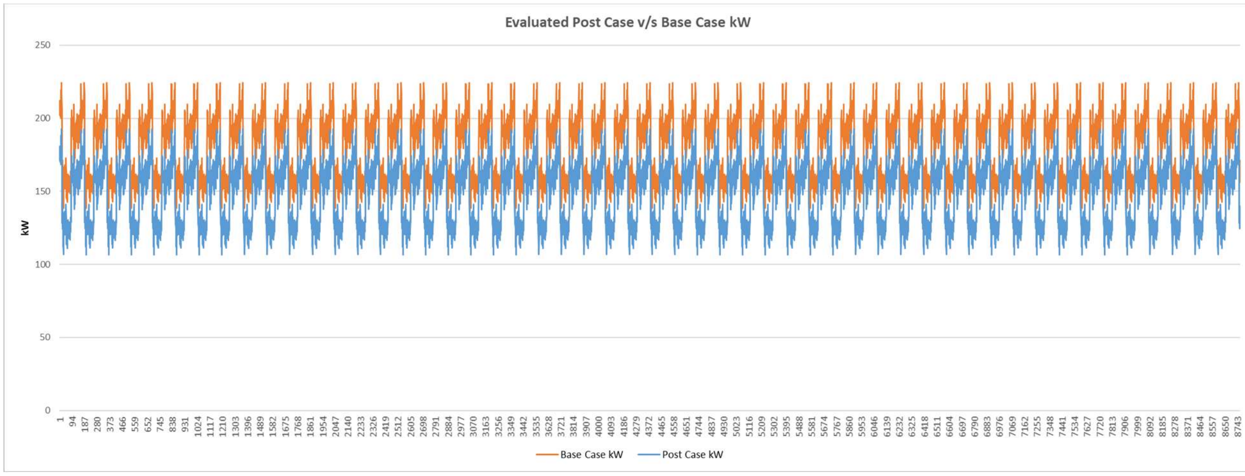
For the actual leakage repair, the evaluators found three of the ten compressed air leaks to be leaking about a year to two years after the measure was installed. This measure has a 2 year assumed measure life, so the evaluators believe that it is not unreasonable to find 30% of the leaks fixed to be leaking air again. A measure like this with multiple smaller actions with a two year life would assume that on average 50% of the leaks would return after two years, or 25% after 1 year. Since the level of measure degradation was below what would be expected no adjustments to the leakage rate reduction were made.

The evaluators recommend for consideration, additional research into the persistence of compressed air leak repair projects. Since the applicant performed measurement and verification at the time of the project and it resulted in a 214 cfm reduction, any additional M&V performed a year after the initial M&V would be informative to the persistence and longevity of the measure but not the first year savings.

The annual energy savings was the difference between the modeled base case and the post case kWh consumption. The Figure 2-6 below shows the evaluated base and post case kW:

[7] https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-431

Figure 5-6. Evaluated Post Case v/s Base case kW



The measure resulted in total evaluated energy savings of 290,465 kWh/yr and evaluated demand savings of 33.16 kW.

3 Final Results

Table 5-9 summarizes the key parameters that were used in the estimation of savings and compares them with the tracking and post case:

Table 5-26. Summary of Key Parameters

Parameter	BASELINE		PROPOSED / INSTALLED	
	Tracking Value(s)	Evaluation Value(s)	Tracking Value(s)	Evaluation Value(s)
Compressor #1 HP	150	150	150	150
Compressor #2 HP	150	150	150	150
Compressor #3 HP	150	150	150	150
Compressor #4 HP	350	350	350	350
Compressor #5 HP	350	350	350	350
Leak Amount (cfm)	214	150	214	150
Operating Hours Per Year	8,400	8,400	8,760	8,760
Compressor Efficiencies (cfm/kW)	4.99	6.67	4.99	6.67
Post Case cfm	2,607	908	2,607	908

3.1 Explanation of Differences

The evaluation savings are 290,465kWh/yr which are lower than the tracking savings. The decrease in savings is primarily due to the higher compressor efficiency in the post case compared to the applicant estimate. Table 5-10 provides a summary of the differences between tracking and evaluated values.

Table 5-27. Summary of Deviations

Measure	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
1722075	Operations	Efficiency	-19%	**Decreased savings –** The efficiency of the compressed air system was found to be higher in the post case since it factored in the changes in compressed air loads
Final RR				**81%**

3.2 Lifetime Savings

The evaluators classified this measure as retrofit with a single baseline.

Table 5-11 provides a summary of key factors that influence lifetime savings.

Table 5-28. Measure 1722075 - Lifetime Savings Summary

Factor	Tracking	Application	Evaluator
Lifetime savings	720,480kWh	720,480 kWh	580,930 kWh
First year savings	360,240 kWh	360,240 kWh	290,465 kWh
Measure lifetime	2 years	2 years (project BCR)	2 years (RI TRM)
Baseline classification	Retrofit	Retrofit	Retrofit

(*) The tracking lifetime savings value is net of all program adjustment factors

3.2.1 Ancillary impacts

There are no ancillary impacts such as HVAC interactive effects.

RICE20N047

Report Date: 7/29/21

Application ID(s)	047 10356221	
Project Type	C&I Initial Purchase & End of Useful Life	
Program Year	2020	
Evaluation Firm	DNV	
Evaluation Approach	Full M&V	
Evaluation Engineer	Joe St. John	
Senior Engineer	Max MA	

5.9 Evaluated Site Summary and Results

This project was installed at a jewelry manufacturing facility. It consists of installing (2) 150 VSD air compressors equipped with integrated cycling-refrigerated air dryers as a replacement-on-failure of a 150 HP variable displacent compressor, a non-working 125 HP variable speed compressor, and a 50 HP modulating air compressor, along with installing (4) 500 gallon air storage receivers. The 125 HP variable speed compressor needed regular repair. According to the site contact, in the 2-3 years prior to this project being completed, the 125 HP VFD compressor would regularly have maintenance issues, like the motor overheating, so the regular need for repair, and the equipment's eventual failure which led to the facility using the back-up, less efficient, variable displacement compressor as the primary compressor was a main driver for this project. The installed system also includes upgrading the main compressed air distribution header from 2" to 3" to accommodate increased loads, and reduce pressure drop from the compressor room to the end-uses. The addition of the receivers, and the increased size is referenced as a reason for decreasing the operating pressure of the system from 125 to 115 psi. The evaluators consider all of the measures installed replace on failue measures, with a non-regressive baseline, in accordance with the Massachusetts baseline framework document[8] which was thought to apply in Rhode Island by the evaluators. The tracking calculations indicate that the baseline consisted of a cycling refrigerated air dryer, and that there were (4) electronic, timer-based, solenoid drains which were replaced with zero-loss condensate drains. The tracking calculations chose for a baseline an industry standard practice baseline for new construction, which includes a load/no-load compressor with 1 gallon/cfm of storage. This baseline used in the tracking calculations did not conform to guidance of incorporating a non-regressive baseline for replace on failure measures, outlined in the Massachusetts baseline framework document.

There was no COVID impact on the facility for the operation of the measure. For this reason, a full M&V approach was used to analyze the data collected from this site during a previous evaluation monitoring, which occurred during the COVID pandemic.

The evaluation results are presented in Table below.

Table 5-29. Evaluation Results Summary

PA Application ID	Measure Name		Annual Electric Energy (kWh)	% of Energy Savings On-Peak	Summer On-Peak Demand (kW)	Winter On-Peak Demand (kW)
047 10356221	New VFD compressors with integrated cycling refrigerated air dryer, reducing pressure from 125 to 110 psi, and installation of (4) zero loss	Tracked	253,411	44.0%	25.60	22.90
		Evaluated - ops	52,090	53.5%	7.00	6.46
		Realization Rate	20.6%	121.7%	27.3%	28.2%

[8] https://ma-eeac.org/wp-content/uploads/MA-Commercial-and-Industrial-Baseline-Framework-1.pdf

	condensate drains					

5.9.1 Explanation of Deviations from Tracking

The evaluated savings are lower than the applicant-reported savings because the applicant savings assumed a less efficient baseline system, i.e. load/no-load with 1 gallons/cfm of receiver storage, whereas the evaluators used a more efficient baseline system, a VFD system at 125 psi, based on the the guidance from from the Massachusetts baseline framework document[9], which states that for replace on failure measures, the baseline efficiency selected should be no less efficient that the baseline efficiency found on site, even if the industry standard practice is less efficient than what is found on site. Because the original design of the system was VFD control, and that system was in place and operating in the 2-3 years prior to when this project was installed, a VFD system was selected by the evluators for the baseline system. The Massachusetts baseline framework document allows for several exceptios to this guidance, such as if the original equipment was incentivized by the efficiency program, but none of the exceptions were found to be applicable for this project.

Further details regarding deviations from the tracked savings are presented in Section 3.1.

5.9.2 Recommendations for Program Designers & Implementers

The evaluators recommends that program designers and implementers become familiar with the approach that evaluators will use to evaluate replace on failure projects in cases like this, where the industry standard practice baseline has a lower efficiency than the in-situ baseline.   From the MA Baseline Framework Document, the following text can be found:

Non-regressive. For site-specific evaluation of ROF measures, a regressive baseline generally is not allowed, that is, the installed measure’s baseline should be at least as efficient as the efficiency of the system it replaces, even if ISP indicates a lower baseline. There are three specific allowable exceptions: (1) If restaurant cooking equipment is replaced as part of gut rehabilitation, the preexisting equipment efficiency need not be considered the minimum standard. (2) If a variable frequency drive (VFD) replaces a failed VFD but the prior drive is documented to have failed more than two years prior to replacement and the system is documented not to have been controlled via speed modulation during this time, then the non-VFD baseline is allowable. (3) The preexisting condition was program-funded. Other exceptions may be allowed, with a high threshold required to demonstrate plausibility.

5.9.3 Customer Alert

There were no customer alerts.

[9] https://ma-eeac.org/wp-content/uploads/MA-Commercial-and-Industrial-Baseline-Framework-1.pdf

5.10 Evaluated Measures

The following sections present the evaluation procedure, including the findings from an in-depth review of the supplied applicant calculations and the evaluation methodology determined to be the best fit for the site and the information available.

The project consisted of: New VFD compressors with integrated cycling refrigerated air dryer, reducing pressure from 125 to 110 psi, and installation of (4) zero loss condensate drains.

5.10.1 Application Information and Applicant Savings Methodology

This section describes the applicant's application information, savings methodology, and the evaluation assessment of the savings calculation algorithm used by the applicant.

5.10.2 Applicant Description of Baseline and Proposed Key Parameters

The measure was classified as a replace on failure (ROF) measure, where ISP was selected for the baseline compressor type and control type. The dryer savings were not incorporated into the applicant savings correctly, apparently due to an error. Even though a non-integrated cycling dryer was replaced an integrated dryer, a change that would result in zero savings, the tracking calculations applied a penalty of -28,449 kWh savings to this portion of the project. The first row of their 40,031 row calculation sheet (which is minute by minute) includes the baseline and post-case compressor, dryer, and drain kW, but the subsequent rows only include the compressor and drain in the baseline, per Table 5-30 and Table 5-31, effectively leaving out the baseline dryer usage, but including the post-case dryer usage.

Key parameters used in the tracking calculations for the compressed air leak repair measure are shown in Table 5-30 and Table 5-31,

Table 5-30. Baseline key parameters

Variable	Compressor	Dryer	Drain	Total
Average input power (kW)	118	0	2.2	120
Annual operating hours	8,400	0	8,400	
Annual energy consumption (kWh)	989,393	0	18,799	1,008,192

Table 5-31. Post key parameters

Variable	Compressor	Dryer	Drain	Total
Average input power (kW)	86	3.4	0	90
Annual operating hours	8,400	8,400	0	
Annual energy consumption (kWh)	726,332	28,449	0	754,781

Table 5-32. Savings

Variable	Compressor	Dryer	Drain	Total
Demand (kW)	31	-3.4	2.2	30
Electric energy (kWh)	263,062	-28,449	18,799	253,411

5.10.2.1 Applicant Energy Savings Algorithm

The savings were estimated using a spreadsheet which relied on compressor, dryer, and drain specification sheets which had information on the kW/CFM values, and applied those kW/CFM relationships to CFM data collected between 11/13/2017 and 12/11/17 (a representative typical manufacturing period), which was then extrapolated to an entire year. The tracking calculations accounted for reducing the operating pressure from 125 to 115 psi. As noted above, the dryer savings were not properly incorporated into the applicant savings, apparently due to an error. The first row of their 40,031 row calculation sheet (which is minute by minute) includes the baseline and post-case compressor, dryer, and drain kW, but the subsequent rows only include the compressor and drain in the baseline, not the dryer, but the dryer and compressor is included in the post-case.

Applicant Savings Approach

$$kWh_{Savings} = \left(kWh_{Base-compressor} + Wh_{Base-drains}\right) - \left(kWh_{Post-compressors} + kWh_{Post-dryers} + kWh_{Post-drains}\right)$$

Correct Savings Approach

$$kWh_{Savings} = \left(kWh_{Base-compressors} + \mathbf{kWh_{Base-dryers}} + kWh_{Base-drains}\right) - \left(kWh_{Post-comp} + kWh_{Post-dryers} + kWh_{Post-drain}\right)$$

The tracking calculations used the following equation to adjust for the fact that in the post-case, the

$$kW_{operatingpressure} = kW_{nominalpressure} \times 0.995^{(Rated\ Pressure\ - Operatin\ \ Pressure)}$$

This is somewhat different than the approach recommended by the Uniform Methods Project for Quantifying Savings for Compresses Air Systems[10], but follows a similar principal.

5.10.2.2 Evaluation Assessment of Applicant Methodology

The evaluator generally agrees with the overall approach used in the tracking energy savings estimation methodology, apart from their omission of carrying the correct calculations through the entire year, rather than just having the first row correct.

[10] https://www.nrel.gov/docs/fy17osti/68577.pdf

5.10.3 Site Visit Findings

An initial site visit occurred on 2/25/21 for a previous project evaluation related to their compressed air system (RICE18N059), which involved compressed air leak repairs. During that site visit, loggers were installed on the two new VFD air compressors to capture input power. A return site visit occurred on 4/22/21 to retrieve the loggers. A follow up site visit to interview the customer about this project in particular (RICE20N047) was conducted on 7/21/22 but a decision was made to use the metering from the previous evaluation because the site contact stated that operation of the compressed air plant had not changed since when the previous metering had been conducted in early 2021.

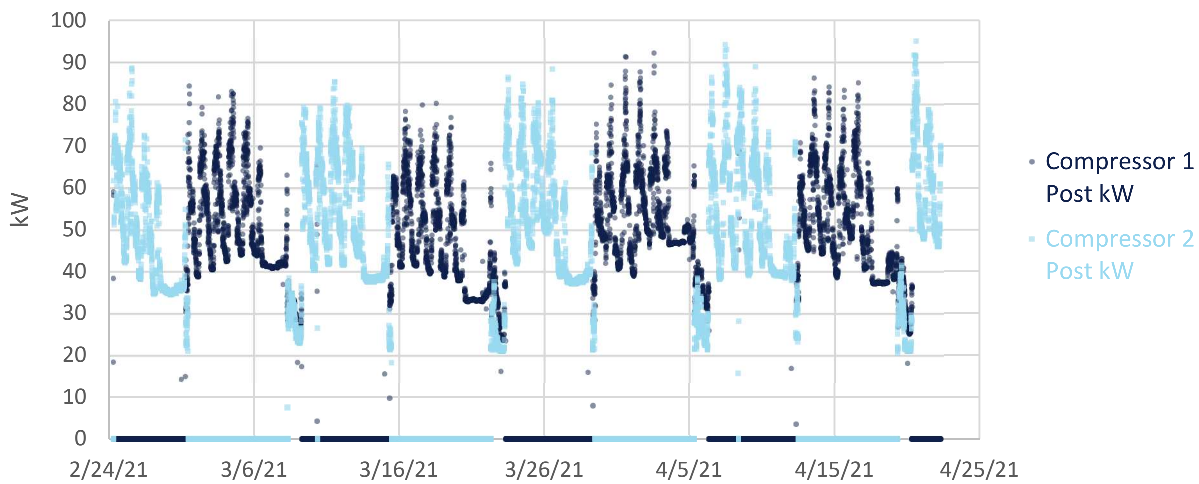
The planned and completed site visit activities for the compressed air project are shown in Table 5-33.

Table 5-33. Site visit task list and results

Task	Result
Visual inspection of compressed air equipment	Two new identical VFD air compressors were added in June of 2020. Both are Atlas Copco, GA110VSD+ FF 147.6 HP units.
Note discharge pressure of all compressors	Discharge pressure was found to be 110 PSI
Install kW power meters to all compressors	Power loggers were installed on both compressors between 2/25/21 and 4/22/21.
Site interview	Interview completed. A key finding from the conversation with the customer is that the existing compressor as designed was that the VFD machine would be the main compressor, with the variable displacement compressor serving as the back-up compressor when the main VFD compressor needed maintenance. In the 2-3 years prior to when this project occurred, the main VFD compressor had to be fixed more and more frequently, eventually leading to the variable displacement compressor serving as the main compressor until this project could get underway, and the original system design of having a VFD compressor provide compressed air to the facility could be restored. This is an important finding, because it means that, in accordance with the MA baseline framework document, a non-regressive baseline should be selected, which in this case is a VFD compressor, and not a load/no-load compressor as used in the applicant calculations. This was the key finding from speaking with the site-contact.

Figure 5-4 shows the post kW collected between 2/25/21 and 4/22/21.

Figure 5-4. Post kW measurements collected between 2/25/21 and 4/22/21



5.10.4 Evaluation Methods and Findings

This section describes the evaluator methods and findings.

5.10.4.1 Evaluation Description of Baseline

The evaluator reviewed the project files and interviewed the site contact to gather information on the baseline. The evaluator classified this measure as a replace on failure with the following baseline equipment:

- (2) 150 HP VFD air compressors operating at 125 psi, because the although the MA Compressed Air ISP document[11] states that a load/no-load machine is the ISP for ROF events, the MA Baseline Framework document[12] states that in most ROF cases, a non-regressive baseline be chosen, meaning that the baseline should be no less efficient then the pre-existing system that the new equipment replaces. Since the old equipment that failed is a VFD system that operated at 125 psi, that is the baseline that the evaluators chose for this project.

- A non-integrated cycling refrigerated air-dryer was selected as the baseline for the the integrated cycling air dyer that was installed as part of this project, since a non-integrated cycling refrigerated air dyer was in fact in the pre-existing. Although the MA Compressed Air ISP baseline document[13] suggests using a non-cycling dryer in the baseline, because this facility had a cycling dryer already in the pre-existing case, a cycling baseline was selected as the baseline for this particular project, again in accordance with the non-regressive baseline principal outlined in the MA Baseline Framework document[14]. The evaluators do not attribute any savings to this measure, since the evaluators view no difference in energy consumption between a non-integrated, and integrated cycling refrigerated air dryer.

[11] https://ma-eeac.org/wp-content/uploads/AirCompressors_ISP_Memo_final.pdf
[12] https://ma-eeac.org/wp-content/uploads/MA-Commercial-and-Industrial-Baseline-Framework-1.pdf
[13] https://ma-eeac.org/wp-content/uploads/AirCompressors_ISP_Memo_final.pdf
[14] https://ma-eeac.org/wp-content/uploads/MA-Commercial-and-Industrial-Baseline-Framework-1.pdf

- (4) electronic solenoid timer drains were selected as the baseline for the (4) zero-loss condensate drains installed as part of this project, since (4) electronic solenoid timer drains were in fact in the baseline.

5.10.4.2 Evaluation Calculation Method

The evaluators used the following formula for calculating energy savings:

$$kWh_{Savings} = kWh_{As-Built} - \left(kWh_{Base-compressors} + kWh_{Base-dryers} + kWh_{Base-drains}\right)$$

Calculation details on each component are described in the following sub-sections.

Apart from the selection of which baseline to use, and the apparent incorrect execution of the correct formulas for the entire year (i.e. including post-case dryer energy use, but not baseline energy use, except for the first row) to the evaluates agree with the methodology used to develop with the tracking estimate.

As-built compressor, dryer, and no-loss condensate drain energy

The as-built compressor and dryer energy was based on the post-project kW data measurements that were made on the (2) 150 HP VFD compressors with integrated refrigerated cycling air dryers between 2/25/21 and 4/22/21. This kW data was normalized to a week, and then extrapolated to a full year, accounting for the (5) holidays indicated by the site contact (assumed to operate like Sundays, which have lower loads).

The as-built no-loss condensate drain energy was set to be zero, since they do not result in any wasted CFM.

Baseline compressor energy

The baseline compressor energy was calculated by converting the as-built compressor and dryer kW data to CFM by first separating out the compressor kW and the dryer kW.

Using the 125 psi CAGI sheet for the as-built VFD compressor the evaluators determined the compressor CFM from the compressor kW. That CFM data was then converted to baseline kW data at 110 psi, where the baseline system consisted of 150 HP VFD compressor, in accordance with the non-regressive ISP baseline. The baseline kW vs. CFM curve for the baseline 110 psi VFD machine used the as-built CAGI sheet, using the following formula from the uniform methods project[15]:

$$kW_{Adjusted} = Full\ Load\ kW_{rated} \times [1 - \left(\left(\frac{P_{rated} - P_{discharge}}{2}\right) \times 0.01\right)]$$

Baseline dryer energy

Since the baseline and post-case dryer were both cycling refrigerated dryers, no savings are attributed by the evaluators for this measure. When the post-case dryer plus compressor kW data was disaggregated, the baseline dryer kW was simply set to equal the post-case dryer kW.

