FINAL REPORT

Rhode Island PY2018 & PY2019 Custom Electric Installations

RICE2018 & RICE2019

Date: March 9, 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

M&V measurement and verification

MBSS model-based statistical sampling

ML measure life

Non-Ops

PA program administrator

PY program year

PYR plan year report

RR realization rate

SCADA supervisory control and data acquisition

TMY3 typical meteorological year 3

TA studytechnical 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) 2018 and PY2019 Custom Electric Installations, conducted for National Grid Rhode Island (RI, carried out from November 2019 to August 2021. The DNV team includes expertise from our partner firms, DMI and legacy ERS.[1]

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 were used to determine the gross realization rates for custom electric energy efficiency projects implemented in 2022 and will be updated annually as subsequent impact evaluations are completed.

PY2018 and PY2019 samples were originally intended to be studied separately in 2020 and 2021. But, due to the pandemic and stoppage of the fieldwork, DNV produced desk reviews (includes non-operational characteristics only) for PY2018 and combined them with the previous study results (RI PY2016[2] and MA PY2017/18[3]) and delivered an interim report for National Grid's PY2021 planning filing. Once National Grid cleared DNV for fieldwork, both PY2018 & PY2019 studies were combined and delivered the results presented in this report. The PY2018 sites were essentially redone during the PY2019 evaluation to include on-site operational adjustments, where possible.

The key objectives of this evaluation were as follows:

Evaluate savings impacts of PY2018 & PY2019 custom electric projects and pool those results with the results of the PY2016 study. This study[4] quantified:

Achieved electric energy savings for custom lighting and non-lighting segments statewide, with a targeted combined sampling precision of ±10% at 90% confidence when pooled with the PY2016.

Achieved electric energy savings for custom lighting and non-lighting projects targeted sampling precision of ±15% at 90% confidence when pooled with PY2016.

Summer and winter on-peak demand realization rates, calculated at 80% confidence for custom lighting and custom non-lighting statewide.

This program report includes the results from the second (PY2018) and third (PY2019) rounds of annual C&I custom electric impact evaluations in Rhode Island using the rolling average approach.

Key changes compared to previous custom electric studies (PY2016) are:

Outreach to healthcare facilities was out of scope for this study to reduce any additional personnel workload and risk of COVID-19 virus spread during the pandemic. This included hospitals, assisted living, and nursing home facilities.

Site work was on hold for a significant portion of 2020 with some limitations in site access for 2021 as well, so no onsite verification, M&V planning, or meter installs were included in the base scope of this study and where possible, M&V was performed as add-ons.

---

[1] Effective April 1, 2021, ERS is part of DNV.

[2] http://rieermc.ri.gov/wp-content/uploads/2020/08/rice2016_final_clean.pdf

[3] https://ma-eeac.org/wp-content/uploads/MA_CIEC_Stage5_Report_C07_Custom_Electric_Impact_Evaluation_PY2017_18_FINAL-2020-06-01.pdf

[4] Note that the discussions in all sections of this report are based on the evaluator's observations from both PY2018 and PY2019 sampled sites unless specified otherwise.

Due to the slight relaxing of the Pandemic restrictions, options for onsite audits and M&V were available later in 2020 and 2021, provided the following conditions were satisfied:

Condition 1: Site contact was on site, and it was deemed safe by both the customer and the evaluator to perform these audits onsite.

Condition 2: Customer operation was not affected by the pandemic.

Condition 3: The metering window was not affected by seasonality for seasonally dependent measures.

When these conditions were met, and customer approval was obtained, the evaluators presented each case to National Grid for approval before onsite activities. This resulted in 42 approved evaluated sites that were classified, as shown in Table 1-1 below.

Realization rates were based on a combination of verified parameters of this current sample, historical operation adjustments from the RI PY2016 impact evaluation, and pooling with RI PY2018 and PY2019 results to produce three-year average rolling results (RI only). Results are based on data from RI only; this is the first study in which RI has not pooled its results with Massachusetts (MA) to determine realization rates for custom electric projects.