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15 https://www.nrel.gov/docs/fy17osti/68577.pdf

Baseline drain energy

The baseline drain energy was estimated by assuming each baseline drain would be on for 10 seconds for each cycle, and off for 4 minutes per cycle, resulting in 350.4 hours of it being on per year, and then when on, it would use 75 cfm, at 0.1654 kW/cfm, which is the weighted average post-case compressor efficiency. This uses the post-case kW/cfm value so as not to double count savings. The baseline drain energy was estimated to be 17,385 kWh, using the following math:

75 CFM x 0.1654 kW/CFM x 350.4 hours/year x 4 drains = 17,385 kWh.

5.11 Final Results

This section summarizes the evaluation results determined in the analysis above.

Table 5-34 shows the differences in the key parameters used in the tracking analysis and the evaluator analysis. The main driver in the higher savings is the fact that the evaluators used a different baseline compared with the tracking calculations. The tracking calculations assumed a load/no-load baseline with 4 gal/cfm of storage, whereas the evaluator calculations assumed a load/no-load baseline with 1 gal/cfm of storage. This resulted in the tracking calculations having an average baseline compressor efficiency of 0.2473 kW/cfm, while evaluator had an average baseline compressor efficiency of 0.1815 kW/CFM.

Table 5-34. Summary of key parameters used in tracking and evaluator methodology

	BASELINE		PROPOSED / INSTALLED	
Parameter	**Tracking Value(s)**	**Evaluation Value(s)**	**Tracking Value(s)**	**Evaluation Value(s)**
Compressor Average CFM Demand	476	294	476	294
Compressor control	L/NL 1 gal/cfm	VFD at 125 psi	VFD at 115 psi	VFD at 110 psi
Compressor Average kW/CFM	0.2473	0.1797	0.1815	0.1663
Compressor Annual Hours	8,400	8,760	8,400	8,760
Compressor Total kWh	989,393	462,813	726,332	428,266
Compressor Savings			**263,062**	**34,547**
Dryer Average kW	0	3.14	3.39	3.14
Dryer Annual Hours	0	8,760	8,400	8,760

	BASELINE		PROPOSED / INSTALLED	
Parameter	Tracking Value(s)	Evaluation Value(s)	Tracking Value(s)	Evaluation Value(s)
Dryer Total kWh	0	27,525	28,449	27,525
Dryer Savings			**-28,449**	**0**
Drain Average kW	2.24	2.00	0	0
Drain Annual Hours	8,400	8,760	0	8,760
Drain Total kWh	18,799	17,542	0	0
Drain Savings			**18,799**	**17,542**
Compressor, Dryer, Drain Total kWh	1,008,192	507,880	754,781	455,790
Compressor, Dryer, Drain Total Savings			**253,411**	**52,090**

N/A – not applicable

5.11.1 Explanation of Differences

This section describes the key drivers behind the difference in the application and evaluation estimates. Table 3-2 provides a summary of the differences between tracking and evaluated values.

Table 5-35. Summary of Deviations

Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
Efficiency	Compressor Efficeincy Improvement	-82.6%	**Increased savings -** evaluated efficiency improvement is 0.0134 kW/cfm, and tracking efficiency improvement is 0.0658 kW/cfm. The evaluated efficiency improvement is due to the reduction in pressure from 125 psi to 110 psi.
Operations	Average CFM Demand	-39.7%	**Decreased savings -** evaluated cfm demand is 294 cfm, tracking CFM demand is 476 cfm.

Operations	Compressor Operating Hours	-4.3%	**Increased Savings -** evaluated hours are 8,760, tracking hours are 8,400
Methodology	Correctly accounting for dryer savings	47.6%	**Increased Savings -** evaluated savings are 0 kWh, tracking savings are -28,449 kWh
Methodology	Correctly accounting for drain savings	-0.4%	**Increased Savings -** evaluated savings are 17,385 kWh, tracking savings are 18,799 kWh
Final Realization Rate			**20.6%**

5.11.2 Lifetime Savings

This project has a single ISP baseline. The evaluators calculated applicant and evaluated lifetime savings values using the following formula:

$$\mathrm{LAGI} = FYS \times (EUL)]$$

where:

LAGI = lifetime adjusted gross impact (kWh)

FYS = first-year savings (kWh)

EUL = measure life (years)

The evaluated lifetime savings are more than the tracking lifetime savings because the evaluated first-year savings are more than the tracking first-year savings.

Table 5-20 provides a summary of key factors that influence lifetime savings.

Table 5-36. Measure 047 10356221 - Lifetime Savings Summary

Factor	Tracking	Application	Evaluator
Lifetime savings	3,801,165 kWh	3,801,165 kWh	781,342 kWh
First year savings	253,411 kWh	253,411 kWh	52,090 kWh
Measure lifetime	15 years	15 years	15 years
Baseline classification	Replace on Failure	Replace on Failure	Replace on Failure

5.11.2.1 Ancillary impacts

There no further ancillary impacts from this project.

DNV

RICE20N068

Report Date: 7/12/2022

Program Administrator	National Grid	
Application ID(s)	11759508	
Project Type	Non-Ops	
Program Year	2020	
Evaluation Firm	DMI	DMI
Evaluation Engineer	Brian Paonessa	
Senior Engineer	Mickey Bush	

5.12 Evaluated Site Summary and Results

This project consisted of the installation of a new energy management system (EMS) at a 42,000 ft² auto shop to control 6 packaged rooftop units (RTUs), which provide space conditioning and ventilation for the building. The applicant used the Existing Building Energy Management Systems application for this project and identified a number of control strategies for RTUs that will reduce supply fan and condensing unit (condenser fans and compressors) energy use:

- 7-day scheduling
- Optimal start/stop
- Night Setbacks
- DDC Temperature Controls
- Enthalpy control

The applicant moved into the facility in mid-2020 and fit-out the pre-existing play room and gym to an auto shop. The applicant installed the EMS measure in late 2020 and the application was classified as a retrofit. There are 11 total RTUs serving the space, but the application only claimed savings for the EMS installation on 6 of the 11 RTUs. The remaining 5 RTUs were installed at the same time as the fit-out occurred, which led the PA to classify these units as a New Construction and make them ineligible for EMS savings.

The evaluators spoke with the site and the vendor that installed the EMS system and determined that because the space use changed as part of a fit-out the entire fit-out scope should be considered with a new construction measure event type. The EMS installation was part of this fit-out scope of work, leading the evaluators to classify the baseline for the new controls as new construction. For new construction projects, the control strategies implemented with the EMS were found to be baseline per the energy code, resulting in zero realized savings for the project, shown in Table 5-1.

Table 5-37. Evaluation Results Summary

PA Application ID	Measure Name		Annual Electric Energy (kWh)	% Of Energy Savings On-Peak	Summer On-Peak Demand (kW)	Winter On-Peak Demand (kW)
11759508	New EMS	Tracked	34,508	13.3%	3.2	0.0
		Evaluated	0	0%	0.0	0.0
		Realization Rate	0%	0%	0%	0%

5.12.1 Explanation of Deviations from Tracking

Deviations from the tracked savings are a result of changing the baseline from a retrofit to a new construction. The change to a new construction baseline results in the controls added by the EMS system being considered baseline, so no savings are able to be considered.

5.12.2 Recommendations for Program Designers & Implementers

There are no recommendations at this time.

5.12.3 Customer Alert

There is no relevant customer alert.

5.13 Evaluated Measures

The project consisted of the installation of an EMS system to add control systems to 6 RTUs at an auto shop. The applicant claims that the new EMS includes a 7-day schedule, optimal start/stop, night setbacks, DDC temperature control, and enthalpy control.

5.13.1 Application Information and Applicant Savings Methodology

This section describes the applicant's application information, savings methodology, and the evaluation assessment of the savings calculation algorithm used by the applicant.

5.13.2 Applicant Description of Baseline

The applicant describes the measure as a retrofit with a single baseline. The pre-installation site condition is the existing 6 RTUs with no EMS system installed and the RTUs are controlled by local thermostats. Documentation on the local thermostat controls is not provided with the application, but the calculations assume that the RTU supply fans run continuously and the units maintain a fixed space temperature setpoint 24 hours / day and 7 days / week. Table 5-2 summarizes the key baseline parameters assumed by the applicant.

The application noted that there are 11 RTUs on site and connected to the EMS. However, 5 of the 11 were newly installed and therefore not considered for savings because the baseline for these 5 units would include all of the control strategies covered in this application. The PA also pointed to the EMS application itself, which states that "only the installation of a new EMS or expansion of an existing system to control additional equipment is eligible for incentives…The installation of EMS on new equipment is not eligible for incentives."

Table 5-38. Applicant baseline summary

Measure	Parameter	Value(s)	Source of Parameter Value
ECM 1	Condenser fans connected kW	9.22	Applicant savings analysis (custom express tool)
	Condenser fans annual operating hours	4,368 (168 hours/week, 26 weeks/year)	Applicant savings analysis (custom express tool)

	DX compressors connected kW	70.43	Applicant savings analysis (custom express tool)
	DX compressors annual operating hours	4,368 (168 hours/week, 26 weeks/year)	Applicant savings analysis (custom express tool)
	RTU supply fan connected kW	20.62	Applicant savings analysis (custom express tool)
	RTU supply fan annual operating hours	8,736 (168 hours/week, 52 weeks/year)	Applicant savings analysis (custom express tool)

5.13.2.1 Applicant Description of Installed Equipment and Operation

This section describes the proposed condition assumed in the applicant analysis. The proposed case includes the following control strategies: 7-day scheduling, optimized start/stop, night time setbacks, DDC temperature control, and enthalpy control. Table 5-3 summarizes the key proposed case inputs used in the applicant savings analysis.

Table 5-39. Application Proposed Case Key Parameters

Measure	Equipment	Parameter	Value(s)	Source of Parameter Values
ECM 1	Condenser fans	Connected kW	9.22	Applicant savings analysis (custom express tool)
		Annual operating hours	1,430 (55 hours per week for 26 weeks per year)	Applicant savings analysis (custom express tool)
	DX Compressors	Connected kW	70.43	Applicant savings analysis (custom express tool)
		Annual operating hours	1,430 (55 hours per week for 26 weeks per year)	Applicant savings analysis (custom express tool)
	Supply Fans	Connected kW	20.62	Applicant savings analysis (custom express tool)
		Annual operating hours	2,860 (55 hours per week for 52 weeks per year)	Applicant savings analysis (custom express tool)

5.13.2.2 Applicant Energy Savings Algorithm

The applicant used the prescriptive EMS tool with built-in savings factors to calculate the measure savings. The applicant entered the key parameters from Table 5-2 and Table 5-3 into the tool and selected the following EMS control strategies: 7-day scheduling, optimized start/stop, night time setbacks, DDC temperature controls, and enthalpy control to calculate the savings. Enabling these control strategies in the prescriptive tool implies that the existing/baseline case did not include these control strategies. The total savings from the tool are represented as:

$$\mathrm{E_{Total}} = \mathrm{E_{Condenser\ Fans}} + \mathrm{E_{Compressors}} + \mathrm{E_{Supply\ Fans}}$$

where,

$\mathrm{E_{Total}}$ = Total electric energy saved from the EMS system installation

$\mathrm{E_{Condenser\ Fans}}$ = Energy saved from condenser fans

$\mathrm{E_{Compressors}}$ = Energy saved from RTU DX compressors

$\mathrm{E_{Supply\ Fans}}$ = Energy saved from RTU supply fans

The condenser fans, compressor and supply fan savings can then be individually calculated as:

$$\mathrm{E_{Condenser\ Fans}} = \mathrm{E_{Run\ Time}} + \mathrm{E_{DDC\ \ Controls}} + \mathrm{E_{Enthalpy\ Controls}}$$

$$\mathrm{E_{Compressors}} = \mathrm{E_{Run\ Time}} + \mathrm{E_{DDC\ \ Controls}} + \mathrm{E_{Enthalpy\ Controls}}$$

$$\mathrm{E_{Supply\ Fans}} = \mathrm{E_{Run\ Time}} + +\mathrm{E_{Enthalpy\ Controls}}$$

The energy saved from the run time reduction, DDC temperature controls, and enthalpy controls are then calculated as:

$$\mathrm{E_{Run\ Time}} = \mathrm{kW} \times \mathrm{Hours\ Saved} \times \mathrm{SF_{Run\ Time}}$$

$$\mathrm{E_{DDC\ Controls}} = \mathrm{kW} \times \mathrm{Post\ Hours} \times \mathrm{SF_{DDC\ Controls}}$$

$$\mathrm{E_{Enthalpy\ Controls}} = \mathrm{kW} \times \mathrm{Post\ Hours}\ \times \mathrm{SF_{Enthalpy\ Controls}}$$

where,

kW = The full load connected kW for the DX compressors or supply fans as shown in Table 5-3.

Hours Saved = Reduction in hours between the base case (no EMS) and proposed case (installed EMS). Base case and proposed case hours are directly input by the applicant, seen in Table 5-3.

Post Hours = Proposed case hours with the EMS installed.

SF = the savings factors for each of the run time, DDC controls, and DCV.

The savings factor change based on if the DX compressors or supply fans are being analyzed. The savings factors for the different parameters used in the applicant’s analysis are summarized in Table 5-5 and explained in more detail below.

Table 5-40. Savings factors summary

Equipment	Savings Factors		
	Run Time	DDC Controls	Enthalpy Controls
Condenser Fans	0.2	0.025	0.01
DX Compressors	0.2	0.025	0.01
Supply Fans	1.0	N.A.	0.01

N.R. = Not Applicable

The applicant then applied a 20% adjustment factor to the total savings calculated by the tool, so that the savings are a reasonable percentage of the annual building electric use. The savings tool includes an input for annual electric use to provide a sanity check of the savings, but the annual use entered into the tool, 254,000 kWh, includes 7 months of data (November 2019 through June 2020) when the building was vacant, so 254,000 kWh is not reflective of the auto shop base or proposed annual use.

The vast majority of the applicant's savings (97.3%) come from scheduling savings on the condenser fans, DX compressors, and supply fans. The table below provides a breakdown of the savings source for each control strategy for the condenser fans, DX RTU compressors, and the RTU supply fans. Please note, the EMS tool uses 7-day Scheduling, Optimal Start/Stop, and Night time Setbacks to determine if equipment runtime savings can be calculated. These 3 controls strategies enable the tool to calculate savings, but the actual savings are calculated based on the key parameters (i.e., kW demand and the reduction annual hours). The savings shown in Table 5-41 include the 20% adjustment factor applied by the applicant.

Table 5-41. Applicant savings breakdown based on control strategy

Applicant Savings			
EMS Control Strategy	**kWh Saving**	**% Of Claimed Savings**	**Note**
Condenser Fans			
Reduction in Annual Hours	1,084 kWh	3.1%	7-day Scheduling, Optimal Start/Stop, or Night time Setbacks must be enabled in the prescriptive EMS tool for it to calculate savings from equipment runtime. Toggling between these 3 control strategies does not affect the calculated kWh savings.
7-day Schedule	N.R.	N.R.	Included in annual hours reduction
Optimal Start/ Stop	N.R.	N.R.	Included in annual hours reduction
Night time Setbacks	N.R.	N.R.	Included in annual hours reduction
DDC Controls	66 kWh	0.2%	
Enthalpy Control	26 kWh	0.1%	
DX RTU Compressors			
Reduction in Annual Hours	8,277 kWh	24.0%	7-day Scheduling, Optimal Start/Stop, or Night time Setbacks must be enabled in the prescriptive EMS tool for it to calculate savings from equipment runtime. Toggling between these 3 control strategies does not affect the calculated kWh savings.
7-day Schedule	N.R.	N.R.	Included in annual hours reduction
Optimal Start/ Stop	N.R.	N.R.	Included in annual hours reduction
Night time Setbacks	N.R.	N.R.	Included in annual hours reduction
DDC Controls	504 kWh	1.5%	
Enthalpy Control	201 kWh	0.6%	
RTU supply fans			
Reduction in Annual Hours	24,233 kWh	70.2%	7-day Scheduling, Optimal Start/Stop, or Night time Setbacks must be enabled in the prescriptive EMS tool for it to calculate savings from equipment runtime. Toggling between these 3 control strategies does not affect the calculated kWh savings.
7-day Schedule	N.R.	N.R.	Included in annual hours reduction
Optimal Start/ Stop	N.R.	N.R.	Included in annual hours reduction
Night time Setbacks	N.R.	N.R.	Included in annual hours reduction
DDC Controls	N.R.	N.R.	Not included in custom express tool
Enthalpy Control	118 kWh	0.3%	

N.R. = Not Relevant

5.13.2.3 Evaluation Assessment of Applicant Methodology

The evaluators agree with the methodology the custom express tool uses for the run time calculation. The 0.2 run time savings factors on the condenser fans and DX compressors are assumed to represent an average duty cycle. The Rhode Island TRM indicates that there is a default of 855 effective full load cooling hours in Rhode Island, and there are 3,813 hours above 55°F according to TMY-3 weather data in Providence RI. This represents a calculated 22.4% duty cycle, similar to the 20% factor used by the EMS tool.

The DDC Controls are not defined in the tool, and the evaluators have been unable to properly define what this control strategy is supposed to entail.

It is also unclear to the evaluators where the enthalpy controls savings factor is derived from.

5.13.3 On-Site Inspection and Metering

No site visit or virtual site visit occurred for this evaluation. Discussions with the site contact overrode any potential on-site findings.

5.13.4 Evaluation Methods and Findings

This section describes the evaluator methods and findings.

5.13.4.1 Evaluation Description of Baseline

The evaluator reviewed the project files and interviewed the site contact and EMS installation vendor to gather information on the baseline. The evaluators learned that the EMS installation was part of a fit-out of the building, which converted the building use from a gym to the auto shop. The act of fitting out the space and changing the space type would trigger a baseline measure event type change to new construction for all equipment modified during the fit out. The existing RTU equipment was not touched, so the mechanical performance of those units did not have to be adjusted. The RTU controls however were affected by the addition of the EMS system, triggering a baseline adjustment to new construction

The original application is assumed to not have considered the EMS project with a new construction baseline because the EMS was installed in late 2020 versus the fitout occurring in mid-2020, making the PA unaware of the space change during their review. However, the evaluators spoke extensively with the site and learned the following, which indicate the EMS installation was part of the fit-out:

- The site contact believed that the vendor who did the fit-out and the vendor who installed the EMS were separate entities, leading to a delay between fit-out construction and EMS installation.

- The evaluated site is a secondary site for the customer, and the same EMS system already existed in the main site next door prior to the fit out of this building. This indicates that the EMS would have likely been considered by the designers as part of the move-in fit-out process.

- Prior to the fit-out the space was a gym that was open 24 hours per day. The auto shop is now open with standard business hours. Industry standard practice necessitates that the HVAC equipment run hours should be updated to reflect the new occupied hours. Therefore, the new RTU controls would need to be included as part of the fit-out scope.

Because the facility space type changed, which triggers a baseline event type adjustment for equipment modified during the fit out, and the EMS was part of the fit-out, the evaluators adjusted the baseline measure event type for this EMS application to be new construction.

A new construction baseline is based on the energy code in place at the time of the project, which was IECC 2015 or industry standard practice. The relevant code section for new controls is C403.2.4 HVAC system controls, which requires all of the control strategies supported by this application. IECC 2015 section C403.2.4.2 states that ‘each zone shall be provided with thermostatic setback controls that are controlled by either an automatic time clock or programmable control system” and subsection C403.2.4.2.2 says that ‘automatic time clock or programmable controls shall be capable of starting and stopping the system for seven different daily schedules.” Economizer controls (“Enthalpy Controls” in the custom-express tool) is also a baseline control per IECC 2015 C403.3.1.

5.13.4.2 Evaluation Calculation Method

Since all the controls that the applicant claimed savings for are included in the baseline, the evaluators opted to remove all the savings from this project for a 0% realization rate.

5.14 Final Results

The project consisted of installing an EMS system at an auto shop on 6 RTUs. The applicant indicated a number of control strategies would be implemented to control the RTUs with the new EMS system installed. However, from discussions with the site and vendor the evaluators adjusted the measure event type to new construction, which results in the baseline controls being the same as the proposed controls. This baseline adjustment resulted in 0 savings for the project.

Table 5-42. Summary of Key Parameters

Parameter	Applicant	Evaluator
Measure Event Type	Retrofit	New Construction
Baseline	Existing Conditions	Code Compliant Controls
Savings		
Annual electric savings (kWh)	34,508	0.0
Electric realization rate (%)	0.0%	

5.14.1 Explanation of Differences

The evaluated savings are 0% of the applicant’s savings because of the project adjustment from a retrofit to a new construction, which results in the baseline controls being the same as the proposed controls.

End-use	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
HVAC	Baseline	Measure Event Type Classification Adjustment	100%	**Decreased Savings-** The evaluators changed the measure event type to new construction. The controls are considered baseline, so all savings were removed from the project.

5.14.2 Lifetime Savings

The EMS system has a measure life of 10 years and the underlying RTUs have a measure life of 12 years. Because the EMS measure life is more than 2/3 that of the RTUs, this project has a dual baseline. The evaluators calculated applicant and evaluated lifetime savings values using the following formula:

$$\mathrm{LAGI} = \mathrm{FYS} \times [\mathrm{RUL} + \mathrm{outyear}\,\% \times (\mathrm{EUL} - \mathrm{RUL})]$$

where:

LAGI = lifetime adjusted gross impact (kWh)

FYS = first year savings (kWh)

EUL = measure life (years)

RUL = 1/3 of EUL (years)

Outyear % = 90% for dual baseline measure

The evaluated lifetime savings are zero because the evaluated first year savings are zero. Table 5-11 provides a summary of key factors that influence the lifetime savings.

Table 5-43. Measure 11160436 - Lifetime Savings Summary

Factor	Tracking	Evaluator
Lifetime savings (kWh)	345,080	0
First year savings (kwh)	34,508	0
Measure lifetime (years)	10	10
Measure life reference	Screening Tool	Screening Tool
Measure event type	Retrofit	New Construction
Baseline classification	Single – Pre existing	Single – Initial Purchase and End of Useful Life
Measure status (operational or removed)	N/A	Operational

N/A = Not Applicable

The evaluation uses the same 10-year measure life as the applicant.

5.14.2.1 Ancillary impacts

There were no ancillary impacts associated with the evaluated measure.

RICE20N070

Report Date: 7/18/2022

Application ID(s)	10251545	
Project Type	C&I Existing Buildings Retrofit	
Program Year	2020	
Evaluation Firm	DNV	
Evaluation Engineer	Matthew Piana	
Senior Engineer	Max Ma	

5.15 Evaluated Site Summary and Results

The evaluated project was implemented at a food production facility located in Providence, RI. The site contact reported that the facility mainly sells to restaurants which have not fully recovered from the COVID pandemic. Because of this, the site's production was impacted by the pandemic from the beginning and was still impacted at the time of the evaluation. Due to the effect of the pandemic on the facility, the evaluation method was a non-operation only with a verification through a site visit.

The installed measure at this facility was pipe insulation on cold pipes that carry glycol used for food production purposes. The evaluators classified the installed measure as an add-on with preexisting conditions as the single baseline. This measure saves energy because it reduces the amount of heat gain from the unconditioned space to the bare cold surfaces of the pipes, which reduces the demand on the glycol coolant system. The evaluators applied on-site verified pipe lengths, diameters, materials, and temperatures to the 3EPlus heat gain modelling software to calculate measure savings. The total annual tracking energy savings for this site is 9,728 kWh. The evaluated savings are 9,323 kWh/yr yielding a 96% realization rate. The evaluation results are presented in This retrofit project consisted of a new energy management system (EMS) at a 120,350 ft² high school. The new EMS controls the existing HVAC system as the site, including 5 rooftop units (RTUs) and 65 variable air volume (VAV) terminal boxes. Electric savings associated with the new EMS were claimed based on the following control strategies:

- 7-day scheduling
- Optimal start/stop
- Night setback
- DDC temperature controls
- Demand control ventilation (DCV)

This evaluation is considered non-ops because the evaluated measures are heavily impacted by COVID. The majority of savings for this project are derived from demand control ventilation controls. However, these controls are overwritten for health and safety purposes. The site contact indicated that the school is running with as much outside air as possible for ventilation purposes. From approximately April through mid-November the school operates with 100% outside air unless required to turn down for dehumidification. Over the winter the outside air is lowered to the maximum possible point necessary to keep the building warm. The site indicated that these control adjustments were temporary and normal operation would resume following the end of the pandemic.

The evaluators conducted an in-person visit to observe the EMS and HVAC system and learn more about the control strategies present. The evaluators observed 7-day scheduling, optimal start/stop, night setbacks, and demand control ventilation strategies possible in the EMS. The Demand Control Ventilation strategy was overwritten as expected to increase ventilation. “DDC temperature controls” refers to the installation of DDC controls themselves to enable tighter controls. The evaluators did not observe installed controls that would support claiming savings for these controls. The evaluators therefore removed this control strategy from the custom-express tool savings.

This measure is classified as a single baseline retrofit. The evaluated savings are 102.8% of the tracked savings. The savings claimed by the applicant for this project are 51,582 kWh.

The evaluation results are presented in Table 5-1.

Table 5-1.

Table 5-44. Evaluation results summary

PA Application ID	Measure Name		Annual Electric Energy (kWh)	% of Energy Savings On-Peak	Summer On-Peak Demand (kW)	Winter On-Peak Demand (kW)
10251545	Pipe insulation	Tracked	9,728	45%	1.1	1.1
		Evaluated – non-ops	9,323	45%	1.1	1.1
		Realization Rate	96%	100%	100%	100%

5.15.1.1 Explanation of Deviations from Tracking

The evaluated savings are less than the applicant-reported savings due to a discrepancy in piping material between the applicant reported piping and the piping observed by the evaluators while on site. Further details regarding deviations from the tracked savings are presented in Section 3-1.

5.15.1.2 Recommendations for Program Designers & Implementers

The evaluators recommend that program implementers inventory baseline piping characteristics (pipe length, diameter, and material) to a more granular level as to capture variations within piping groups.

5.15.1.3 Customer Alert

There were no customer alerts.

5.16 Evaluated Measures

The following sections present the evaluation procedure, including the findings from an in-depth review of the supplied applicant calculations and the evaluation methodology determined to be the best fit for the site and the information available.

The project consisted of the installation of insulation on 500 ft of piping that transport glycol for cooling purposes in the food production facility.

5.16.1 Application Information and Applicant Savings Methodology

This section describes the applicant's application information, savings methodology, and the evaluation assessment of the savings calculation algorithm used by the applicant.

5.16.1.1 Applicant Description of Baseline

The applicant classified the measure as a retrofit with pre-existing conditions as the baseline. The applicant baseline consisted of bare cold surfaces without insulation. The applicant estimated the cold surface temperatures to be 40°F for the 2-inch piping and 30°F for the 1.5-inch piping with an ambient temperature of 80°F. The applicant also estimated the cold surfaces to be energized 8,424 hours annually. The efficiency of the chiller given by the applicant is 3.41 (COP). The applicant stated that the 2-inch PVC piping was 440 ft long and that the 1.5-inch stainless steel piping was 60 ft long. The existing energy loss per foot was estimated by the applicant to be 33.73 Btu/hr/ft for the 2-inch piping and 32.05 Btu/hr/ft for the 1.5-inch piping. The baseline conditions as estimated by the applicant are listed below in Table 5-45. All values listed in Table 5-45 originate from the applicant savings analysis file. The heat gain values presented were calculated by the applicant using 3EPlus software.

Table 5-45. Applicant baseline key parameters

Pipe Size (in)	Pipe Length (ft)	Pipe Material	Chiller Efficiency (COP)	Hours of Operation	Glycol Temperature (°F)	Ambient Temperature (°F)	Bare Pipe Heat Gain (BTU/hr/ft)
2	440	PVC	3.41	8,424	40	80	33.73
1.5	60	Stainless steel	3.41	8,424	30	80	32.05

5.16.1.2 Applicant Description of Installed Equipment and Operation

The measure installed at the facility was pipe insulation. 1-inch-thick insulation was installed to all the sections of pipe listed above in Table 5-45. The applicant assumed that the installed insulation would be Micro Lok JM Fiberglass insulation. The applicant assumed that all operational parameters would remain the same and that the only difference from the installed measure would be that the heat gain by the cold process pipes would be reduced. The applicant installed equipment conditions are listed below in Table 5-46. The heat gain values presented were calculated by the applicant using 3EPlus software.

Table 5-46: Application proposed key parameters

Pipe Size (in)	Pipe Length (ft)	Pipe Material	Chiller Efficiency (COP)	Hours of Operation	Glycol Temperature (°F)	Ambient Temperature (°F)	Insulated Pipe Heat Gain (BTU/hr/ft)
2	440	PVC	3.41	8,424	40	80	6.57
1.5	60	Stainless steel	3.41	8,424	30	80	7.28

5.16.1.3 Applicant Energy Savings Algorithm

The applicant used 3EPlus to calculate the baseline proposed heat gain rates. The savings are the difference between baseline and proposed heat gain. The formula used by the applicant are shown below:

$$\Delta Q = \frac{L \times Hours \times (q_b - q_i)}{3412 \times E_C}$$

where:

ΔQ	= annual energy savings (in kWh)
L	= pipe length (in linear ft)
$Hours$	= annual operating hours, 8424
q_b	= heat gain from bare component (Btu/hr/ft), estimated using 3EPlus
q_i	= heat gain from insulated component (Btu/hr/ft), estimated using 3EPlus

3412	= conversion factor (1 kWh = 3412.14 Btu)
E_C	= installed chiller plant efficiency (COP), 3.41

The applicant used the heat gain values calculated in 3EPlus to estimate the total proposed kWh savings using an excel-based calculator. A screenshot of the applicant calculator is depicted below in Figure 5-5.

Figure 5-5 Screenshot of applicant calculator

Description	Fuel	Pipe Material	Efficiency	Hours of Operation	Process Temp	Ambient Temp	Wind Speed	Pipe Size	Pipe Length (SF)	Existing Energy Loss per Foot (BTU/hr/ft)	Proposed Energy Loss per Foot (BTU/hr)	Total Existing Energy Loss (BTU)	Total Proposed Energy Loss (BTU)	kWh Savings
Process Glycol Piping (2")	Electric	PVC	3.41	8424	40	80	0	2.0"	440	33.73	6.57	125,022,268.80	24,352,099.20	8,652
Process Glycol Piping (1-1/2")	Electric	Stainless	3.41	8424	30	80	0	1.5"	60	32.05	7.28	16,199,352.00	3,679,603.20	1,076
														9,728

Additional details on the applicant algorithm could be found in the project files.

5.16.1.4 Evaluation Assessment of Applicant Methodology

The evaluators agree with the applicant savings methodology.

5.16.2 On-site Inspection

This section provides details on the tasks performed during the site visit and the gathered data.

5.16.2.1 Summary of On-site Findings

The evaluators conducted an on-site verification on 6/16/2022. The evaluators did not install any metering equipment while on site because this project was evaluated as non-operation only. During the site visit, the evaluators conducted an interview with the facility manager on the scope of the project and visually verified the installed pipe insulation. Table 5-47 presents the on-site verification findings.

Table 5-47. Measure verification

Measure Name	Verification Method	Verification Result
Pipe insulation	Verify the pipe insulation was installed visually during facility walkthrough	Pipe insulation was verified to be installed; insulation thickness was verified to be 1-inch on all pipes in scope.
Pipe insulation	Verified the pipe length and material	The 2-inch 440-foot piping is not entirely PVC. It is 70% PVC and 30% stainless steel. The 1.5-inch 60-ft piping is stainless steel.
Pipe insulation	Interview the site contact to verify the facilities' operating hours and profile	The site's operations are still impacted by Covid-19 with non-typical operating hours. The site contact indicated that the applicant-reported typical operations of 8,424 hours per year is accurate.
Pipe insulation	Spot measurements of process and ambient temperatures	The process temperatures given by the applicant were verified to be accurate. The evaluator verified that installation locations are not space-conditioned, but receive a high heat load from surrounding process steam/hot water pipes.

Measure Name	Verification Method	Verification Result
		Therefore, the ambient temperature of 80°F reported by the applicant is reasonable as an annual average, which also agreed with spot measurements taken by the evaluators.
Pipe insulation	Interview site contact to verify the chiller type and expected efficiency range and collect chiller documentation	The cooling glycol is supplied by one Trane CGWD water-cooled chiller. The reported 3.41 COP value (1.03 kW/ton) is reasonable.

Figure 5-6 below is a photo captured by the evaluators while on site that shows the insulation installed on the glycol pipes.

Figure 5-6 Photo of installed insulation

5.16.3 Evaluation Methods and Findings

This section describes the evaluator methods and findings.

5.16.3.1 Evaluation Description of Baseline

The evaluator reviewed the project files and interviewed the site contact to gather information on the baseline. Based on the project files and interview with the site contact, the evaluator determined that this pipe insulation measure is an add-on with a single baseline, and the baseline is the preexisting conditions.

5.16.3.2 Evaluation Calculation Method

The evaluators used the same analysis method as the applicant to calculate savings for this site. The formula used by the evaluator to calculate savings is listed below:

$$\Delta Q = \frac{L \times Hours \ \times (q_b - \ q_i)}{3412 \ \times \ E_C}$$

where:

ΔQ	= annual energy savings (in kWh)
L	= pipe length (in ft)
$Hours$	= annual operating hours, 8424
q_b	= heat gain from bare component (Btu/hr/ft), estimated using 3EPlus
q_i	= heat gain from insulated component (Btu/hr/ft), estimated using 3EPlus
3412	= conversion factor (1 kWh = 3412.14 Btu)
E_C	= installed chiller plant efficiency (COP), 3.41

The evaluators used 3EPlus to verify the heat gain values on each line item. For example, Figure 5-7 below shows that with an insulation thickness of 1-inch (value in blue) at the operating conditions outlined by the applicant and verified by the evaluator, the expected heat gain rate for 2-inch PVC piping is 6.57 BTU/hr/ft. This value matches the value found in the applicant calculation file.

Figure 5-7 Screenshot of evaluator 3EPlus calculation

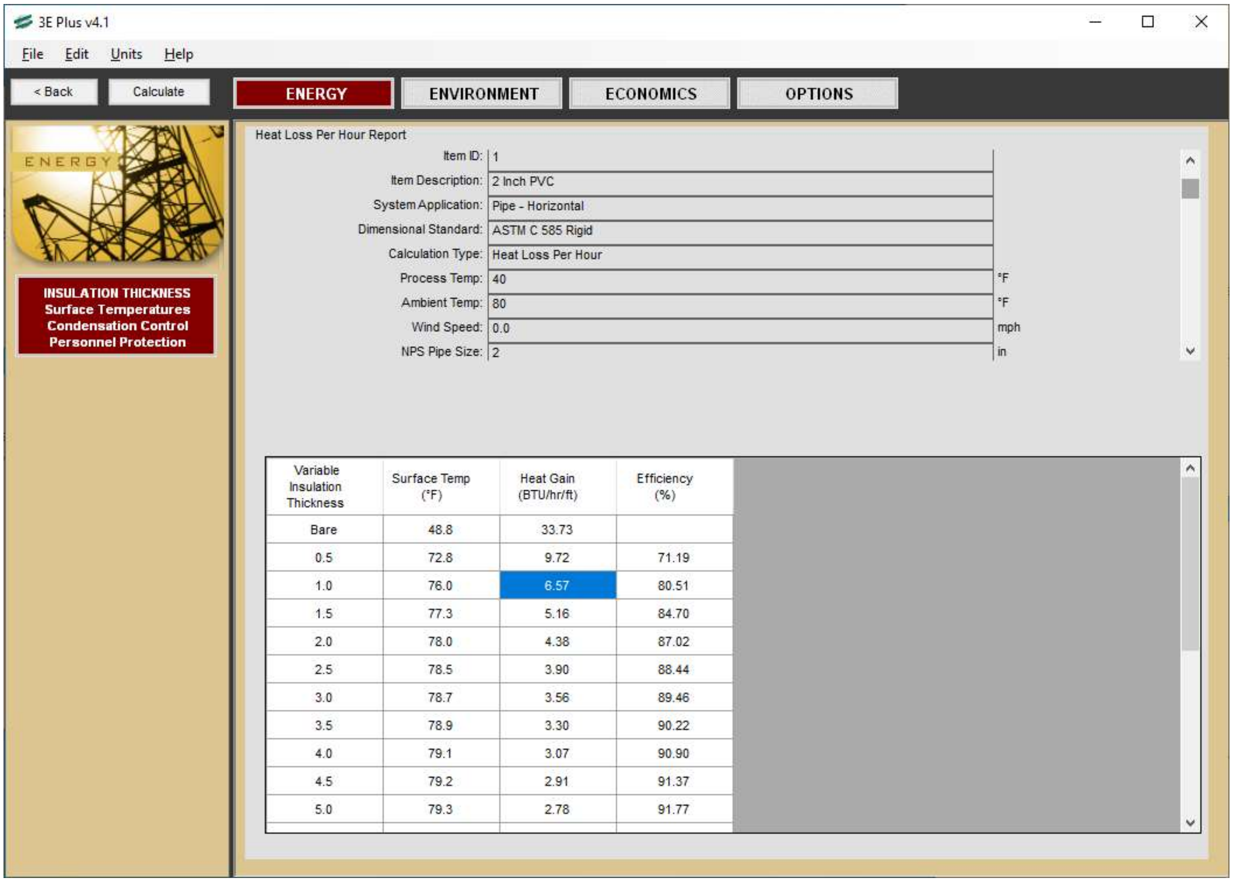


Figure 5-8 below depicts the evaluator calculator used to verify applicant savings. The evaluators added an extra line item of 2-inch piping to account for the variance in pipe material discovered while on site (70% of 2-inch piping is PVC and 30% is stainless steel).

Figure 5-8 Screenshot of evaluator calculator

Description	Fuel	Pipe Material	Efficiency	Hours of Operation	Process Temp	Ambient Temp	Wind Speed	Pipe Size	Pipe Length (SF)	Existing Energy Loss per Foot (BTU/hr/ft)	Proposed Energy Loss per Foot (BTU/hr)	Total Existing Energy Loss (BTU)	Total Proposed Energy Loss (BTU)	kWh Savings
Process Glycol Piping (2")	Electric	PVC	3.41	8424	40	80	0	2.0"	308	33.73	6.57	87,515,588.16	17,046,469.44	6,056
Process Glycol Piping (2")	Electric	Stainless	3.41	8424	40	80	0	2.0"	132	29.77	6.85	33,103,287.36	7,616,980.80	2,190
Process Glycol Piping (1-1/2")	Electric	Stainless	3.41	8424	30	80	0	1.5"	60	32.05	7.28	16,199,352.00	3,679,603.20	1,076
														9,323

5.17 Final Results

The evaluated project consisted of a single measure: the installation of insulation onto piping sections carrying cold glycol for cooling. Because Covid-19 continues to impact the operations of this site, the evaluators conducted a non-ops-only evaluation with on-site verification to update non-operational parameters only. The evaluators used the same methodology as the applicant's in evaluating energy savings: characterizing piping lengths and materials based on on-site inventory, quantifying heat gain values based on 3EPlus software, and applying the glycol chiller efficiency to calculate energy savings. Table 5-9 shows a summary of the key parameters.

Table 5-48. Summary of key parameters

Parameter	PROPOSED / INSTALLED	
	Tracking Value(s)	Evaluation Value(s)
Length of 2-inch PVC pipes	440	308
Length of 2-inch stainless steel pipes	0	132
Length of 1.5-inch stainless steel pipes	60	60
2-inch pipe glycol temperature	40°F	40°F
1.5-inch pipe glycol temperature	30°F	30°F
Annual operating hours	8,424	8,424
Ambient temperature	80°F	80°F
Glycol chiller efficiency (COP)	3.41	3.41
Resulting chiller energy savings from pipe insulation	9,728 kWh	9,323 kWh

5.17.1 Explanation of Differences

The evaluated savings are less than the tracking savings, due to adjustments to non-operational parameters. The summary of deviations is presented below in Table 5-10.

Table 5-49. Summary of deviations

Measure	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
10251545	Technology	Pipe material	-4%	**Decreased savings** – the evaluators updated the material for 132 linear feet of 2-inch piping from the applicant reported PVC to the on-site verified stainless steel.
Final RR				**96%**

5.17.2 Lifetime Savings

Because the chiller will outlive the installed measures, the evaluators classified this measure as an add-on with a single baseline. The evaluators calculated applicant and evaluated lifetime savings values using the following formula:

$$\text{LAGI} = FYS \times [RUL + \text{out} - \text{year}\,\% \times (EUL - RUL)]$$

where:

$LAGI$ = lifetime adjusted gross impact (kWh)

FYS = first-year savings (kWh)

EUL = measure life (years)

RUL = 1/3 of EUL (years)

Out-year % = 100% for this single-baseline measure

The evaluated lifetime savings are smaller than the tracking lifetime savings because the evaluated first-year savings are smaller than the tracking first-year savings. Table 3-3 provides a summary of key factors that influence lifetime savings.

Table 5-50. Measure 10251545 - Lifetime savings summary

Factor	Tracking	Application	Evaluator
Lifetime savings	145,920 kWh	145,920 kWh	139,845 kWh
First year savings	9,728 kWh	9,728 kWh	9,323 kWh
Measure lifetime	15 years	15 years (project BCR)	15 years (RI TRM)
Baseline classification	N/A	Retrofit	Add-on single

(*) The tracking lifetime savings value is net of all program adjustment factors

5.17.2.1 Ancillary impacts

This project does not have any significant impacts on space heating or cooling energy, and thus do not have ancillary impacts on non-electric energy sources.

RICE20N076

Report Date: 8/1/2022

Program Administrator	National Grid	
Application ID(s)	11404547	
Project Type	Existing Building Retrofit	
Program Year	2020	
Evaluation Firm	DNV	
Evaluation Engineer	Laeng Khoun, Matt Piana	
Senior Engineer	Max Ma	

5.18 Evaluated Site Summary and Results

This retrofit project consisted of the installation of two 15 horsepower (HP) pump motors and two variable frequency drives (VFD) with "Pump Genius" software programmed for constant pressure control at a Middle School. The two pumps operate in a lead/lag manner. Although the site contact indicated the end uses include domestic hot water and field sprinkler systems, the project application as well as the evaluator's metered data indicate that end uses are mostly always-on, fairly constant loads.

The baseline for this retrofit project is the pre-existing system, which consisted of two 15 HP pump motors operating in a lead/lag manner with a throttling valve to maintain the required pressure. The pre-existing motors were rated at 87.8% efficiency compared to the installed 91% efficient motors. The energy savings for this measure comes from the reduced energy use of the motors due to the inclusion of VFDs programmed for pressure control and higher efficiency of the pump motors.

The site contact indicated that the evaluated pumping system was not impact by Covid-19 and that metering for one month would capture representative data to extrapolate to the rest of the year. Therefore, the evaluators conducted a full M&V with metered data informing updates to operational parameters. The metered profile was extrapolated to all hours of the year to calculate evaluated savings – more details on evaluator's methodology can be found in subsequent sections. The evaluated savings are lower than the applicant reported savings primarily due to differences in operating profiles between the tracking estimate and evaluation data. Table 5-1 provides a summary of the evaluation results.