The PY2018 sample design was developed assuming the results would be pooled with prior (PY2016) and future (PY2019) custom electric results, and PY2019 was developed assuming the results from the PY2016 and PY2018 will be pooled to achieve the required precision targets when combined for all three years (i.e., 2016+2018+2019).

Table 1-1: Sampled Site Classification

Program Year	Evaluation Type	Sample Size
2018	Onsite visit with non-operational and operational impacts (or full M&V)	14
	Onsite Audit with only Non-Operational Impacts (or Non-Ops only)	4
	Full M&V for Non-Lighting measures Non-Ops for Lighting measures	1
	Desk Review only	2
2019	Onsite visit with non-operational and operational impacts (or full M&V)	11
	Onsite Audit with only Non-Operational Impacts (or Non-Ops only)	6
	Full M&V for Non-Lighting measures Non-Ops for Lighting measures	3
	Desk Review only	1
	Total	**42**

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, Recommendations, and Considerations
- Appendices

2 METHODOLOGY AND APPROACH

As mentioned in the previous section, the PY2018 and PY2019 populations were developed individually from the respective year's program participation data provided by National Grid. The DNV team determined relative precision and confidence interval targets using this sampling population and information provided by National Grid. This information included characteristics of the sampling population, the relative impact of the sampling population on National Grid's total electric portfolio, and historic evaluation targets and results.

The PY2018 sample design was developed by pooling the PY2016 results, PY2018 population and an estimated PY2019 population. Whereas the PY2019 sample was developed using the actual results from PY2016, PY2018 design estimates and the PY2019 population to achieve the required precision targets. Once the sampling targets were set, the DNV team selected a primary and backup sample for the evaluation that minimized the number of sample points required to meet the targets and provided these samples to the National Grid for review. Sampling targets consisted of a single application or multiple custom applications completed at a single service address during a calendar year. A single service address is considered a sampling unit or "site" in the study except for SEMP[5] sites. These SEMP sites are atypical and primarily large and complex sites. To reduce the customer burden and evaluation costs, the SEMP site is sub-sampled by disaggregating the savings to building or measure level. Additional details on SEMP sites will be discussed in Section 2.1.1.1.

For some large applications, National Grid releases incentives in two phases, namely parent and child, and these applications sometimes are claimed in multiple program years. Parent-child applications are included in the population based on the year of completion of the child application. The study population included nine such parent-child applications in PY2018 and 23 in PY2019. National Grid provided the DNV team with documentation supporting the tracked savings for each primary sample point.

2.1 Sample development

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 lighting and non-lighting gross energy realization rates. Likewise, the annual overall custom target must be set at ±17% precision at 90% confidence to achieve a rolling three-year result at ±10% precision at 90% confidence for both lighting and non-lighting gross annual energy realization rates in Rhode Island. Since the sampling was done individually for PY2018 and PY2019, two sections are presented individually per the respective study's workplans.

The lighting and non-lighting targets and assumed error ratios[6] are presented below in Table 2-2:

Table 2-1. Sampling targets

Annual Sampling Target	3-Year Pooled Sampling Target	Error Ratio
±26% on Lighting Energy (kWh) at the 90% confidence interval	±15% on Lighting Energy (kWh) at the 90% confidence interval	PY2019 = 0.35 PY2018 = 0.31
±26% on Non-Lighting Energy (kWh) at the 90% confidence interval	±15% on Non-Lighting Energy (kWh) at the 90% confidence interval	PY2019 = 0.60 PY2018 = 0.60
±17% on Overall Energy (kWh) at the 90% confidence interval	±10% on Overall (L+NL) Energy (kWh) at the 90% confidence interval	N.A.

PY2018 and PY2019 samples were designed individually, but due to the pandemic-related delays, the field work for both studies was combined. Table 2-2 presents the sample design for PY2019 combined with estimated PY2018 results and

[5] Strategic Energy Management Partnership (SEMP) is RI National Grid's portfolio partnership program with a few large customers in the state. The program constitutes an assortment of multiple energy efficiency projects that are completed in these facilities in a given program year. The projects included in the portfolio range anywhere from a few measures to over 50 measures installed across multiple buildings on the campus

[6] 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.