Table 5-51. Evaluation results summary

PA Application ID	Measure Name		Annual Electric Energy (kWh)	% Of Energy Savings On-Peak	Summer On-Peak Demand (kW)	Winter On-Peak Demand (kW)
11404547	Booster Pump Motors and VFDs	Tracked	46,221	47%	10.4	10.4
		Evaluated	17,241	42%	1.8	1.8
		Realization Rate	37%	90%	17%	18%

5.18.1 Explanation of Deviations from Tracking

The evaluated savings are less than the applicant reported savings primarily because the evaluated lead pump operations are closer to full speed than the applicant estimated. Further details regarding deviations from the tracked savings are presented in Section 3.1.

5.18.2 Recommendations for Program Designers & Implementers

Evaluators recommend that program implementers follow up with installations where savings are significantly dependent on controls, so that the applicant-reported control sequences are maintained and optimized where applicable.

5.18.3 Customer Alert

There is no relevant customer alert.

5.19 Evaluated Measures

The following sections present the evaluation procedure, including the findings from an in-depth review of the supplied applicant calculations and the evaluation methodology determined to be the best fit for the site and the information available.

The project consisted of the installation of two high-efficiency pump motors and two VFDs programmed for constant pressure control on sprinkler system and DHW.

5.19.1 Application Information and Applicant Savings Methodology

This section describes the applicant's application information, savings methodology, and the evaluation assessment of the savings calculation algorithm used by the applicant.

5.19.1.1 Applicant Description of Baseline

The applicant describes the measure as a retrofit with a single baseline consisting of the two pre-existing 15 HP pump motors operating for 8,736 hours/year without VFDs. In the pre-existing condition the applicant reported the pumps were controlled with a throttling valve to maintain pressure. The pre-existing pumps were claimed to be 87.8% efficient. The lead pump had the capacity to meet 80% of the total water flow demand before the lag pump started. Table 5-2 provides a summary of the applicant's baseline parameters.

Table 5-52. Applicant baseline summary

Measure	Parameter	Value(s)	Source of Parameter Value
11404547	Motor efficiency	88%	Applicant savings analysis
11404547	Pump load factor	80%	Applicant savings analysis
11404547	Motor nameplate hp	15	Applicant savings analysis
11404547	Existing controls	Throttling valve	Applicant savings analysis
11404547	Lead pump average % flow	50%	Applicant savings analysis

11404547	Lag pump % time on	2%	Applicant savings analysis

5.19.1.2 Applicant Description of Installed Equipment and Operation

The applicant described the installed equipment as replacing the existing two pump motors with same-sized (15 hp each) high-efficiency motors and adding VFD controls based on loop pressure. Table 5-3 provides a summary of the applicant's installed equipment parameters.

Table 5-53. Application proposed case key parameters

Measure	Parameter	Value(s)	Source of Parameter Value
11404547	Motor efficiency	91%	Applicant savings analysis
11404547	Pump load factor	80%	Applicant savings analysis
11404547	Motor nameplate hp	15	Applicant savings analysis
11404547	Proposed controls	VFD based on pressure sensors	Applicant savings analysis
11404547	Lead pump average % flow	50%	Applicant savings analysis
11404547	Lag pump average % flow	2%	Applicant savings analysis

5.19.1.3 Applicant Energy Savings Algorithm

The applicant estimated savings using a custom bin analysis with flow bins in 10% increments. The applicant determined savings based on the following formulas and user-provided inputs:

$$Svgs = Baseline\ Annual\ Energy\ Use - Proposed\ Annual\ Energy\ Use$$

$$Baseline\ Annual\ Energy\ Use\ (kWh) = \frac{HP \times 0.746 \times \%\ Power_b\ \times Operating\ Hours\ \times LF}{Eff_{motor}}$$

$$Proposed\ Annual\ Energy\ Use\ (kWh) = \frac{HP \times 0.746 \times \%\ Power_p\ \times Operating\ Hours\ \times LF}{Eff_{motor}\quad \times EFF_{VFD}}$$

where,

$Svgs$ = Annual energy savings per year (kWh)

HP = Motor horsepower, 15HP

0.746 = HP to kW conversion ratio

$\%\ Power_b$ = Baseline % operating power of the motor, based on typical pump curves

$\%\ Power_p$ = Proposed % operating power of the motor, based on affinity laws

$Operating\ Hours$ = Annual operating hours, 8,736

LF = Load factor, 0.8

Eff_{motor} = Baseline motor efficiency, 87.8%

$Eff_{motor-p}$ = Proposed motor efficiency, 91.0%

Eff_{VFD} = VFD efficiency, based on part load

The applicant calculated the baseline % power in a bin analysis based on the following formula[16]:

$$\%Power = -1.6275 \times \%Flow^4 + 4.6096 \times \%Flow^3 - 4.7876 \times \%Flow^2 + 2.5645 \times \%Flow + 0.2392$$

where,

$\%Flow$ = Percent flow of the pump

The applicant calculated the installed % power using the following formula:

$$\%Power = (\%Flow)^{exp}$$

where,

exp = Modified affinity exponent, 2.5

For both the baseline and proposed models, the applicant's bin analysis considers the % flow of Pumps 1 and 2 in bins of 10% to 100%. More details on the applicant-estimated %flow profile are presented in Section 2.3.2 Evaluation Calculation Method.

5.19.1.4 Evaluation Assessment of Applicant Methodology

The evaluators found the applicant's overall analysis methodology appropriate at the time of the project development. However, the applicant's analysis contained estimated input parameters such as motor load factor and flow profiles, which require update based on post-installation metered data.

5.19.2 On-Site Inspection and Metering

This section provides details on the tasks performed during the on-site inspection, the date it was conducted, and how it was conducted.

Evaluators visited the site on May 26th, 2022 to inspect the pump system and install metering equipment. The evaluators installed Dent Elite Pro kW loggers on both the lead and lag pump VFDs with Hobo amp loggers also installed as a backup for the kW loggers. The evaluators also interviewed the site contact who indicated that the pump system's end uses include domestic hot water as well as sprinkler systems. The site contact is not sufficiently

[16] The applicant derives the formula from the DOE Motor Systems Tip Sheet 11, Adjustable Speed Drives Part-Load Efficiency.

knowledgeable to explain all end uses and expected annual flow profiles. The site contact also indicated that they did not know of a "Pump Genius" software being installed nor was there a display panel relating to the pumps and VFDs. Table 5-54 provides a summary of the on-site verification.

Table 5-54. Measure verification

Measure Name	Verification Method	Verification Result
VFDs on new pump motors	On-site inspection and metering	Both pumps and motors are operational as reported. Nameplate size is 15 hp each motor, also as reported.
VFDs on new pump motors	Interview of site contact for typical operations	The pumps systems are typically energized 24/7, all year round.
VFDs on new pump motors	Interview the site contact for pre-existing controls	The site contact confirmed the pre-existing controls are through throttling valves without VFDs.
VFDs on new pump motors	Inspect installed controls	The installed VFDs are operating and modulating as designed. The pre-existing throttling valves are fully open.

The evaluator's metering for this site included:

1. One (1) Dent ElitePro data logger on each of the 15HP pump motors. The loggers measured kW and amperage data in 1-min intervals for 30 days.
2. As a back up, evaluators also installed two (2) HOBO Amp loggers on the 15HP pump motors. These loggers measured amp data in 10-minute intervals for a duration of 30 days in conjunction with the ElitePro loggers. Spot measurements of voltage, amperage and power factor were also collected.

Because both sets of metered data were found to corroborate each other, the evaluators used the metered true power as the primary evaluation data. The evaluator's metered data indicated that the lead pump is mostly operating near full speed and its operations do not vary significantly between days of the week, while the lag pump is rarely on and operate briefly when on at low speeds Overall, the metered data suggest fairly constant end uses (such as recirculation loops) and insignificant contributions from intermittent end uses (such as sprinkler systems). Therefore, the evaluators processed weekly average profiles from metered data as representative of year-round flow profiles. Figure 5-9 and Figure 5-10 provide a plot of the metered input power on the lead pump and lag pump, respectively.

Figure 5-9. Metered lead pump input power

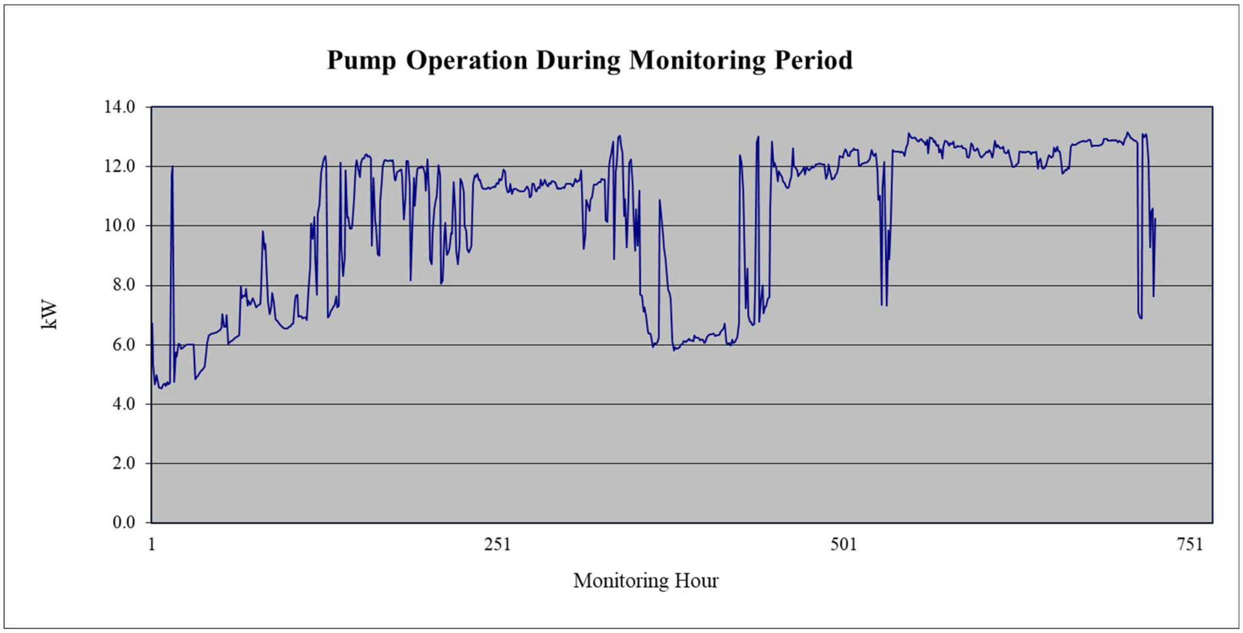


Figure 5-10. Metered lag pump input power

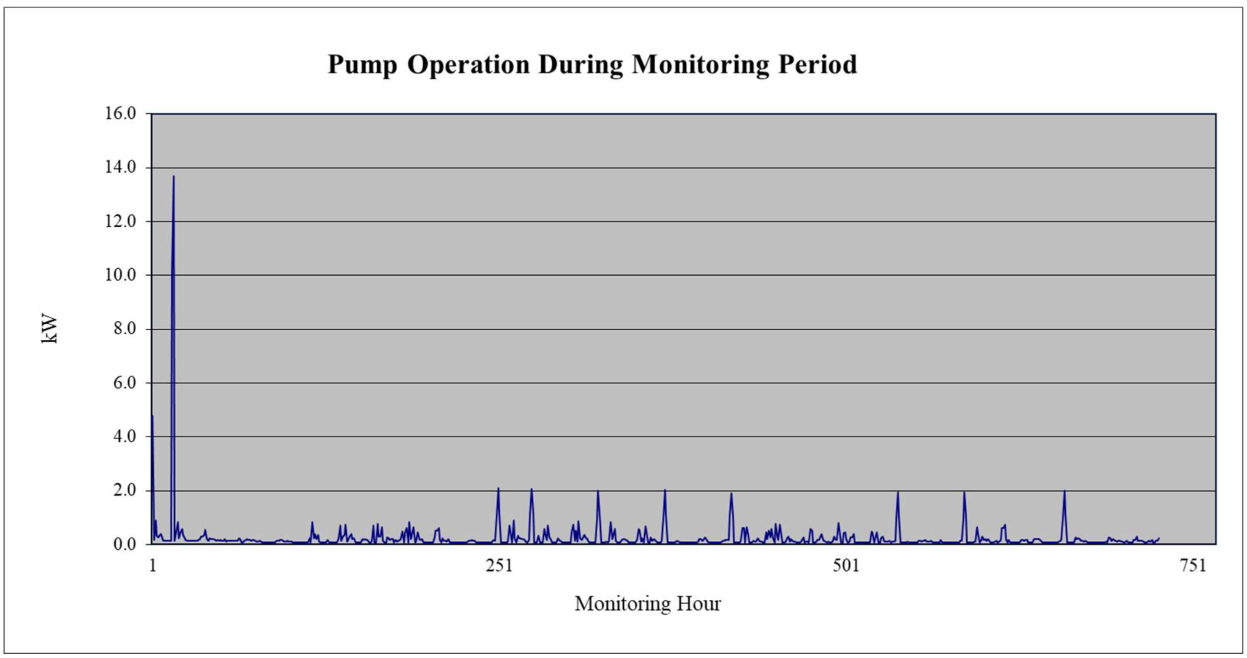
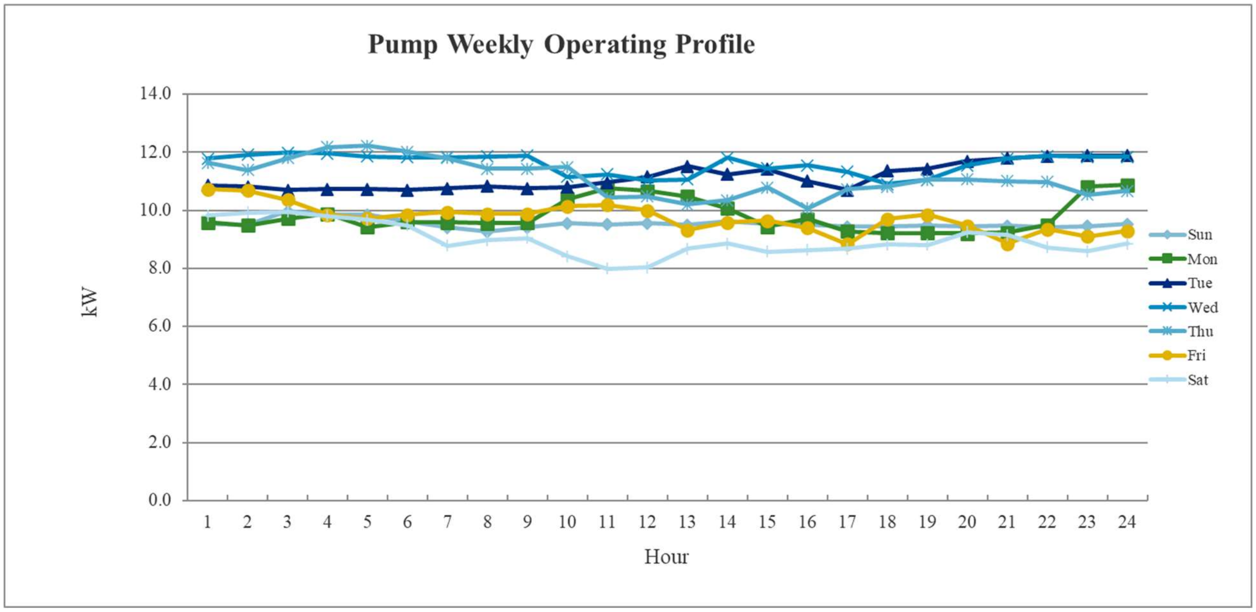


Figure 5-11 provides a plot of the hourly input power profile averaged for each day of the week.

Figure 5-11. Lead pump's weekly operating profile



5.19.3 Evaluation Methods and Findings

This section describes the evaluator methods and findings.

5.19.3.1 Evaluation Description of Baseline

The evaluators have classified this measure as an add-on retrofit. The baseline is the pre-existing condition which consisted of the pre-existing pump motors without VFDs, controlled with throttling valves.

5.19.3.2 Evaluation Calculation Method

The evaluators calculated savings using a custom 8,760 savings analysis based on metered operational data. The evaluator's as-built model was based on the hourly average input power profile from the metered data. Table 5-55 and Table 5-56 provide the average weekly input power profile for the lead and lag pumps, respectively.

Table 5-55. Average power profile of lead pump

Hour	Sun	Mon	Tue	Wed	Thu	Fri	Sat
1	9.55	9.58	10.86	11.79	11.63	10.72	9.82
2	9.52	9.48	10.82	11.91	11.39	10.68	9.92
3	9.96	9.71	10.70	11.98	11.79	10.35	9.95
4	9.86	9.88	10.73	11.96	12.18	9.84	9.81
5	9.85	9.43	10.72	11.86	12.22	9.72	9.68
6	9.63	9.60	10.69	11.82	12.02	9.84	9.49
7	9.41	9.59	10.75	11.82	11.79	9.94	8.77
8	9.26	9.56	10.83	11.86	11.43	9.87	8.97
9	9.41	9.57	10.76	11.88	11.43	9.87	9.04
10	9.55	10.38	10.80	11.16	11.49	10.14	8.41
11	9.51	10.78	10.96	11.24	10.44	10.19	7.99
12	9.55	10.67	11.16	11.01	10.48	9.99	8.03
13	9.50	10.48	11.52	11.06	10.20	9.33	8.68
14	9.61	10.06	11.23	11.81	10.34	9.58	8.85
15	9.53	9.43	11.41	11.45	10.78	9.64	8.57
16	9.52	9.71	11.01	11.55	10.06	9.39	8.63
17	9.44	9.28	10.69	11.32	10.73	8.83	8.68
18	9.45	9.22	11.36	10.90	10.81	9.70	8.82
19	9.48	9.22	11.43	11.05	11.05	9.85	8.81
20	9.45	9.21	11.69	11.55	11.06	9.47	9.25
21	9.47	9.24	11.80	11.78	11.01	8.86	9.14
22	9.43	9.50	11.87	11.87	10.97	9.35	8.72
23	9.46	10.82	11.89	11.84	10.53	9.10	8.58
24	9.53	10.87	11.89	11.84	10.66	9.30	8.85

Table 5-56. Average power profile of lag pump (inclusive of VFD parasitic power)

Hour	Sun	Mon	Tue	Wed	Thu	Fri	Sat
1	0.12	0.10	0.06	0.13	0.07	0.09	0.10
2	0.13	0.11	0.07	0.14	0.09	0.11	0.09
3	0.79	0.32	0.07	0.55	0.08	0.44	0.09
4	1.50	0.57	0.07	1.07	0.08	0.85	0.11
5	0.82	0.44	0.07	0.61	0.09	0.50	0.11
6	0.07	0.12	0.11	0.15	0.10	0.17	0.14
7	0.06	0.31	0.12	0.09	0.17	0.22	0.11
8	0.07	0.25	0.15	0.09	0.09	0.26	0.12
9	0.06	0.42	0.23	0.26	0.43	0.28	0.18
10	0.06	0.14	0.43	0.36	3.07	0.13	0.14
11	0.07	0.38	0.31	0.23	1.06	0.43	0.15
12	0.08	0.47	0.25	0.27	0.47	0.35	0.13
13	0.09	0.17	0.37	0.55	0.42	0.32	0.12
14	0.09	0.44	0.30	0.12	0.27	0.36	0.10
15	0.08	0.23	0.37	0.11	0.34	0.22	0.13
16	0.09	0.14	0.15	0.17	0.18	0.19	0.08
17	0.08	0.16	0.16	0.24	0.18	0.23	0.09
18	0.09	0.15	0.09	0.17	0.14	0.15	0.10
19	0.09	0.16	0.10	0.19	0.19	0.15	0.10
20	0.09	0.16	0.15	0.16	0.14	0.15	0.09
21	0.09	0.12	0.11	0.09	0.13	0.11	0.10
22	0.10	0.14	0.16	0.08	0.14	0.08	0.11
23	0.13	0.09	0.12	0.09	0.13	0.09	0.10
24	0.14	0.07	0.14	0.08	0.09	0.10	0.09

For each hour in the 8760 model, the evaluator quantified the average as-built input power for the lead and lag pumps, respectively, based on the day of the week and hour of day as presented in Table 5-55 and Table 5-56 above.

The evaluators calculated the percentage water flow for each hour for each pump based on the following formula:

$$\%\,Flow = \left(\frac{kW_{VFD}}{kW_{Max}}\right)^{\frac{1}{Exp}}$$

where,

$\%\,Flow$ = water flow as a percentage of pump capacity

kW_{VFD} = modelled hourly input power into the VFD, in kW

kW_{Max} = maximum observed input power, in kW

Exp = modified affinity exponent, 2.5

The evaluators calculated % power in the baseline using the same formula as the applicant used, as follows:

$$\%Power\ = -1.6275 \times \%Flow^4 + 4.6096 \times \%Flow^3 - 4.7876 \times \%Flow^2 + 2.5645 \times \%Flow + 0.2392$$

The evaluators calculated the baseline input power using the following formula:

$$Baseline\ Annual\ Energy\ Use\ (kWh) = \frac{HP \times 0.746 \times \%\ Power_b\ \times LF}{Eff_{moto}}$$

where,

HP = Motor horsepower, 15HP

0.746 = HP to kW conversion ratio

$\%\ Power_b$ = Baseline % operating power of the motor

LF = Load factor, calibrated based on metered data, 100%

Eff_{motor} = Baseline motor efficiency, 87.8%

The annual energy savings are calculated as the annual total of hourly savings per the following formula:

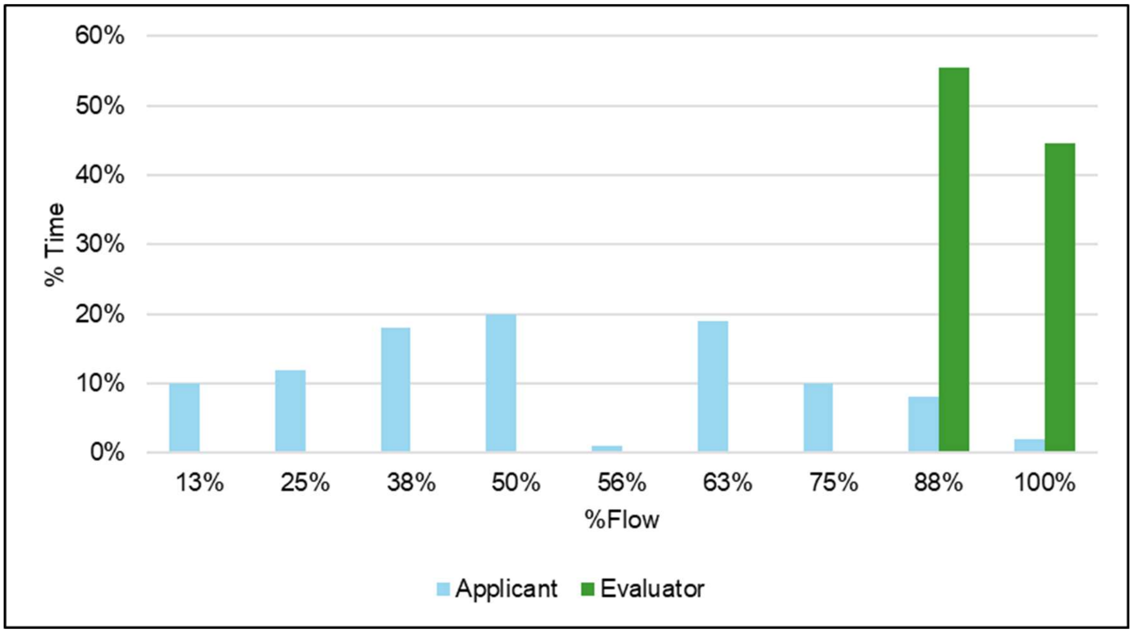
$$Svgs = \sum_{8760} (Baseline\ Annual\ Energy\ Use - Installed\ Annual\ Energy\ Use)$$

The evaluator modelled the %flow profile of each pump under baseline and installed models identically, i.e. when a pump is on in the proposed model, the pump is also on in the baseline model, with the same %flow because that is dictated by end use requirements. This approach is consistent with the applicant's methodology, that baseline and proposed models share identical run hours and % flow profiles.

The evaluator's data indicated that the end use is fairly constant (always-on, variation in flow mostly within 80% to 100% of the lead pump's capacity, with the lag pump operating less than 7% of the time). The metered data suggest that DHW and sprinkler loads, if any, are not significant contributors to flow requirements; the end use system is likely recirculation loops. Therefore, the evaluators applied the weekly profile from metered data over one typical month to the rest of the year (8760 hourly profile for the whole year) to extrapolate annual savings.

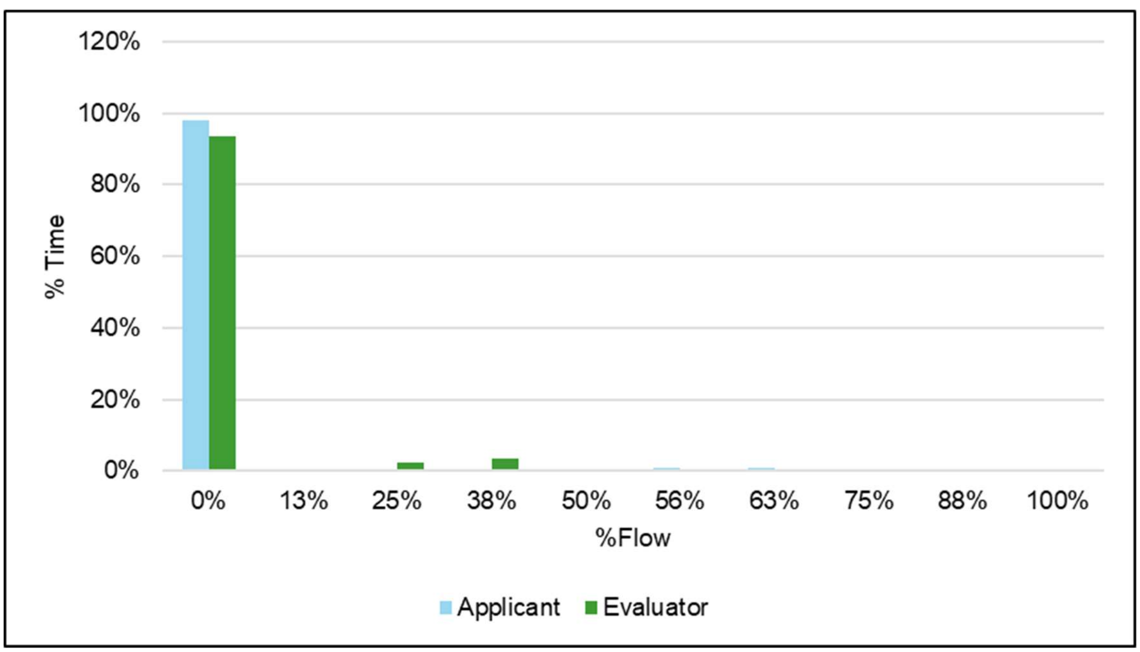
The evaluators observed that the most significant difference between the applicant's and evaluator's analysis lies in the flow profile for the lead pump. The applicant's estimated flow profile for the lead pump results in significantly lower and more distributed average flow than what the evaluator processed from metered data. The evaluator's analysis indicated that the lead pump predominantly operated near full speed. This difference contributed most significantly to savings deviations., because VFD savings are higher when the end use (i.e. % flow) is low, and savings are lower to zero when the %flow approaches full capacity. Figure 5-12 presents a visual comparison between the applicant's and evaluator's operating profile for the lead pump, in terms on percentage time operating at each percentage flow.

Figure 5-12. Comparison of applicant's and evaluator's lead pump flow profile



The lag pump's operations are less impactful to savings, because, in both the applicant's and evaluator's analysis, the lag pump's runtime is less than 10%. Figure 5-13

Figure 5-13. Comparison of applicant's and evaluator's lag pump flow profile



5.20 Final Results

The project consisted of retrofitting two pump motors with new motors and VFDs at a Middle School. The evaluator performed an 8760 hourly analysis, informed by site inspection and metered data, to calculate project savings. The evaluator's analysis indicated that the lead pump operated significantly more near full speed than the applicant estimated, which contributed to significantly lower evaluated savings compared to tracking savings. Table 5-57 provides a comparison of the key parameters.

Table 5-57. Summary of key parameters

Parameter	BASELINE		PROPOSED / INSTALLED	
	Tracking Value(s)	Evaluation Value(s)	Tracking Value(s)	Evaluation Value(s)
Motor size (hp each)	15	15	15	15
Motor efficiency	88%	88%	91%	91%
Pump load factor	80%	100%	80%	100%
Pump controls	Throttle valve	Throttle valve	VFD	VFD
Lead pump average % flow	50%	93%	50%	93%
Lag pump % time on	2%	7%	2%	7%
Annual operating hours	8,736	8,760	8,736	8,760

5.20.1 Explanation of Differences

The evaluated savings are lower than the applicant-reported values predominantly because of discrepancies in operations. The evaluation findings indicated that that lead pumps is predominantly fully loaded while the lag pump kicks on only occasionally. This contrasts with the applicant's estimation that the lead and lag pumps will have more evenly distributed operating speed profiles. VFD savings are lower when pumps are either not operating or operating near full speed. Table 5-58 provides a summary of savings deviations.

Table 5-58. Summary of deviations

Measure	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
11404547	Operation	Operating profile	-72.0%	**Decreased savings -** evaluation findings indicate one pump is typically fully loaded while the other is typically off, reducing VFD savings.
11404547	Operation	Load factor	9.3%	**Increased savings -** the calibrated load factor of 100% is higher than the applicant-assumed 80%.
Final RR				**37.3%**

5.20.2 Lifetime Savings

This measure has been classified as an add-on retrofit. The baseline is the pre-existing condition which consisted of the pre-existing pump motors without VFDs, controlled using a throttling valve.

The evaluators calculated applicant and evaluated lifetime savings values using the following formula:

$$\mathrm{LAGI} = \mathrm{FYS} \times \mathrm{EUL}$$

where:

LAGI = lifetime adjusted gross impact (kWh)

FYS = first year savings (kWh)

EUL = measure life (years)

Table 5-11 provides a summary of key factors that influence the lifetime savings.

Table 5-59. Measure 11404547 - lifetime savings summary

Factor	Tracking	Application	Evaluator
Lifetime savings	693,315 kWh	693,315 kWh	258,610 kWh
First year savings	46,221 kWh	46,221 kWh	17,241 kWh
Measure lifetime	15 years	15 years	15 years
Baseline classification	Retrofit	Retrofit	Add-on retrofit

5.20.2.1 Ancillary impacts

There were no ancillary impacts associated with the evaluated measure.

RICE20N009

Report Date: 8/2/2022

Program Administrator	National Grid
Application ID(s)	8044397
Project Type	Ops
Program Year	2020
Evaluation Firm	DMI
Evaluation Engineer	Bennett Rose
Senior Engineer	Mickey Bush

5.21 Evaluated Site Summary and Results

The evaluation site is a university and the evaluated project is the campus wide installation of a plug load management system. The plug load management system allows the site to cut power to plug loads according to a time of day schedule. The system provides energy savings by shutting equipment off at night when it is not in use, and therefore, eliminating stand-by plug losses.

The plug loads addressed by this project, based on the applicant counts, which differ from the post inspection counts, include: 593 window AC units, 250 printers, 144 printer/copiers, 82 TV/monitors, 18 snack vending machines, 32 soda vending machines, 8 large coffee dispensers, and 54 hot/cold water dispensers (588 total plug loads). The AC units and non window AC loads are located in office spaces, which are occupied year round. The total square footage covered by this project is 625,728 ft².

The tracking savings for this project is 289,016 kWh. The savings from window AC unit controls are 137,769 kWh (48% of total) and the savings from office equipment plug loads are 151,247 kWh (52% of total). This project is classified as a retrofit add-on project.

The total evaluated savings for this measure are 53,792 kWh per year. This is less than the tracking savings primarily due to the quantity of plug load controllers found to be in use being much less than assumed by the applicant and a lower AC unit cooling load than predicted. The evaluated savings are shown in Table 5-1.

Table 5-60. Evaluation Results Summary

PA Application ID	Measure Name		Annual Electric Energy (kWh)	% Of Energy Savings On-Peak	Summer On-Peak Demand (kW)	Winter On-Peak Demand (kW)
8044397	Plug Load Controls	Tracked	289,016	13.30%	8.34	15.71
		Evaluated	53,792	18%	1.55	2.17
		Realization Rate	19%	133%	19%	14%

5.21.1 Explanation of Deviations from Tracking

The evaluated savings are less than the tracking savings. One of the largest contributing factors was the quantity of controllers that are being utilized. The total installed quantity was less than assumed in the tracking analysis and a fraction of the installed controllers are being used at the time of the evaluation. In addition, the AC unit cooling load and the plug load standby demand were found to be lower than predicted and resulting in a decrease in savings.

5.21.2 Recommendations for Program Designers & Implementers

There are no recommendations at this time.

5.21.3 Customer Alert

After the site visit, where a large number of plug loads and AC units were plugged into uncontrolled outlets despite a controlled outlet being available, the site has indicated that they will conduct an inventory of the plug load controllers on campus and make an effort to improve the utilization rate of the controllers.

5.22 Evaluated Measures

The project consisted of the installation of inline plug load controllers to implement operating schedules for window AC units and plugin load controllers to implement operating schedules for office plug loads. The project was implemented on a college campus and covered multiple buildings. The campus wide plug load project was considered as one energy conservation measure under one application.

5.22.1 Application Information and Applicant Savings Methodology

This section describes the applicant's application information, savings methodology, and the evaluation assessment of the savings calculation algorithm used by the applicant.

5.22.2 Applicant Description of Baseline

The applicant classified this measure as a retrofit. The applicant described the pre-installation conditions at the facility as plug loads and AC units connected 24/7 with no automated controls.

Table 2-1 summarizes the applicant's baseline assumptions.

Table 5-61. Applicant baseline summary

Measure	Parameter	Value(s)	Source of Parameter Value
ECM 1	AC Unit Quantity	593	Applicant savings analysis
	AC Unit Enable Hours	1,028	Applicant savings analysis
	Average AC Demand	282.6 kW	Applicant savings analysis
	Plug Load Hours	8,760	Applicant savings analysis

	Plug Load Controller Quantity	M Print=250 / L Print/Copy=144 TV/Mon=82 / Snack Vend=18 Soda Vend=32 / Lg Coffee=8 H/C Water Disp.=54	Applicant savings analysis
	Plug Load Demand	M Print=20W / L Print/Copy=40W TV/Mon=8W / Snack Vend=40W Soda Vend=320W / Lg Coffee=56W H/C Water Disp.=75W Weighted Average=26.9W	Applicant savings analysis

5.22.2.1 Applicant Description of Installed Equipment and Operation

This section describes the proposed condition assumed in the applicant analysis. The proposed case includes plug load controls on window AC units and office plug loads that implement operating schedules that cut power during unoccupied periods. Table 5-3 summarizes the key proposed case inputs used in the applicant savings analysis.

Table 5-62. Application Proposed Case Key Parameters

Measure	Parameter	Value(s)	Source of Parameter Values
ECM 1	AC Unit Quantity	593	Applicant savings analysis
	AC Unit Enabled Hours	514	Applicant savings analysis
	Average AC Demand	296.8 kW	Applicant savings analysis
	Plug Load Hours	3,132	Applicant savings analysis
	Plug Load Controller Quantity	M Print=250 / L Print/Copy=144 TV/Mon=82 / Snack Vend=18 Soda Vend=32 / Lg Coffee=8 H/C Water Disp.=54	Applicant savings analysis
	Plug Load Demand	M Print=20W / L Print/Copy=40W TV/Mon=8W / Snack Vend=40W Soda Vend=320W / Lg Coffee=56W H/C Water Disp.=75W Weighted Average=26.9W	Applicant savings analysis

5.22.2.2 Applicant Energy Savings Algorithm

Inline Plug Load Controllers (AC Units)

The applicant assumes 593 window AC units will be included in the project with an average capacity of 1 ton per unit. It is assumed that the AC units have a cooling performance of 8 SEER.

A bin analysis is used to compare cooling loads and hours with a base and proposed operating schedule. The base schedule is 6AM through 8PM, 7 days/week 26 weeks per year, which assumes that the AC units are manually turned off and on at these times. The proposed schedule is 7AM-6PM Monday through Friday 22 weeks per year.

The total hours when the OAT is greater than 60°F (i.e., when AC units are expected to run) is 1,028 hours for the base case schedule, 514 hours for the proposed case schedule.

The weighted average demand calculated for each case based on an estimated cooling load profile was 282.6 kW for the base case and 296.8 kW for the proposed case. The calculation of these weighted averages is summarized in the table below.

Table 5-3. AC Unit Bin Analysis

OAT	Cooling Load (%)	Cooling kW	Existing Hours	Proposed Hours	Saved Hours
97	100%	889.5	3	2	1
92	86%	769.3	16	10	7
87	73%	649.1	52	30	22
82	59%	528.9	110	62	48
77	46%	408.7	172	91	81
72	32%	288.5	224	109	114
67	19%	168.3	231	109	122
62	5%	48.1	222	103	119
Total Energy			**290,473**	**152,704**	**137,769**

Plugin Plug Load Controllers (Other Plug Loads)

The analysis assumes a demand for each type of plug load, 8,760 base case operating hours, and 3,132 proposed case hours (equates to 12 hr/day, 5 days/week). Savings are calculated for each type of plug load using the following formula:

Plug Savings = No. of equipment x Average kW x (8,760 hours – 3,312 hours)

The counts and average demand for each plug load is presented in the following table.

Table 5-4. Plug Load Savings Summary

End Use	Demand		Hours			Saved	% of
	QTY	W/Unit	Base	Prop	Saved	kWh	Total
M Print	250	20	8,760	3,132	5,628	28,140	19%
L Print/Copy	144	40	8,760	3,132	5,628	32,417	21%
TV/Mon	82	8	8,760	3,132	5,628	3,692	2%
Snack Vend	18	40	8,760	3,132	5,628	4,052	3%
Soda Vend	32	320	8,760	3,132	5,628	57,631	38%
Lg Coffee	8	56	8,760	3,132	5,628	2,521	2%
H/C Water Disp.	54	75	8,760	3,132	5,628	22,793	15%
Total	**588**	**26.9**	**8,760**	**3,132**	**5,628**	**151,247**	**100%**

5.22.2.3 Evaluation Assessment of Applicant Methodology

The evaluators agree with the applicant's methodology, however there were assumptions made in the analysis that could have been updated including quantity assumptions. The post inspection indicates a total of 520 AC units, not

593 AC units. The post inspection says 435 plug-in controllers were installed not 588. These post inspection findings should have been used to update the savings.

5.22.3 On-Site Inspection and Metering

This section provides details on the tasks performed during the onsite inspection and the date it was conducted, and how it was conducted.

5.22.3.1 Summary of On-Site Findings

This section summarizes the onsite findings and trend data collected from the site.

- Trends were collected for the inline controllers (AC units) and plug-in controllers. The trend data is provided in 1 hour intervals from 10/8/2019 through 7/18/2022 and includes pre-installation and post-installation data.
- The trend data reports 0 watts for the entire trend period for some of the loads. The onsite findings confirmed that controller trend points reading 0 were either removed end users or nothing was plugged into them. In many of these cases it was found that a controller was in place but the plug load intended to be controlled was plugged into a separate outlet so as to bypass the plug load controller. In other cases, it appeared that the plug load intended to be controlled may have been relocated to another space and the controller remained in place but unused.

Table 5-5. Measure Verification

Measure Name	Verification Method	Verification Result
Plug Load Controls	Sample of controllers were observed onsite. For equipment not observed trends were used to determine which equipment is not connected to a controller. Trends were used to observe the installed time of day schedules.	Most plug load controllers were no longer in use or had been bypassed by end users of equipment. 273 AC units and 137 plug loads were found to be plugged into a controller and realizing savings. (This is 31% of the total controllers modelled by the applicant.) As a result of the evaluation site visit, the site is going to conduct a full inventory of plug load controllers to increase usage of installed controllers across campus.

The data shows the wattage for every plug load controller installed on campus over the course of the trend period. The trend period goes from 10/8/19 to 7/18/22, but there are data gaps. According to the plug load control contractor, these data gaps correspond to issues with the server that prevented data collection. The three data periods of continuously collected data used in the evaluated savings analysis are the pre-installation / baseline period (6/20/2020-8/24/2020), and the installed operation period (6/30/2022-7/19/2022). Installed case trend data was also provided from 7/9/21-9/1/21, but the evaluated savings are based on the more recent 2022 installed trend data. These same periods are used in the analysis for AC unit and plug load controllers.

There are some plug loads that did not log data for one or more of the time periods described above. This indicates that the data logging issue is associated with the controller itself and not the server. According to the plug load control contractor, the most likely explanation is that nothing is plugged into the controller or the controller was removed. The onsite findings verified that the controllers were bypassed in these cases. See picture of examples below.

Figure 2-1: Unused Inline Controller (Left) and Unused Plugin Controller (Right)

The trend data for the inline plug load controllers (AC units) is presented below showing the total wattage of units during the metering period.

Figure 5-2. Raw AC Unit Controller Wattage Trend Data

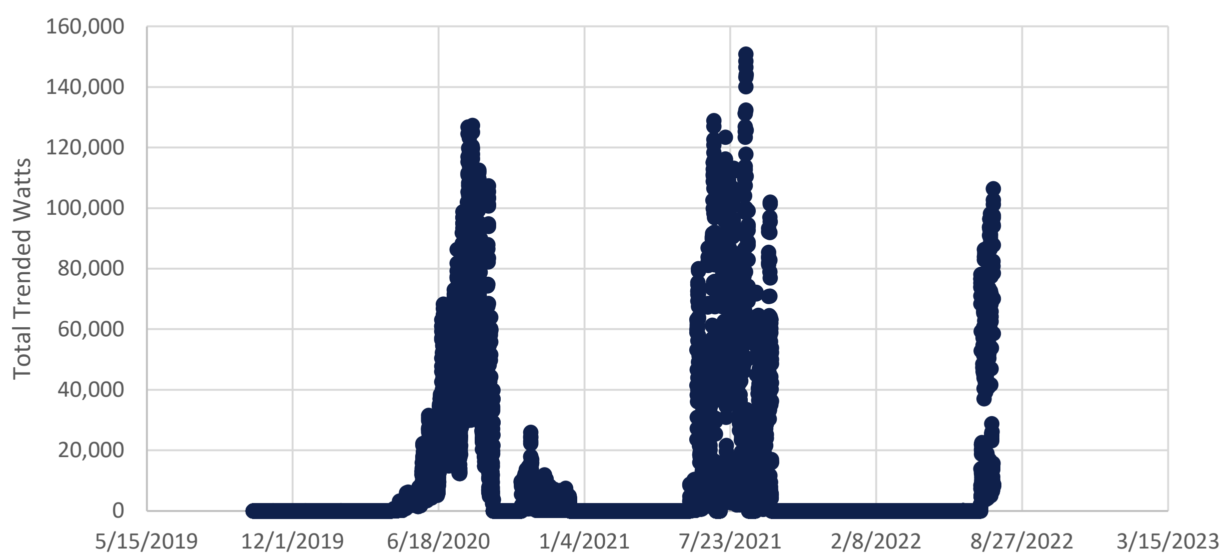
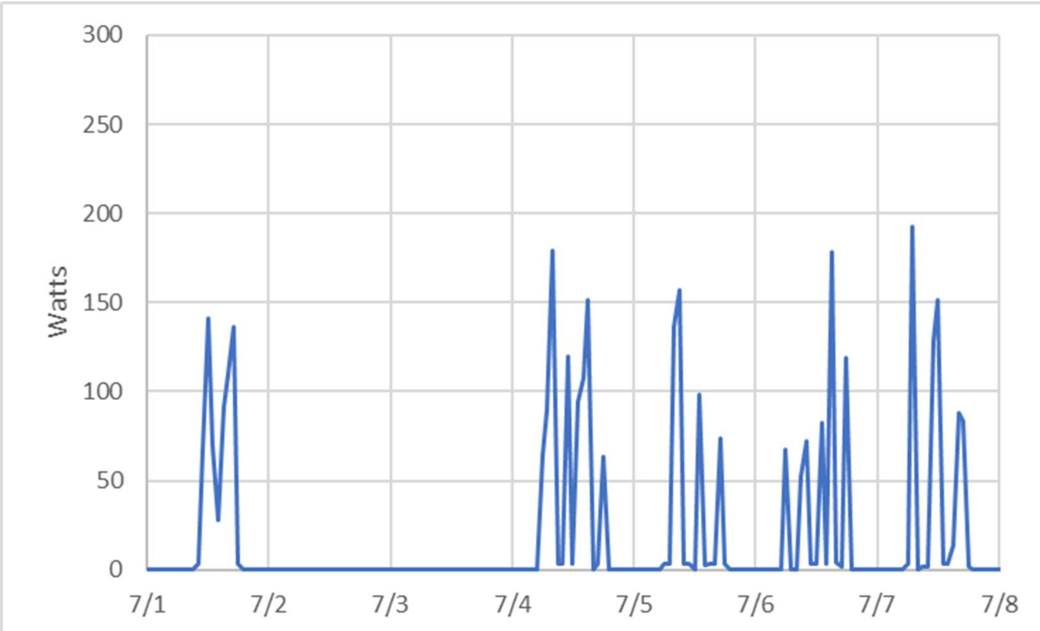


Figure 5-3. Representative AC Unit Controller Installed Case (2022)



The trend data for the plugin plug load controllers is presented below showing the total wattage of all units during the metering period.