PY2016 actual results. The accumulated RI sample for the first three years in the staging evaluation resulted in very reasonable projected relative precision (RP) estimates of ±9.3% @ 90% CI for lighting and ±14% RP @ 90% for non-lighting, and an RP of ±9% @ 90% CI for combined lighting and non-lighting measures completed at the end of year three as shown in Table 2-2.

Table 2-2. 2019 project sample and estimated relative precisions

End-use	Program year	Energy Savings (kWh)	Sample Size	RP @90% CI
Lighting	2016	19,142,741	3	±5.0% (actual)
	2018	13,294,077	9	±18.0%
	2019	17,498,949	8	±22.0%
Lighting (3-year rolling)	**2016+2018+2019**	**49,935,767**	**20**	**±9.3%**
Non-Lighting	2016	21,044,847	8	±23.0% (actual)
	2018	12,910,679	14	±26.0%
	2019	12,804,067	15	±22.0%
Non-Lighting (3-year rolling)	**2016+2018+2019**	**46,759,593**	**37**	**±14.0%**
Lighting + Non-Lighting	2016	40,187,588	11	±14.3%(actual)
	2018	26,204,756	21*	±18.0%
	2019	33,196,172	22*	±16.0%
Lighting + Non-Lighting (3-year rolling)	**2016+2018+2019**	**96,695,360**	**54**	**±9.2%**

*The total includes combination sites that installed both lighting and non-lighting measures.

The primary sample included a large university with a savings of 2,278,505 kWh, and upon project file review, the savings were estimated from measures completed at 41 different buildings at the university. Additional details are provided in the following section on how DNV disaggregated this site into multiple sub-sites for evaluation purposes.

2.1.1.1 Strategic Energy Management Partnership (SEMP) projects sub-sampling

SEMP[7] is RI National Grid's portfolio partnership program with a few large customers in the state. The program includes multiple energy efficiency projects completed in these facilities in a given program year. The projects included in the portfolio range from a few measures to over 50 measures installed across multiple buildings on the campus. The total savings from all the measures are entered into National Grid's tracking system under a single application or two applications as a parent/child system.

In the PY2019 study, the SEMP project was disaggregated and evaluated after the site was chosen for evaluation during sampling. Evaluating these large projects could be very expensive to the ratepayer and burdensome for the customers. Therefore, DNV and National Grid chose to subsample within the SEMP selected in the evaluation sample. DNV selected a sub-sample of 5 subsites from a disaggregated population of 41 subsites to reduce the burden and be cost-effective. The PY2019 study is the first to include a standard error from the subsample and carried into the overall sample design.

[7] Strategic Energy Management Partnership (SEMP) is RI National Grid's portfolio partnership program with a few large customers in the state. The program constitutes an assortment of multiple energy efficiency projects that are completed in these facilities in a given program year. The projects included in the portfolio range anywhere from a few measures to over 50 measures installed across multiple buildings on the campus

Future efforts to include the SEMP in the custom electric impact evaluation are being discussed with National Grid (Section 5.3, bullet 1) and the EERMC consultants.

2.1.2 Sample changes and final sample (PY2018 & PY2019)

Table 2-3 shows the final evaluated sample as completed versus as designed. Note that the sample design consisted of a selection of 43 targeted sites, of which eight sites (3 in PY2018 and 5 in PY2019) had a combination of lighting and non-lighting applications, and one[8] (1) PY2019 site that was added during the fieldwork resulting in a total of 52 sample projects evaluated in this study. Descriptions of the 21 lighting and 31 non-lighting projects are included in APPENDIX A. Detailed descriptions of each project are provided in the site reports in APPENDIX D.

The final evaluation sample changed during the project. For various reasons, some primary sampled sites were replaced with sites from the backup sample. 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 2-3. 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 National Grid-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 National Grid lead for recruiting assistance. If there was no response after National Grid's recruitment efforts, the customers are considered unresponsive.