Figure 5-4. Raw Plugin Plug Controller Wattage Trend Data

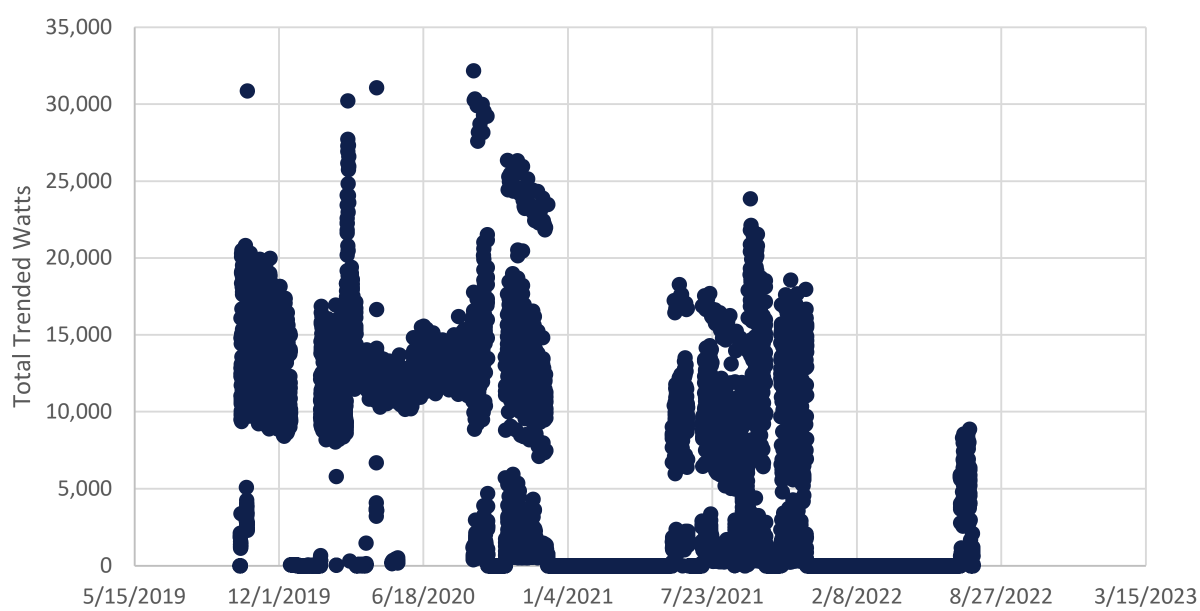
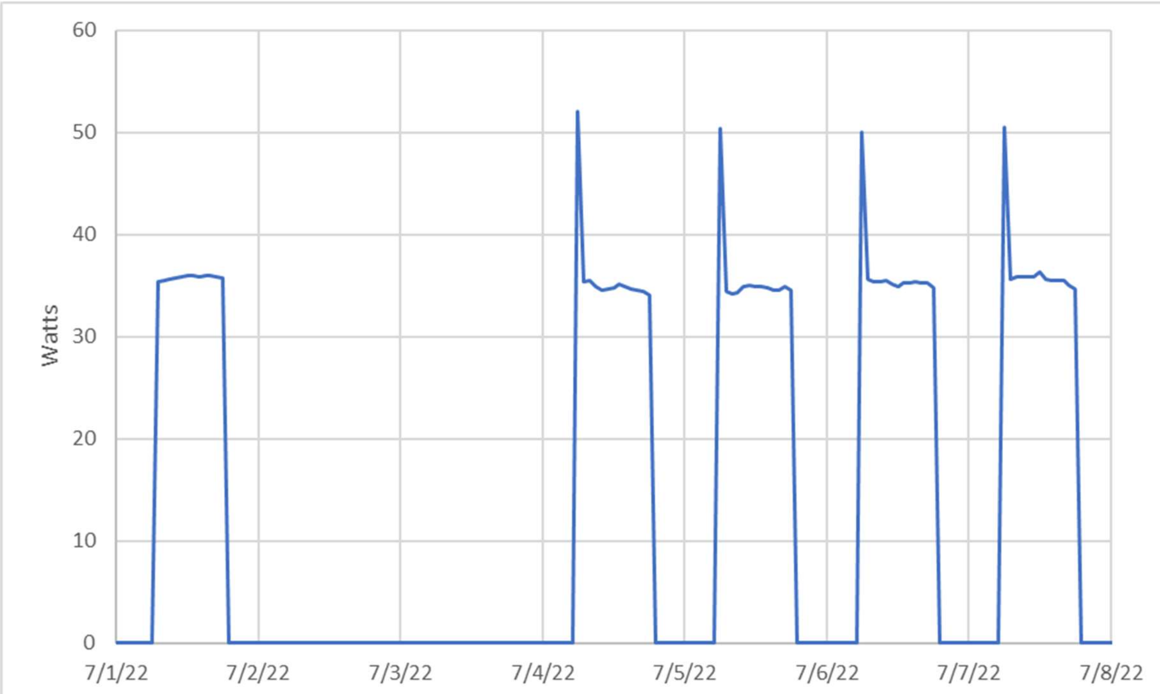


Figure 5-5. Representative Plug Load Controller Installed Case (2022)



5.22.4 Evaluation Methods and Findings

This section describes the evaluator methods and findings.

5.22.4.1 Evaluation Description of Baseline

The project is classified as an add-on retrofit measure. The evaluator agrees with the applicant's baseline of AC units and plug loads plugged into standard wall outlets with no automatic controls to cut off power during scheduled unoccupied periods.

Tables 2-6 and 2-10 show the baseline operation of all AC units and plug loads respectively.

A plot of the baseline input power for a representative AC unit (same as Figure 2-4) over 1 week is shown below in Figure 2-6 to show that the unit was cycling on during all hours.

A plot of the baseline input power for a representative plug load (same as Figure 2-5) over 1 week is shown below in Figure 2-7 to show that the unit operated at the standby demand overnight.

Figure 5-6. Representative AC Unit – Baseline Period (2020)

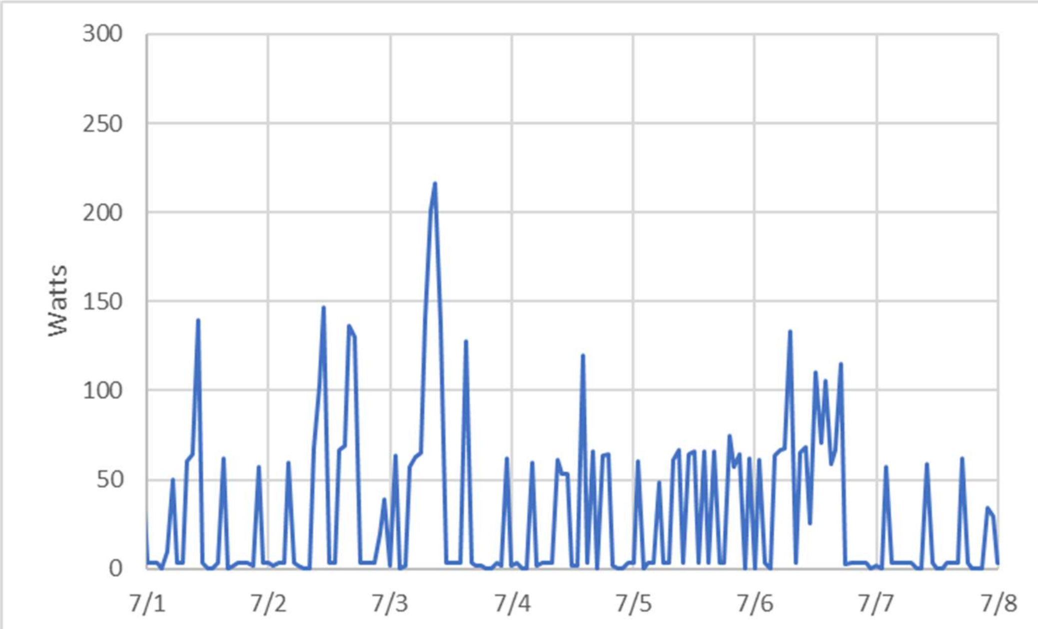
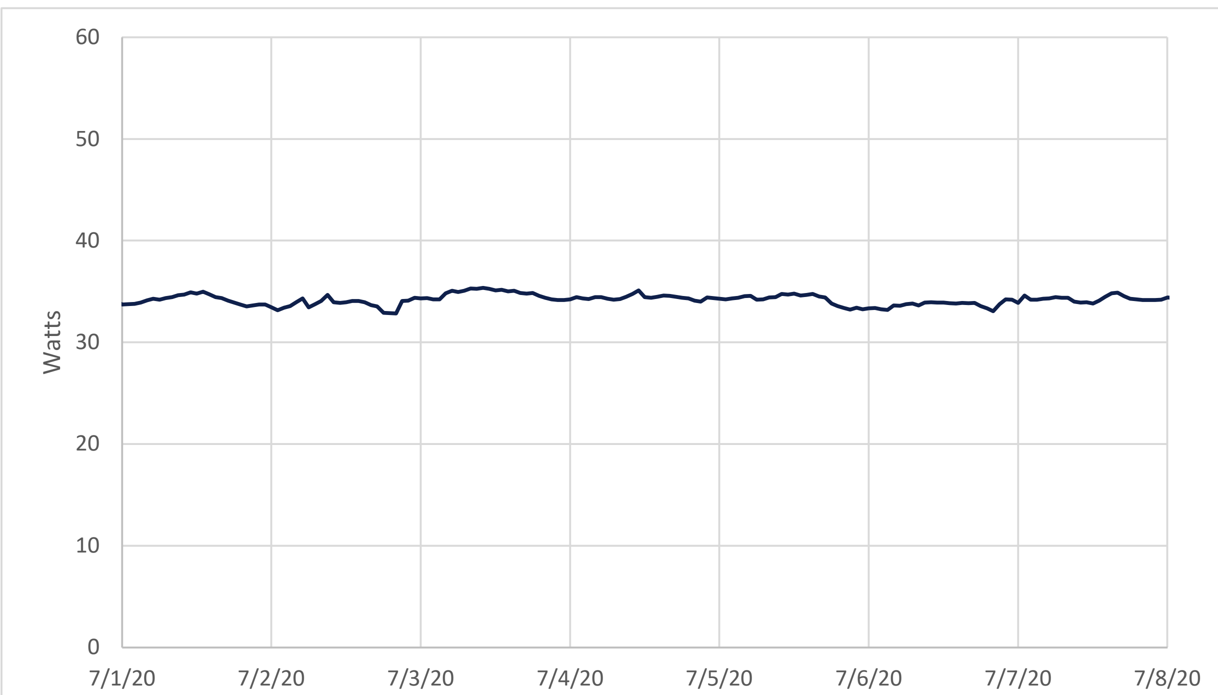


Figure 5-7. Representative Plug Load– Baseline Period (2020)



5.22.4.2 Evaluation Calculation Method

Inline Controllers (AC Units)

AC unit base and proposed energy is calculated using a bin model for a typical weather year.

To ensure an apples-to-apples comparison, the campus wide profile only considers demand associated with controllers that are connected to a load (AC unit) during the pre-installation baseline time period (2020), and the installed case time period (2022). This is determined based on whether or not trends were recorded for a given plug load during these periods.

Inline Controllers (AC Units) – Implemented Schedule

The evaluated energy savings analysis for the AC inline controllers considers the campus wide operating profile during unoccupied hours before and after implementing time of day plug load controls. Unoccupied hours are defined based on the schedules set up in the installed controllers. The occupied hours are 6am to 7pm on weekdays. Unoccupied hours are 7pm to 6am on weekdays and all day on weekends.

The tables below show the average wattage of all controlled units on a day of week/time of day basis during the baseline and post-installation period. The baseline data indicates that there was no time-of-day schedule prior to the controllers. The installed case table trend indicates that the occupied hours are 6AM-7PM Monday through Friday and that approximately 25% of AC units are on a 24/7 schedule. Note that day of week format used in this analysis is Monday=1

The new controllers only save energy by adding a time-of-day schedule which disables the equipment at night. Any changes in daytime operation shown in this plot are due to factors outside of this measure such as outside air temperatures or space temperature setpoints.

A total of 237 AC unit run during the pre- and post-installed case trend period. The units do not run continuously. The average number of units running during the daytime (scheduled on) hours is 135 units. An average of 27 AC units do not appear to include a time of day schedule and are observed running at night.

Table 5-6. AC Unit Baseline (No Schedule) (Total Watts based on time of day/day of week)

Hour	Day of Week						
	1	2	3	4	5	6	7
0	28,166	29,309	26,961	26,302	24,717	20,341	24,142
1	27,615	28,750	26,493	25,299	24,193	19,881	24,211
2	26,100	27,758	24,713	24,369	22,948	19,095	23,454
3	25,606	27,118	23,823	23,320	22,208	18,499	22,669
4	25,840	25,636	23,574	22,732	21,973	18,105	21,848
5	25,893	28,227	25,443	23,686	22,128	18,218	21,785
6	28,405	31,471	30,850	27,462	26,629	19,303	22,368
7	33,774	36,938	34,790	31,606	29,476	22,666	25,971
8	42,212	46,001	40,971	39,996	35,238	28,788	30,786
9	49,561	53,207	45,717	45,809	40,147	31,974	34,711
10	53,589	57,566	49,856	48,742	42,892	33,992	37,289
11	54,800	57,299	50,271	47,288	42,705	34,302	37,697
12	54,259	55,448	49,777	47,146	42,561	34,301	37,196
13	52,988	54,684	49,967	47,723	42,134	33,746	38,172
14	53,800	54,751	49,549	47,889	42,112	34,630	39,717
15	51,375	51,882	48,634	46,917	41,421	35,164	39,636
16	47,584	46,369	45,899	43,465	38,568	34,014	38,786
17	43,223	42,510	42,339	38,260	35,018	31,691	36,439
18	37,648	37,058	36,638	33,330	30,953	29,215	33,990
19	34,224	30,683	32,400	29,488	25,894	26,989	31,582
20	32,288	29,533	29,783	27,495	23,884	25,220	29,390
21	31,140	28,371	28,172	26,426	22,371	24,845	28,099
22	29,867	27,380	27,101	25,720	21,676	24,134	27,483
23	29,753	27,634	26,703	25,806	20,896	23,182	28,225

Table 5-7. AC Unit Installed Case Schedule (Total Watts based on time of day/day of week)

Hour	Day of Week						
	1	2	3	4	5	6	7
0	5,095	4,615	5,679	6,153	3,581	5,245	4,864
1	5,006	4,402	5,796	6,182	3,834	5,077	4,702
2	4,872	4,040	6,236	5,782	3,132	4,903	4,543
3	4,782	4,583	6,576	6,378	3,505	4,932	4,499
4	5,166	5,281	6,974	6,808	3,295	4,918	4,386
5	8,034	5,715	11,865	11,077	4,696	8,278	4,360
6	49,152	41,353	51,955	48,506	25,161	7,858	4,880
7	52,406	42,884	55,168	54,818	29,280	8,738	5,905
8	61,212	49,180	66,383	64,065	40,267	19,551	7,748
9	65,130	57,070	73,707	68,876	59,484	20,926	7,432
10	65,901	58,564	78,247	71,174	61,613	20,172	8,356
11	65,141	58,549	80,141	69,979	60,889	20,046	8,628
12	65,099	61,081	81,270	70,187	61,822	19,650	8,587
13	64,105	61,198	81,710	72,568	63,851	18,575	8,758
14	64,360	61,232	81,110	74,673	65,705	20,881	10,162
15	62,725	54,481	76,622	64,333	64,665	21,233	10,994
16	55,435	46,643	65,298	55,908	56,599	11,779	10,403
17	48,942	40,329	58,255	49,881	49,376	9,613	7,628
18	41,127	35,036	48,309	42,093	42,847	8,081	6,332
19	6,013	5,773	7,038	6,213	5,396	7,500	5,616
20	5,599	5,393	6,884	5,516	4,880	6,934	4,987
21	5,621	4,952	6,512	5,691	4,879	6,864	5,296
22	5,431	5,241	6,282	5,099	4,862	6,886	5,086
23	5,507	5,357	6,886	5,198	4,645	6,644	5,165

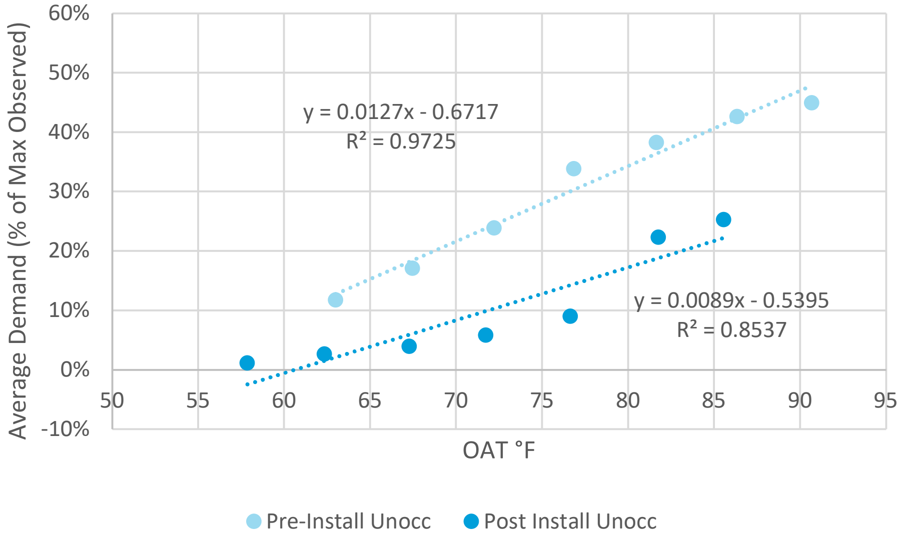
Inline Controllers (AC Units) – Cooling Load Profile

AC unit demand in each temperature bin is calculated based on baseline and installed case trend data.

The evaluated savings are based on the units that were logging data at the time of evaluation as it was found that this indicates the load is still connected to a controller. No evaluated savings are considered for units that are not logging data at the time of evaluation as it was found that this indicates the load is not connected to an inline a controller. There are 273 units that were logging data at the time of evaluation which is greater than the 237 units that were logging data during both the baseline and evaluation trend period.

The figure below compares the pre-install and post-install AC demand profile during unoccupied hours as a function of outside air temperature for the 237 units where baseline and evaluation trend data is available.

Figure 5-8. Unoccupied AC Load Summary



A percent of peak demand is used instead of watts in Figure 2-8 because baseline data is not available for all of the installed AC units. The average demand percentage shown in Figure 2-8 used to calculate the unoccupied load profile is defined by the following formula.

$$Average\ Hourly\ Demand\ \% = \frac{Total\ Demand}{Maximum\ Total\ Demand}$$

The maximum total demand is the observed peak cooling load for all units. Each unit runs at its peak demand (and associated cooling capacity) at some point during the trend period. The sum of the maximum demand associated with each individual load is the total cooling capacity.

These two values are used to calculate the diversity factor or % cooling load associated with campus wide AC loads. The diversity factor is calculated using the following formula.

$$Diversity\ factor = \frac{Maximum\ Total\ Demand\ (or\ Peak\ load)}{\sum Maximum\ Demand\ For\ Each\ AC\ Unit\ (or\ Total\ Capacity)} = \frac{106{,}800\ W}{234{,}784\ W} = 0.455$$

The diversity factor is used to scale the modelled savings from the data set used to make the unoccupied load comparison (237 units) based on the total connected load of all the evaluated AC Unit controllers (273 units). Table 2-8 summarizes this calculation.