Some of the customers classified as unresponsive in Table 2-3 responded initially but became unresponsive during evaluator follow-up. In all cases, backups sites were selected for sites in the same strata with available backups.

Refusals: Three sites 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. One of the sites refused for security reasons, and the other two refused to reduce the exposure from non-essential personnel onsite.

Pandemic Related closure: In this study, DNV differentiated between business closures related to the pandemic and business closures unrelated to the pandemic[9]. Backup sites replaced closures due to the pandemic, and closures for other reasons were evaluated with savings reflecting the period over which the measures were in place.

- The study encountered one permanently closed site (RICE19N146), which was deemed a result of the pandemic and was replaced by another site (RICE19N060).

Additional Sample Site: One site was added to the overall sample to the PY2019 sample with a weight of 1. This streetlighting measure was split into two standalone National Grid applications, of which one was paid out in PY2018 and another in PY2019. DNV evaluated both applications. The PY2018 application was part of the primary sample, and the PY2019 application was added to the overall sample with a unity weight during expansion analysis.

Hospital/Healthcare: In March 2020, per National Grid's recommendation, all Hospitals, Senior Living and Healthcare centers were excluded from the sample due to the pandemic. One hospital site was skipped, and a backup was selected for evaluation in the PY2019 primary sample.

[8] Site RICE19L019 was not part of the original sample but was added to the evaluation sample per National Grid’s recommendation. In the expansion analysis the site was given unit weight.

[9] Based on the customer interview and web-search, DNV determined that the facilities were closed in late 2019 (pre-pandemic), therefore unrelated to the Pandemic.

Table 2-3. Summary of replaced sites

End Use	Hospital	Pandemic related closure	Unresponsive	Refusal	Total Replaced Sites
Lighting	0	0	0	1	1
Non-Lighting	1	1	2	2	6
Total	**1**	**1**	**2**	**3**	**7**

2.2 Description of methodology

Due to COVID-19 restrictions limiting site work, this study's methodology was modified from previous years. The key changes were:

- Increased scope of desk review tasks, including a more in-depth review of applicants' assumptions and calculation methodology
- The use of historical operation adjustments from the last evaluation combined with partial samples of PY2018 and PY2019 sites. 25 out of 42 sites had operation adjustments in the PY2018 and PY2019 samples when combined. 4 more sites included operational adjustments for non-lighting measures only (see Table 1-1, Full M&V for Non-Lighting measures, Non-Ops for Lighting measures). These combined operation adjustments were used as substitutes for samples where metering and M&V were not in scope due to the pandemic.
- Not performing fieldwork at any Hospital/Healthcare/Senior Living Facilities.

2.2.1 Desk reviews

DNV conducted an in-depth desk review (without a site visit) of three sampled sites (0) to provide an accurate assessment of the project event type changes on the baseline and the impact of any administrative tracking savings errors identified, and the impact of changes due to differences between application and evaluation approach and calculation methodology. These adjustments were used as non-operation components of the program realization rates. The remaining sampled sites were evaluated using an Onsite visit, and more details on the evaluation type are presented in the section below.

As mentioned earlier, the desk reviews were not part of the original scope but were included due to the stoppage of fieldwork due to the Pandemic in March 2020. The reasons for exclusion are presented below:

1. **RICE18L098**: Unresponsive customer but included since the Desk Review results were available from the PY2018 Interim Program Report.
2. **RICE18N115**: This was a Hospital site and excluded from the fieldwork per National Grid recommendation, but the desk review results were included in the final expansion for the same reason as the previous site.
3. In the PY2019 sample, all unrecruited sites were replaced with a backup except **RICE19N172**. This site was part of a census stratum and did not have any backup sites to replace it.

2.2.1.1 Customer outreach

Project engineers reached out to customer site contacts using an updated COVID-19-compliant, National Grid-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, 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, National Grid 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.
- 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 types of data would be meaningful to collect.