Table 5-8. Evaluated AC Unit Total Watts

Parameter	Analysis Data Set	Evaluated Data Set
# of Units	237	273
Connected Watts (Cooling Capacity)	234,784	267,067
Diversity Factor	45%	45%
Total Peak Load in Watts (Peak Occupied Load)	106,800	121,485

The modelled baseline and proposed wattage in each bin is

$$Modeled\ Total\ Demand\ for\ 273\ units\ =\ Max\ Total\ Demand\ for\ 273\ units\ x\ Average\ Demand\ \%\ (Figure\ 2-8)$$

Inline Controllers (AC Units) – Typical Year Savings

TMY3 bin data based on the unoccupied schedule of weekdays 7pm to 6am and all day on weekends and assuming the units are enabled April to October, the pre-install and post-install unoccupied demand profile summarized in Figure 2-1, and the diversity factor described above are used to calculate the evaluated inline plug load controller savings. The table below summarizes the evaluation savings calculated for the inline plug load controls (AC units).

Table 5-8. Evaluated Inline AC Unit Controller Savings

Hours	OAT	Pre Install		Post Install		Savings	
		% of Peak	W	% of Peak	W	kW	kWh
1.0	95.0	53.3%	64,637	17.4%	21,189	43.4	41
12.7	91.8	49.3%	59,858	16.0%	19,472	40.4	513
23.6	87.8	44.2%	53,737	14.2%	17,273	36.5	861
103.4	81.9	36.7%	44,792	11.6%	14,059	30.7	3,159
209.9	76.6	30.0%	36,756	9.2%	11,171	25.6	5,198
306.6	72.4	24.7%	30,432	7.3%	8,900	21.5	6,448
524.4	68.0	19.1%	23,792	5.4%	6,514	17.3	8,560
594.1	62.4	12.0%	15,531	2.9%	3,546	12.0	5,984
395.9	57.0	5.1%	7,137	0.4%	530	6.6	1,934

The total evaluated savings for the inline plug load controllers are 28,745 kWh. The on peak energy savings are summarized in Table 2-6. There are no peak demand savings associated with the inline plug controllers due to the observed occupancy schedule.

Table 5-9. Evaluated Inline Plug Load Controller Savings

Season	Savings kWh	
	On-Peak	Off-Peak
Winter	579	3,272
Summer	5,325	23,523

Plugin Plug Load Controllers (Other Plug Loads)

The evaluated energy savings for this measure consider the campus wide operating profile before and after implementing time of day plug load controls.

There is a total of 145 installed end uses connected to plug load controllers.

There is pre-installation / baseline and installed case trend data available for 136 of the plug loads and savings for these loads are based on a comparison of the trend data sets.

There are 9 plug loads for which trend data is available during the installed case trend period, but not during the baseline trend period. Savings for these plug loads are included in the evaluation savings because the evaluation has found that these plug loads are being controlled and standby losses are being eliminated during scheduled unoccupied periods. The baseline night time standby demand for these loads is calculated based on the installed case trend data as described below.

136 Plug Loads with Baseline and Installed Trends

The plug load profile was found to be independent of outside air temperature.

The tables below show the total wattage of these systems on a day of week/time of day basis during the pre-installation / baseline and installed period. Note that day of week format used in this analysis is Monday=1.

Table 5-10. Pre-Installation Plug Load Demand Profile (Watts)

Hour	Day of Week						
	1	2	3	4	5	6	7
0	3,681	3,694	3,678	3,641	3,765	3,811	3,787
1	3,740	3,747	3,712	3,698	3,731	3,817	3,812
2	3,822	3,737	3,717	3,785	3,705	3,791	3,685
3	3,758	3,724	3,714	3,614	3,674	3,773	3,793
4	3,769	3,723	3,626	3,598	3,748	3,678	3,809
5	3,756	3,686	3,683	3,720	3,642	3,642	3,760
6	3,741	3,731	3,738	3,764	3,742	3,786	3,750
7	3,742	3,819	3,744	3,698	3,739	3,723	3,789
8	3,819	3,865	3,780	3,882	3,725	3,679	3,686
9	3,928	3,907	3,995	4,017	3,863	3,801	3,826
10	4,207	4,004	4,008	4,035	3,982	3,734	3,826
11	3,950	4,008	4,003	3,989	3,929	3,682	3,867
12	3,944	3,910	4,005	3,905	3,963	3,737	3,866
13	3,979	3,997	4,031	3,904	4,009	3,825	3,865
14	4,044	4,090	3,889	3,990	4,062	3,803	3,828
15	4,003	3,991	3,987	3,791	3,926	3,783	3,897
16	3,808	3,873	3,812	3,853	3,868	3,793	3,765
17	3,782	3,890	3,758	3,789	3,877	3,768	3,818
18	3,825	3,813	3,782	3,787	3,764	3,915	3,853
19	3,790	3,786	3,735	3,712	3,836	3,697	3,872
20	3,721	3,755	3,706	3,679	3,650	3,784	3,811
21	3,643	3,721	3,673	3,744	3,745	3,701	3,782
22	3,779	3,672	3,731	3,670	3,788	3,704	3,781
23	3,693	3,759	3,681	3,727	3,745	3,869	3,883

Table 5-11. Post-Installation Plug Load Demand Profile (Watts)

Hour	Day of Week						
	1	2	3	4	5	6	7

0	520	543	618	549	541	519	511
1	542	549	567	528	564	540	526
2	492	509	594	544	534	554	538
3	482	527	620	572	585	540	486
4	554	538	535	539	459	561	544
5	516	525	609	499	595	509	539
6	7,893	7,574	7,730	7,656	7,842	544	469
7	4,282	4,032	4,197	4,108	4,062	539	530
8	4,407	4,016	4,311	4,151	4,262	676	563
9	4,395	4,165	4,491	4,038	4,468	595	477
10	4,444	4,000	4,453	4,160	4,326	628	509
11	4,165	4,167	4,266	4,081	4,095	640	582
12	4,061	4,025	4,089	4,295	4,007	610	527
13	4,131	3,858	4,074	4,161	4,082	614	501
14	4,237	3,910	3,923	4,272	4,090	597	539
15	4,426	4,275	3,952	4,094	3,914	636	516
16	4,098	4,108	3,891	3,773	3,611	500	549
17	3,554	3,540	3,615	3,596	3,564	526	517
18	2,446	2,602	2,548	2,569	2,603	593	518
19	723	739	727	733	738	473	560
20	685	742	734	687	720	518	477
21	554	642	565	585	539	572	526
22	568	587	558	584	584	506	551
23	517	585	562	522	577	541	495

An impact of the plug load controls is the spike in demand when all of the plug loads are started at 6AM on the weekdays. This indicates that the initial start-up demand for these plug loads is higher than the average operating demand.

Because these load profiles are considering the same individual plug loads and the schedule does not need to be generalized to calculate the impact of outside air temperature on plug load demand, the savings are calculated on a time of day, day of week basis by subtracting Table 2-8 from Table 2-7. It is assumed that any variation in plug loads from 7AM-5PM Monday through Friday is not due to plug loads controls installed as part of this application and are not considered. Daytime differences in plug load energy is assumed to be due to the number of uses of the plug load, which is unrelated to the installed controllers. The time of day, day of week demand savings are presented in Table 2-9.

Table 5-12. Plugin Plug Load Controller Time of Day, Day of Week Savings (kW)

Hour	Day of Week						
	1	2	3	4	5	6	7

0	3.2	3.2	3.1	3.1	3.2	3.3	3.3
1	3.2	3.2	3.1	3.2	3.2	3.3	3.3
2	3.3	3.2	3.1	3.2	3.2	3.2	3.1
3	3.3	3.2	3.1	3.0	3.1	3.2	3.3
4	3.2	3.2	3.1	3.1	3.3	3.1	3.3
5	3.2	3.2	3.1	3.2	3.0	3.1	3.2
6	-4.2	-3.8	-4.0	-3.9	-4.1	3.2	3.3
7	0.0	0.0	0.0	0.0	0.0	3.2	3.3
8	0.0	0.0	0.0	0.0	0.0	3.0	3.1
9	0.0	0.0	0.0	0.0	0.0	3.2	3.3
10	0.0	0.0	0.0	0.0	0.0	3.1	3.3
11	0.0	0.0	0.0	0.0	0.0	3.0	3.3
12	0.0	0.0	0.0	0.0	0.0	3.1	3.3
13	0.0	0.0	0.0	0.0	0.0	3.2	3.4
14	0.0	0.0	0.0	0.0	0.0	3.2	3.3
15	0.0	0.0	0.0	0.0	0.0	3.1	3.4
16	0.0	0.0	0.0	0.0	0.0	3.3	3.2
17	0.0	0.0	0.0	0.0	0.0	3.2	3.3
18	1.4	1.2	1.2	1.2	1.2	3.3	3.3
19	3.1	3.0	3.0	3.0	3.1	3.2	3.3
20	3.0	3.0	3.0	3.0	2.9	3.3	3.3
21	3.1	3.1	3.1	3.2	3.2	3.1	3.3
22	3.2	3.1	3.2	3.1	3.2	3.2	3.2
23	3.2	3.2	3.1	3.2	3.2	3.3	3.4

This time of day, day of week energy savings profile is applied to an 8,760 model to calculate energy savings for the plugin plug load controls. The evaluated energy savings for the 136 plugin plug load controllers with baseline and installed trend data using this methodology are 19,913 kWh.

9 Plug Loads with Installed Trends Only

There are 9 plug loads for which trend data is available during the installed case trend period, but not during the baseline trend period. The savings for these plug loads is not included in table 2-12.

The standby losses for these plug loads are calculated assuming that the standby load is equal to the non-zero minimum during the evaluation trend period. The sum of the standby losses for these nine (9) plug loads is equal to 219 W. The savings for these plug loads are calculated using the following formula where the unoccupied hours is based on the time of schedule identified in Table 2-12. The unoccupied hours are 6pm to 6am on weekdays and all day on weekends.

Additional Plug Load Savings = 219.7W*5,380 unoccupied hours = 1,182 kWh

The total evaluated plugin plug load controller savings are 21,094 kWh.

The peak energy and demand savings are summarized in the table below.

Table 5-14. Peak Savings Summary

Season	Savings kWh	
	On-Peak	Off-Peak
Winter	2,844	11,259
Summer	1,464	5,527
Peak Demand Savings		
Summer kW		1.55
Winter kW		2.17

5.23 Final Results

The evaluated savings are less than the tracking savings for this project. The biggest contributing factor to this difference in savings is the amount of plug load controllers in use at the time of the evaluation. Other applicant analysis assumptions were found to be overly aggressive. A complete comparison of the tracking and applicant savings parameters are presented in the table below.

Table 5-63. Summary of Key Parameters

	BASELINE		PROPOSED / INSTALLED	
Parameter	Tracking Value(s)	Evaluation Value(s)	Tracking Value(s)	Evaluation Value(s)
AC Units w/ Inline Controls	0 of 593	0 of 506	593 of 593	273 of 506
Average Total AC Unit Demand during scheduled off periods	255 kW	23.3 kW	0 kW	7.5 kW
AC Unit Saved Hours	514	1,930	514	1,930
Plugin Loads w/ Plug Load Controls	0 of 588	0 of 414	588 of 588	145 of 414
Average Plug Load Demand Occupied	26.9 kW	4.33 kW	26.9 kW	4.36 kW
Average Plug Load Demand Unoccupied	26.9 kW	4.38 kW	0 kW	0.43 kW
Plug Load Occupied Hours	3,132	3,380	3,132	3,380
Plug Load Unoccupied Hours	5,628	5,380	5,628	5,380
Total Plug Load Powered Hours	8,760	8,760	3,132	3,380

5.23.1 Explanation of Differences

The evaluated savings are 19% of the applicant's savings. The largest discrepancies are the quantity of plug load controllers in use at the time of evaluation being less than assumed by the applicant (40% of assumed AC controller quantity and 22% of assumed plug load controller quantity) and the lower AC unit cooling load than predicted.

Table 5-64. Discrepancy Table

Measure	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations

8044397	Quantity	Controller Quantity	-33%	**Decreased savings –** 237 AC controllers being used and 145 plug load controllers being used compared the applicant estimate of 593 AC controllers and 588 plug load controllers. The difference in quantities is due to a difference in installed controllers as identified during the post inspection and a difference in installed controllers that are tied to a piece of equipment.
8044397	Operation	AC Unit Cooling Load	-38%	**Decreased savings –** The average cooling load and associated AC unit demand are lower than estimated by the applicant. The applicant assumed the units would run fully loaded on a peak cooling day, but the evaluation found the peak nighttime (savings period) load was ~24% of the cooling capacity. Also, the cooling capacity for each AC unit was estimated to be 1.5 kW input, but the capacity is 0.8 kW. The decrease in the cooling load is partially offset by an increase in cooling hours. The applicant appeared to assume that the AC units would be manually shut off for some of the night hours in the baseline, but the evaluator found that a significant number of units

				remained on all night in the baseline.
8044397	Operation	Plug Load Hours	-1%	**Decreased savings –** The applicant assumed the plug load schedule would provide savings for 5,628 hours per year and the evaluation found the implemented schedule provides savings for 5,380 hours per year.
8044397	Operation	Plug Load Demand	-10%	**Decreased savings –** The evaluator found a lower standby load (watts) per unit compared to the applicant. The applicant standby demand was 45.7 watts/unit and the evaluated standby demand is ~32 watts/unit. Also, the evaluator found that a small number of plug loads remain on 24/7 in the installed case.

5.23.2 Lifetime Savings

The evaluators classified the measure as an add-on with a single baseline. The evaluators calculated applicant and evaluated lifetime savings values using the following formula:

$$\mathrm{LAGI} = \mathrm{FYS} \times \mathrm{EUL}$$

where:

LAGI = lifetime adjusted gross impact (kWh)

FYS = first year savings (kWh)

EUL = measure life (years)

The evaluated lifetime savings are less than the tracking lifetime savings because the evaluated first year savings are less than the tracking first year savings. Table 5-11 provides a summary of key factors that influence the lifetime savings.

Table 5-65. Measure 11160436 - Lifetime Savings Summary

Factor	Tracking	Evaluator
Lifetime savings (kWh)	1,445,079	268,959
First year savings (kwh)	289,016	53,792
Measure lifetime (years)	5	5
Measure life reference	Screening Tool	Screening Tool
Measure event type	Retrofit	Retrofit
Baseline classification	Single – Pre existing	Single – Pre existing
Measure status (operational or removed)	N/A	Operational

N/A = Not Applicable

The evaluation uses the same 5-year measure life as the applicant.

5.23.2.1 Ancillary impacts

There may be an increase in unoccupied space heating load and a decrease in unoccupied space cooling load associated with the reduction in unoccupied plug loads that result from implementing plug load controls for office plug loads.

RICE20N041

Report Date: 7/13/2022

Program	Custom Electric	
Application ID(s)	10566704	
Project Type	C&I Initial Purchase & End of Useful Life	
Program Year	2020	
Evaluation Firm	DNV	
Evaluation Engineer	Shravan Iyer	
Senior Engineer	Joseph St.John	

5.24 Evaluated Site Summary and Results

The site is an industrial facility that uses injection molding machines to manufacture plastic components for various end-use applications. The facility's production schedules are: The first shift begins at 6:45 a.m. and lasts until 3:15 p.m., the second shift between 3:15 p.m. and 10:45 p.m., and the third shift between 10:45 p.m. and 6:45 a.m. The compressed air system in the facility consists of (1) 200HP two-stage variable speed compressor and (1) 150 HP two-stage rotary screw compressor with modulation controls. The air from the compressors runs through a 2000 cfm refrigerated air dryer (with a VFD) to remove the moisture content in the air before feeding the plant. The 150HP compressor operates from Monday through Friday as the baseload compressor, and the 200HP compressor serves as a trim compressor during the week and as the only compressor during the weekend. Both compressors are usually required to run to maintain plant pressure. The production is shut down for two days a year for preventive maintenance. The project consists of single energy efficiency measure (EEM) as follows:

EEM-1: Fixing air leaks in the compressed air system- A total of (95) air leaks were identified during the compressed air-leak audit that was performed at the site, and the identified leaks were tagged and fixed, reducing the leak load from 381 cfm to 79 cfm. The facility also installed a compressed air metering system that measures compressed air flow (cfm) and power (kW) of the compressed air system.

The energy savings for this measure come from the compressor's reduced energy use due to the reduced leak load. Air leaks in a compressed air system result in the compressor drawing more power to maintain the required pressure and cfm levels to compensate for the losses that occur due to leaks. The measure was categorized as a retrofit measure.

The evaluators performed a full M&V evaluation with a site visit and metering deployment, because the site's operations were typical during the evaluation period. Additionally, the evaluators found that the site did not have any COVID-19 related impacts. The evaluation found the measure savings to be 399,179 kWh annually, which is higher than the tracking savings listed in the applicant documentation. The evaluation results are presented in Table 5-66.

Table 5-66. Evaluation results summary

PA Application ID	Measure Name		Annual Electric Energy (kWh)	% of Energy Savings On-Peak	Summer On-Peak Demand (kW)	Winter On-Peak Demand (kW)
10566704	Fixing Compressed Air Leaks	Tracked	404,163	56%	56.13	56.13
		Evaluated - ops	399,179	53%	51.61	50.86
		Realization Rate	99%	95%	92%	91%
Totals		**Tracked**	**404,163**	**56%**	**56.13**	**56.13**
		Evaluated - ops	**399,179**	**53%**	**51.61**	**50.86**
		Realization Rate	**99%**	**95%**	**92%**	**91%**

5.24.1 Explanation of Deviations from Tracking

The evaluated savings are slightly lower than the applicant-reported savings primarily due to the higher operating hours of the compressors compared to what was claimed in the applicant savings calculation and the higher post case efficiency. Further details regarding deviations from the tracked savings are presented in Section 3-1.

5.24.2 Recommendations for Program Designers & Implementers

There are no recommendations currently.

5.24.3 Customer Alert

There were no customer alerts.

5.25 Evaluated Measures

The measures installed at this site include:

EEM-1: Fixing air leaks in the compressed air system- The project consisted of fixing compressed air leaks throughout the facility to reduce the energy use of the facility's compressed air system.

5.25.1 Application Information and Applicant Savings Methodology

The facility conducted a compressed air leak audit to identify air leaks in the compressed air system throughout the facility. A total of (95) air leaks were tagged and fixed, reducing the leak load from 381 cfm to 79 cfm. The applicant savings calculation used a custom spreadsheet-based tool where pre-case and post-case cfm values were plugged into the savings calculator, and the calculator generated the demand, energy, and peak savings for the project based on the user-provided inputs.

5.25.2 Applicant Description of Baseline

The applicant categorized this measure as a retrofit measure. As stated in the above section, the facility operates three shifts per day. The applicant documentation describes the facility's compressed air system as consisting of (1) 200HP two-stage variable speed, rotary screw compressor with a rated capacity of 918 acfm with modulation controls and a full load operating pressure of 125 psig as the trim compressor and (1) 150HP two-stage rotary screw compressor with a rated capacity of 763 acfm and a full load operating pressure of 125 psig as the baseloaded compressor. The facility requires both compressors to run to maintain plant pressure. The air from the compressors runs through a 2000 cfm refrigerated air dryer (with a VFD) to remove the moisture content in the air before feeding the plant. The tracking documentation claims the compressors run 7,200 hours per year.

Table 5-22 shows the key inputs used in the applicant savings calculation methodology:

Table 5-67. Applicant baseline key parameters

		BASELINE		
Measure	Parameter	Value(s)	Source of Parameter Value	Note

Fixing Compressed Air Leaks	Compressor System Efficiency	5.38 cfm/kW	Applicant Documentation	
Fixing Compressed Air Leaks	Hours of Operation	7,200 Hours	Applicant Documentation	
Fixing Compressed Air Leaks	Number of Leaks Fixed	95	Applicant Documentation	
Fixing Compressed Air Leaks	Air Leak Load	381 cfm	Applicant Documentation	

5.25.2.1 Applicant Description of Installed Equipment and Operation

A contractor conducted a compressed air leak survey to identify air leaks throughout the production area. The facility has different types of equipment such as pneumatically actuated conveyors, production equipment, air nozzles, etc., all of which require the use of compressed air. The contractor was able to identify and tag (95) air leaks which were fixed. This reduced the leak load from 381 cfm prior to fixing the air leaks to 79 cfm after fixing the air leaks. Table 5-23 lists the key inputs in the installed case:

Table 5-68. Applicant proposed key parameters

		PROPOSED		
Measure	**Parameter**	**Value(s)**	**Source of Parameter Value**	**Note**
Fixing Compressed Air Leaks	Compressor System Efficiency	5.38 cfm/kW	Applicant Documentation	
Fixing Compressed Air Leaks	Hours of Operation	7,200 Hours	Applicant Documentation	
Fixing Compressed Air Leaks	Number of Leaks Fixed	95	Applicant Documentation	
Fixing Compressed Air Leaks	Air Leak Load	79 cfm	Applicant Documentation	

5.25.2.2 Applicant Energy Savings Algorithm

The applicant used a custom spreadsheet-based savings calculator to estimate savings for this project. The pre and post-repair cfm values (determined in the leak survey) were used as inputs in the calculator tool to estimate the savings as shown in the formula below:

$$kWh\ Save = \frac{(cfm_{pre} - cfm_{post})}{Eff} \times hr$$

where,

$kWh\ Save$	*= electric energy savings, in kWh/yr*
cfm_{pre}	*= pre-project air leak flow, 381 cfm*
cfm_{post}	*= post-project air leak flow, 79 cfm*
Eff	*= compressed air system efficiency, 5.38 cfm/kW*
hr	*= annual operating hours, 7,200 hr/yr*

The applicant calculated tracking savings for this project as 404,164 kWh, and the summer and winter seasonal demand as 56.13[17] kW.

From the above savings calculation, the evaluators determined that the variables that have the greatest impact on the savings are the operational hours of the compressors, compressor efficiency and the air leak reduction amount.

5.25.2.3 Evaluation Assessment of Applicant Methodology

The evaluators determined that the applicant's analysis methodology was reasonable. The evaluators agree with the methodology used determine the pre-repair cfm consumed in the facility, which involved measuring the compressor kW during a time when no processes were running, and there were no process demands for compressed air, and converting the measured kW at that time to cfm using the compressor's CAGI specification sheets. Leaks were identified with an ultrasonic leak detector. The post-repair cfm was measured similarly, using a kW meter on the compressors, and the pre and post-repair no-process load cfm values were used as inputs in the savings calculation spreadsheet. However, the applicant's overall methodology is simplified and does not account for the effects of efficiency changes on the compressed air system as the load changes. The evaluators used an updated methodology that incorporates the performance data on each compressor in calculating the compressors' input kW.

5.25.3 Site Inspection

The evaluators conducted a site visit on 5/10/2022 to verify the compressed air leaks fixed as part of the project and install ElitePRO power loggers to collect data (voltage, amperage, and power factor) on the (2) compressors in the facility. The evaluators had an initial discussion with the maintenance technician (who was the site contact) and learned that the facility runs the 150HP compressor as the baseloaded compressor, and the 200HP VFD controlled compressor serves as a trim to meet load requirements and also runs during the weekend. The facility usually requires both compressors to run to maintain the plant pressure setpoint.

The evaluators verified a sample of 10 compressed air leaks that were tagged and fixed as part of the project as claimed in the applicant documentation using an ultrasonic leak detector. The evaluators were then shown into the compressor room, where the (2) compressors that were described in the applicant documentation were verified. The evaluators found (1) 150HP two-stage rotary screw compressor and (1) 200HP two-stage variable speed, rotary screw compressor. The 150HP compressor was identified as the baseloaded compressor, and the 200HP compressor served as trim and also runs during the weekend. The 150HP compressor modulates using a mechanical control valve and sensors, and the 200HP is controlled using a VFD. In general, cfm levels are usually at about 1,400

[17] Winter peak duration: December and January between 5 p.m. and 7 p.m. Monday to Friday
Summer peak duration: June, July, and August between 1 p.m. and 5 p.m. Monday to Friday

cfm during regular production hours and about 800 cfm during weekends. It was found that the facility has (3) 400 gallon storage tanks that serve the compressors to regulate pressure and cfm requirements. The site contact informed the evaluators that the compressors usually run all the time and are shut down only for preventive maintenance for two days a year during the 4th of July weekend and for a day on Thanksgiving and Christmas day. The major compressed air loads at the facility include pneumatically controlled production equipment, automated conveyors, and other miscellaneous equipment. The site contact also informed the evaluators that new equipment that requires the use of compressed air was added over the past year and this increased the facility's compressed air loads. The leaks inspected by the evaluators are listed in Table 5- below along with the evaluation finding for each leak. All leaks inspected by the evaluator remained fixed.

Table 5-69. Sample Compressed air leaks inspected using Ultrasonic Leak Detector

Index Number	Leak Tag Number	Location	Size Classification	Evaluation Finding (Leaking/Not-Leaking)
1	S1	Compressor Room	LL	Not Leaking
2	S2	Maintenance Room	M	Not Leaking
3	S3	Welding Room	S	Not Leaking
4	S4	Mixing Room	SM	Not Leaking
5	S5	Mixing Room	M	Not Leaking
6	S6	Mixing Room	S	Not Leaking
7	S46	Lab	S	Not Leaking
8	S50	Tool Room Bench-4	S	Not Leaking
9	S51	Tool Room Bench-6	S	Not Leaking
10	S52	Tool Room Bench-7	S	Not Leaking

The evaluators also learned onsite that this particular compressed air leak audit was the last audit that the facility went through with the contractor and applied for an incentive through National Grid's program. After this, the facility purchased the equipment required for conducting compressed air leak surveys and and began performing these using in-house labor as part of their preventive maintenance program. These audits have since been performed every quarter and the facility did not apply for any rebate from National Grid for the subsequent compressed air leak fixes.

The evaluators took photos of the compressors, the nameplates on each compressor, and the respective display screens. The evaluators then installed (1) ElitePRO power logger (XC1808031) in the disconnect of the 200HP compressor and (1) ElitePRO power logger in the disconnect box of the 150HP compressor. The loggers monitored kW data from 5/20/2022 to 6/23/2022 at 5-minute intervals by logging voltage, amperage, and power factor. The evaluators verified with the site contact that the metering period captured typical operations.

5.25.3.1 Summary of Site Visit Findings

The evaluators made the following observations on site:

- Based on conversations with the facility maintenance technician, the evaluators confirmed that the compressed air leak repair project was completed as claimed in the applicant documentation.

- The evaluators confirmed the presence of (2) air compressors, i.e. (1) 150 HP and (1) 200HP two-stage screw compressors as listed in the applicant documentation. The evaluators verified the compressor nameplate data and collected the compressors' make and model numbers and other related information. The production area requires an operating pressure of 125psig.

- The evaluators were able to verify the control types on the compressors, i.e., the 150HP compressor uses modulation (using control valves), and the 200HP compressor uses a VFD. The 200HP compressor serves as the trim compressor and also runs during the weekend, the 150 HP compressor is the baseloaded compressor during weekdays and is off during weekends.

Table 5- shows the summary of the verification methods used to verify the installation of the project and the corresponding evaluation findings:

Table 5-70. Measure verification

Measure Name	Verification Method	Verification Result
Fixing Compressed Air Leaks	Verify the nameplate of the compressors matches the project description via physical inspection	The nameplate of the compressor matched the project description.
Fixing Compressed Air Leaks	Verify the compressed air leaks that were fixed as part of the project using an ultrasonic leak detector	The compressed air leaks were found to be fixed upon inspection using the ultrasonic leak detector
Fixing Compressed Air Leaks	Verify control types on each compressor via physical inspection	The 150 HP compressor modulates using a mechanical control valve, and a VFD controls the 200HP compressor
Fixing Compressed Air Leaks	Interview site contact for typical compressed air operating hours	The compressed air system operates 24/7, staged between the two available compressors, and is shut off for two days per year for maintenance.

5.25.4 Evaluation Methods and Findings

This section describes the evaluator methods and findings.

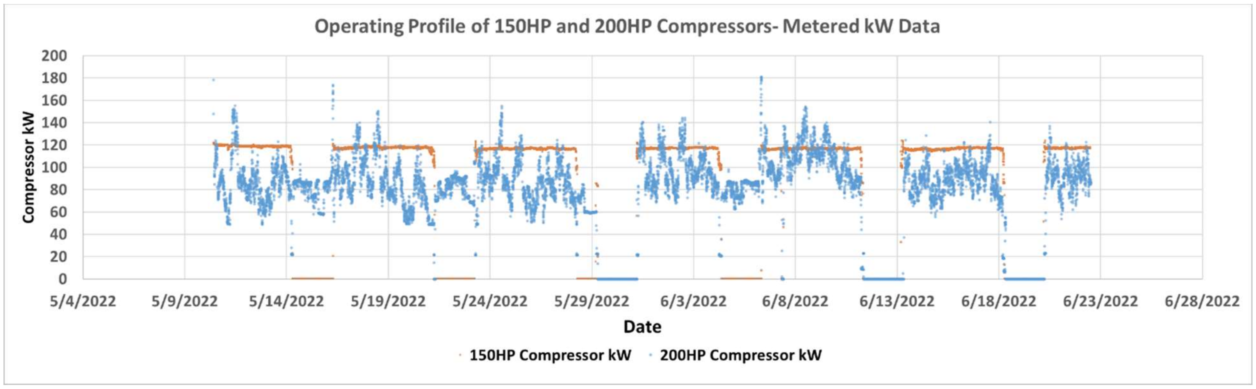
5.25.4.1 Evaluation Description of Baseline

The evaluator reviewed the project files, interviewed the site contact to gather information on the baseline for the compressed air leak measure, and agreed with the tracking baseline. The evaluators inspected a sample of the leaks to verify the tracking documentation and found that the claimed leaks were fixed as described in the above section. The evaluator determined this measure is a retrofit with a single baseline, and the baseline is the pre-existing condition.

5.25.4.2 Evaluation Calculation Method

The evaluators used metered data obtained from the ElitePRO power loggers to understand the operating profile of the 150HP and 200HP compressors. The loggers were installed between May 10th and June 23rd 2022, for seven weeks. During this period, the operating profile was observed to be typical, as shown in Figure 5-1 below:

Figure 5-14. Metered compressor power for both compressors



From Figure 5-1, the evaluators noted that the 150HP compressor runs either at a constant load or is shut off for certain periods, whereas the 200HP modulates as required and operates at a higher kW when the 150HP compressor is shut off to meet plant pressure and cfm requirements, but does not run as high as the 150HP compressor does during the weekdays. Also, it is observed from the above figure that both the 150HP and 200HP compressors are both shut-off simultaneously for multiple weekends during the metering period such as around 5/30, 6/13 and 6/19. On verifying this with the site contact, the evaluators learned that typically, the 150HP compressor is shutoff during the weekend and the 200HP compressor would be operational. However, due to production requirements, during times of low production, both compressors would be shut-off during the weekend. There is no fixed schedule for shutting off both compressors simultaneously, it would depend on what the production planning team decides. The evaluators modeled the operating profile of each compressor individually over the metering period to understand the average hourly kW draw and the individual compressor's operating profile over the six week metering period. The following heat maps show the operating profiles of both compressors where the average hourly kW draw was modeled over a typical week during the metering period as shown in

Figure 5-2 and Figure 5-16 below:

Figure 5-15. Average hourly kW draw of 150 HP compressor (from metered data)

150 HP Compressor Typical Weekly Profile							
Day/Hour	Sun	Mon	Tue	Wed	Thu	Fri	Sat
0	0	0	97	117	117	118	117
1	0	0	97	117	117	117	117
2	0	0	97	117	117	118	116
3	0	0	97	117	117	118	117
4	0	0	97	117	117	117	117
5	2	10	104	117	117	118	115
6	14	38	116	117	117	118	103
7	8	66	117	118	117	117	64
8	0	82	106	118	117	117	27
9	0	96	97	118	117	117	10
10	0	97	110	118	117	117	0
11	0	97	118	118	117	117	0
12	0	97	117	118	117	117	0
13	0	97	117	117	117	117	0
14	0	97	117	117	117	117	0
15	0	97	117	117	117	117	0
16	0	97	117	117	117	117	0
17	0	97	117	117	117	117	0
18	0	97	117	117	117	117	0
19	0	97	117	117	117	117	0
20	0	97	117	117	117	117	0
21	0	97	117	117	117	117	0
22	0	97	117	117	118	117	0
23	0	97	117	117	118	117	0

Figure 5-16. Average hourly kW draw of 200 HP compressor (from metered data)

200 HP Compressor Typical Weekly Profile							
Day/Hour	Sun	Mon	Tue	Wed	Thu	Fri	Sat
0	75	79	84	85	85	82	76
1	72	80	83	84	82	80	77
2	75	80	83	85	84	84	76
3	77	80	85	83	84	81	72
4	78	80	89	86	83	81	70
5	76	88	86	86	84	79	63
6	66	87	81	92	88	86	25
7	67	94	101	113	101	97	27
8	81	93	99	114	100	99	53
9	80	83	104	114	96	99	65
10	81	95	107	113	104	94	76
11	83	105	113	117	106	102	78
12	88	112	115	117	103	102	81
13	86	106	112	121	105	102	81
14	83	106	116	114	109	109	80
15	77	82	85	89	85	82	77
16	75	85	87	89	91	87	78
17	77	87	90	88	81	87	78
18	74	93	92	87	85	88	77
19	78	92	86	86	86	87	77
20	82	90	92	97	88	87	76
21	80	97	95	101	89	87	78
22	81	95	93	98	84	84	77
23	82	85	88	91	79	77	77

The above heat maps help understand the operating profiles of the two compressors. From

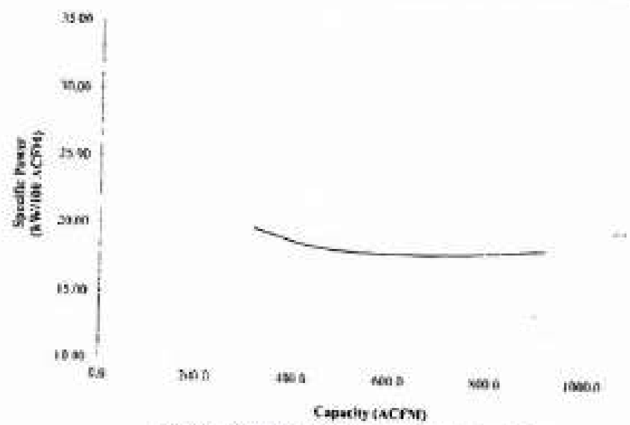
Figure 5-2, the 150HP compressor is shut off for much of the weekend (and is completely shut off on Sundays) while exhibiting a near-constant kW-draw for the rest of the week during the metering period. From

Typical Operating Profile of 150HP Compressor #1							
Hour/Day	**Sun**	**Mon**	**Tue**	**Wed**	**Thu**	**Fri**	**Sat**
0	59	58	51	77	70	73	63
1	55	51	45	73	65	69	60
2	55	49	45	74	64	73	69
3	58	49	48	71	71	75	69
4	55	38	43	71	70	68	65
5	50	42	42	76	70	65	65
6	57	48	51	79	76	66	70
7	53	43	43	73	70	58	67
8	50	47	43	78	64	67	70
9	58	50	52	79	74	76	73
10	54	40	45	73	77	69	66
11	52	38	48	76	74	72	72
12	59	46	55	83	79	77	80
13	52	45	50	59	70	74	73
14	56	50	54	65	76	78	75
15	57	54	63	74	77	80	78
16	51	49	56	65	68	75	73
17	46	46	58	61	66	67	69
18	51	51	63	67	67	70	59
19	48	41	63	60	61	62	55
20	51	44	73	66	57	66	56
21	56	49	78	68	64	67	60
22	54	46	76	66	66	64	54
23	54	45	71	66	66	61	55

Figure 5-3, the 200HP VFD compressor modulates as required and supplements the operation of the 150HP compressor, i.e., it operates based on the pressure and cfm requirements of the plant and operates when the 150HP compressor is shut off, i.e., during the weekends, especially on Sundays. The above data and the corresponding observations made by the evaluators corroborate the information provided by the facility maintenance technician during the initial conversations the evaluator had onsite. However, on further examination, the evalautors observed that both compressors are shut-off for three of the six weekends during the six week metering period. Therefore, the evaluators modelled the operating profile for the six-week metering period, wherein the kW draw of the compressors was averaged for every hour of the day for six weeks instead of a typical weekly profile. While averaging the six week monitoring period as one week would make it look like the compressor ran 7 days a week, modelling the full year as though it repeated this 6 week period 52 weeks / 6 weeks = 8.67 times, resulted in the compressor off time during 3 out of 6 weekends preserved. During these weekends when the compressors are off, no savings occur.

The evaluators modeled the savings using an 8760-analysis profile. The metered kW data was aggregated into a six week, hourly profile averaged by the hour of the day and day of week to represent the typical kW demand of the air compressors. This data was extrapolated to a year (using an 8,760 hourly spreadsheet) to model the as-built annual kWh consumption of the compressors. The baseline compressor kW was modeled using metered data obtained from the loggers installed by the evaluators, which was converted to cfm using compressor performance data from CAGI sheets. The CAGI data sheets used for both compressors is shown below in Figure 2-4 and Figure 2-5:

Figure 5-4. Data from Compressor CAGI Data sheet for 200HP compressor

	Input Power (kW)		Capacity (acfm)[a,d]	Specific Power (kW/100 acfm)[d]
8*	170.6	Max	**918.0**	**18.58**
	146.0		**797.8**	**18.30**
	122.9		**677.6**	**18.14**
	101.4		**557.4**	**18.19**
	81.3		**437.3**	**18.60**
	62.8	Min	**317.1**	**19.81**
9*	Total Package Input Power at Zero Flow[c,d]		**6.0**	kW
10				

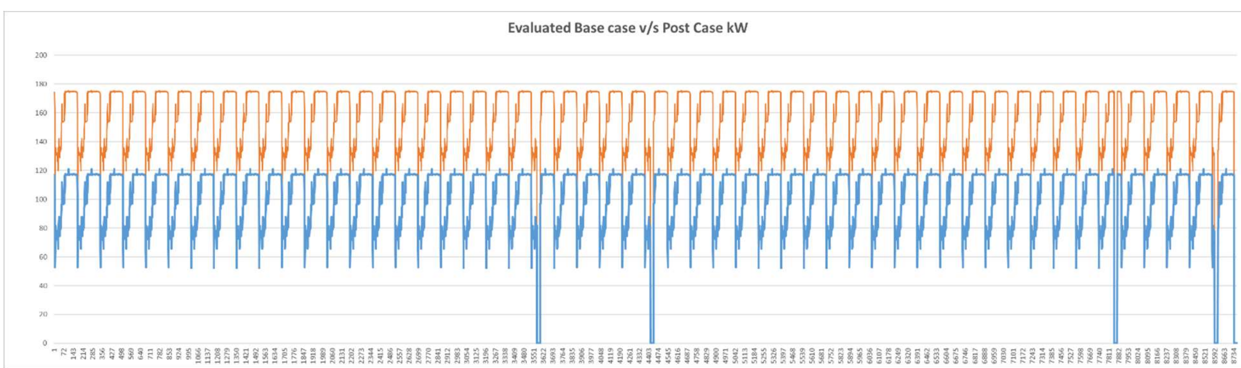
Note: Graph is only a visual representation of the data in Section 8
Note: Y Axis Scale: 10 to 35, + 5kW/100acfm increments if necessary above 35
X-Axis Scale: 0 to 25% over maximum capacity

Figure 5-5. Data from Compressor CAGI Data sheet for 150HP compressor

3*	Rated Capacity at Full Load Operating Pressure [a, e]	763	acfm [a,e]
4	Full Load Operating Pressure [b]	125	psig [b]
5	Maximum Full Flow Operating Pressure [c]	125	psig [c]
6	Drive MotorNominal Rating	150	hp
7	Drive Motor Nominal Efficiency	95.8	percent
8	Fan Motor Nominal Rating (if applicable)	-	hp
9	Fan Motor Nominal Efficiency	-	percent
10*	Total Package Input Power at Zero Flow [e]	34.7	kW [e]
11	Total Package Input Power at Rated Capacity and Full Load Operating Pressure [d]	138.6	kW [d]
12*	Specific Package Input Power at Rated Capacity and Full Load Operating Pressure [e]	18.2	kW/100 cfm [e]

The evaluators added the constant 302 CFM air leak reduction amount to the modeled as-built air demand to calculate the baseline air demand. The evaluators calculated baseline kW using baseline air demand using the compressor performance data. The evaluators did this by adding the cfm to the baseloaded compressor until the 200HP compressor kicked-in. The baseline compressor staging strategy was modeled identically to the as-built strategy, with the 150HP compressor serving as lead and the 200HP compressor serving as trim during weekdays, and the 200HP compressor operating exclusively during the weekend. The evaluators calculated the annual energy savings as the difference between the modeled baseline and as-built total system kW over all active hours of the year. The evaluated base case and post case kW is shown below in Figure 2-6:

Figure 5-6. Evaluated base case and post case kW for both 150 and 200HP compressors



The measure resulted in total evaluated energy savings of 399,179 kWh/yr.

5.26 Final Results

Table 5-9 summarizes the key parameters that were used in the estimation of savings and compares them with the tracking and post case:

Table 5-71. Summary of Key Parameters

Parameter	BASELINE Tracking Value(s)	BASELINE Evaluation Value(s)	PROPOSED / INSTALLED Tracking Value(s)	PROPOSED / INSTALLED Evaluation Value(s)
Compressor 1 - HP	150	150	150	150
Compressor 2 - HP	200	200	200	200
Leak Amount (cfm)	302	302	302	302
Operating Hours Per Year	7,200	7,581	7,200	7,581
Compressor Efficiencies (cfm/kW)	5.38	5.43	5.38	5.45
Total Rated CFM Compressor-1	763	763	763	763
Total Rated CFM Compressor-2	918	918	918	918
CFM Leakage Reduced	N/A	868	N/A	302

5.26.1 Explanation of Differences

The evaluation savings are 399,179 kWh/yr which are slightly lower than the tracking savings. The slight decrease in savings is primarily due to the increased post case compressor efficiency which is counteracted by the increased operating hours of the compressors compared to what was claimed in the applicant documentation. Table 5-10 provides a summary of the differences between tracking and evaluated values.

Table 5-72. Summary of Deviations

Measure	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
10566704	Operations	Operating hours	+5%	**Increased savings -** The savings increased due to increased hours of operation of the compressors in the as-built case compared to what was claimed in the applicant analysis
10566704	Operations	Efficiency	-6%	**Decreased savings –** The efficiency of the compressed air system was found to be higher in the as-built case as it factored in the changes in compressed air loads

				relative to the tracking estimates
Final RR				**99%**

5.26.2 Lifetime Savings

The evaluators classified this measure as retrofit with a single baseline.

Table 5-11 provides a summary of key factors that influence lifetime savings.

Table 5-73. Measure 10566704 - Lifetime Savings Summary

Factor	Tracking	Application	Evaluator
Lifetime savings	808,326 kWh	808,326 kWh	798,358 kWh
First year savings	404,163 kWh	404,163 kWh	399,179 kWh
Measure lifetime	2 years	2 years (project BCR)	2 years (RI TRM)
Baseline classification	Retrofit	Retrofit	Retrofit

(*) The tracking lifetime savings value is net of all program adjustment factors

5.26.2.1 Ancillary impacts

There are no ancillary impacts such as HVAC interactive effects.