Efforts were made to minimize pre-recruitment evaluation activities until the customer site contacted indicated they would accommodate the evaluation process. However, to communicate effectively with the customer site contact, the evaluators had to develop a strong understanding of the installed measures before customer outreach. 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 evaluation process for all sites consisted of three phases: 1) Planning, 2) Customer Outreach, and 3) Site Evaluation.

National Grid 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. <u>Onsite Site Visit with only non-operational impacts</u>: The site is open to an onsite visit, but the COVID-19 pandemic impacts the installed measure's operation, and little meaningful data would be obtained performing 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. <u>Onsite visit with non-operational and operational impacts</u>: The site is open for an onsite visit, and the customer is not impacted by the COVID-19 pandemic. 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 a physical visit).

3. Onsite visit with only non-operational impacts for lighting measures and non-operational and operational impacts for non-lighting measures: It is a mix of #1 and #2 above based on the measure type. -lighting or non-lighting.

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 description of how the tracking savings were originally estimated.
- **COVID-19 Impacts.** A description, if any, impacts of the current health emergency.
- **Project Evaluation.** A description of the methods to be used to evaluate the project, including but not limited to:
  - Procedure to measure post-installation conditions and how current operation will be verified.
  - The data is to be collected by the evaluation team. Where several similar items have been installed or are being controlled, the evaluation plan will describe and justify the sampling rate of the equipment to be monitored.
  - The data to be provided by the site (EMS trends, pre-metering, etc.).
  - Information regarding pre-existing equipment prior to the installation of the measure.

- The expected evaluation analysis method to be used, identifying any deviations from the original savings estimation method. In general, it is expected that the same methodology used to estimate tracking savings will be used to estimate evaluated savings. The evaluation team will only present an alternative methodology if the tracking methodology was not provided, is flawed, or is unfeasible to utilize, or if a more accurate methodology is available that utilizes post-installation data that was unavailable for the tracking analysis.
- Key parameters will be determined through the evaluation and compared to those used in the original savings estimate.

2.2.2.1 Data collection

With National Grid'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. National Grid had, in March 2020, put a hold on onsite work but eased the restrictions in fall 2020 to make onsite an option under certain conditions.

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 equipment. This included assessing the installed technology, 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

The plan for this study assumed that meter installs were not part of the base scope. This assumption applied to all project samples. When National Grid lifted the site work stoppage in the fall of 2020 and a mutual PA/evaluator determination was made to proceed with metering for sites that satisfy the conditions listed in Section 2.2.1.1, DNV applied the full M&V scope for those sites.

Onsite visits were performed with National Grid 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. We performed 39 onsites, of which 25 sites included metering, ten sites were physical inspection/verification without metering, and four sites included a mix of both metering and non-metering evaluation, as shown in Table 1-1.

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, TOU lighting loggers, lumen 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 National Grid 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 APPENDIX D. 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:

- PY2018 and 2019 tracking data provided by National Grid
- PY2016 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 trend data

4 ANALYSIS AND RESULTS

4.1 Introduction

A total of 42 sites were evaluated in this study within the PY2018 and PY2019 populations. These sites were classified into three evaluation categories. Sites that included:

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

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

3) Desk Reviews (no virtual or onsite visit or customer interview)

Table 4-1 below shows the evaluation type sample distribution.

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.

Table 4-1: Sampled Site Classification

Program Year	Evaluation Type	Sample Size
2018	Onsite visit with non-operational and operational impacts (or full M&V)	14
	Onsite Audit with only Non-Operational Impacts (or Non-Ops only)	4
	Full M&V for Non-Lighting measures Non-Ops for Lighting measures	1[10]
	Desk Review only	2
2019	Onsite visit with non-operational and operational impacts (or full M&V)	11
	Onsite Audit with only Non-Operational Impacts (or Non-Ops only)	6
	Full M&V for Non-Lighting measures Non-Ops for Lighting measures	3[10]
	Desk Review only	1
	Total	**42**

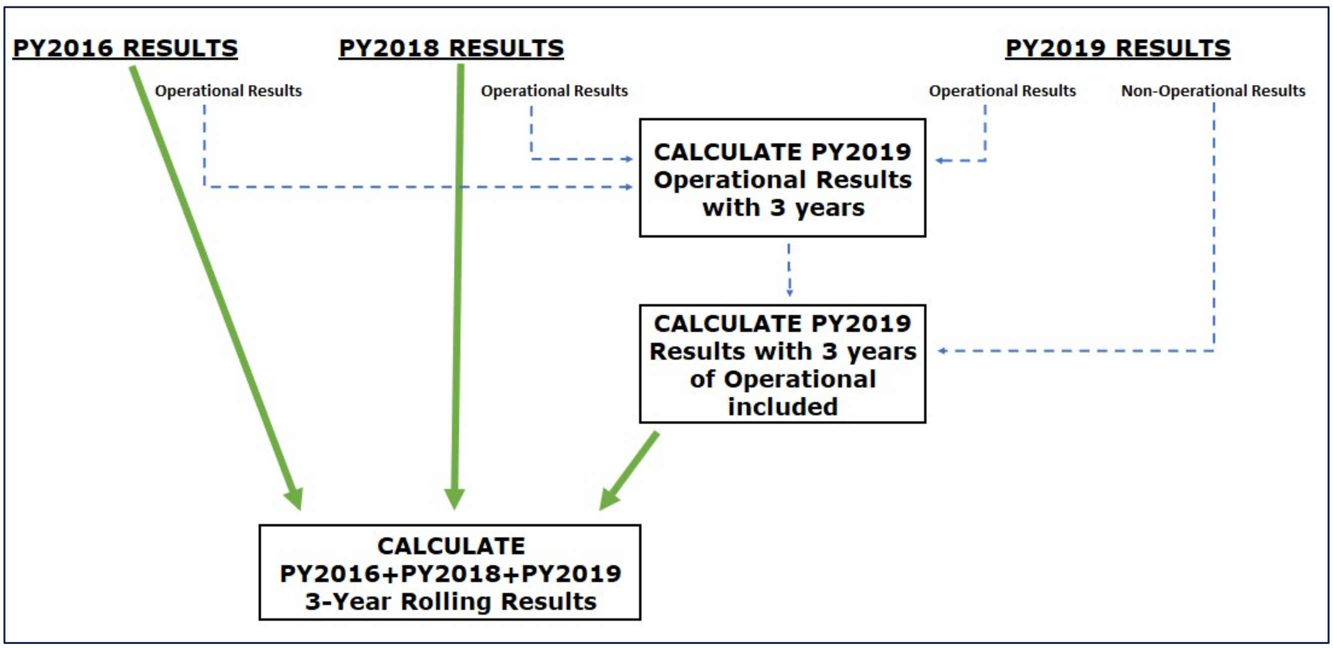
The expansion analysis follows a recently completed MA custom electric study[11], but the MA sites all fell into one of two categories: Full M&V or Non-Ops, while the RI sites fell into one of three categories: Full M&V, Non-Ops, or Desk Review. To compensate for the lack of operational adjustments for both the Non-Ops and Desk Review sites in the sample, the RI study used operational adjustment factors derived in the previous RI custom electric study (PY2016) and combined them

[10] These are part of Combo sites that include both lighting and non-lighting measures. Non-lighting measures at these sites were not impacted by the pandemic, so a full M&V was completed.
[11] MA20C04- PY2018-2019 MA Custom Electric Study

with operational factors from the sites with Full M&V in the current study (PY2018 and PY2019 sampled projects). The operational factors were developed using the following procedure:

- The evaluated results from the 2016 study were separated into operation and non-operation adjustments.
- The 2016 operational results were then combined with the PY2018 and PY2019 operational results using total population-level first year tracking savings from each study to establish the weights each study had on the combined operational results.
- Standard errors and combined operation factor imputation are presented in APPENDIX C.
- All the results were calculated at the measure level (i.e., lighting and non-lighting individually). Therefore, 42 sites were further split into 60 sites that included combo-sites (lighting and non-lighting measures) and large SEMP[12] sites. Site-level results and weights are presented in APPENDIX D.

Figure 4-1: Historical Operations adjustment inclusion map for PY2016, PY2018 and PY2019 three-year rolling results.



Another key difference from the MA study[11] in the expansion analysis is the sub-sampling of a large SEMP site in its own stratum. More details on weighting differences are provided in the section below (4.2).

[12] Strategic Energy Management Partnership (SEMP) is RI National Grid's portfolio partnership program with a few large customers in the state. The program constitutes an assortment of multiple energy efficiency projects that are completed in these facilities in a given program year. The projects included in the portfolio range anywhere from a few measures to over 50 measures installed across multiple buildings on the campus

Table 4-2 shows the adjustment factors used by evaluators to categorize discrepancies from tracking data and how those factors are categorized within the PY2018 & PY2019 sampled sites. Non-operational adjustment factors include factors that are obtained during a desk review, site contact interview, and primary site visit. Operational adjustments require metering or trends collected for analysis which is obtained during logger installation or delivered after the primary site visit.

Table 4-2. Adjustment Factors for Evaluation

	Adjustment Factors						
Ratio Name:	Non-Operational Adjustments					Operational Adjustments	
Obtain During:	In-depth desk review			1st site-visit		Logger Installation	
Factor:	Baseline	Methodology	Tracking & Admin	Technology	Quantity	Operational	HVAC Interactive

4.2 Site-level findings

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 APPENDIX D.

RICE18L049: *Technology & Operational Discrepancies*: Onsite observation resulted in changes to the baseline and installed fixture wattages which accounted for -87.5% of tracking savings, and the metered data showed a decrease in hours of use (operational adjustment) which accounted for -4.7% tracking savings. The site had an Energy RR of 7.8% for energy (kWh).

RICE19L091 *Baseline Discrepancy:* Decrease in savings due to the change in baseline LPD. The evaluator applied a 0.78 factor to code LPD based on the findings from the Rhode Island Commercial and Industrial Impact Evaluation of 2013-2015 Custom CDA Installations report that suggests standard practices outpace code LPD. The site had a 55% energy RR.

RICE19C005_L *HVAC Interactive & Operational*: There was a 14% increase in savings due to the inclusion of cooling from a rooftop unit and a 9% increase from the operational adjustment based on the metered data at this big box retail store. The site also had a quantity adjustment of -1% from a change in installed quantities of fixtures. The final Energy RR for the site is 122%.

RICE18N089 *Baseline, Quantity & Operational*: The site had a reduced average lighting output throughout the year in baseline and installed cases for -34.9% operational adjustment and a -1.1% savings adjustment due to a change in quantity. There was also a baseline adjustment of -32.5% due to:

1) efficiency adjustment (EER) -6.6%
2) ballast losses -7.8%
3) oversizing of RTU fans -17.3%
4) reheat penalty of the variable refrigerant flow heat pump -0.8%

The site had an overall energy RR of 31.5%.

RICE18N053 *Operational:* This industrial site had increased operational hours for the compressors compared to the tracking savings. The overall energy RR for the site is 117%.

RICE19N015 *Operational:* The evaluator discovered the site to be closed and out of business during the recruitment process. The business closed before March 2020, and the closure was unrelated to the COVID pandemic. The measure operated for less than one year. Because of the nature and timing of the business closure, no savings were applied to this site. The site had an overall energy RR of 0%.

4.3 PY2018 & PY2019 combined results

This section presents results from both PY2018 and PY2019 studies individually and also rolled up/program level realization rate by combining PY2016, PY2018, and PY2019 evaluated sample results.

4.3.1 Historic Operational Adjustment

National Grid and DNV chose to keep the integrity of the randomly selected sample by collecting as much information from each site. If a minimum amount of information was collected to confirm a measure installation verification for Non-Ops sites, and Baseline, Methodology and Tracking & Administrative corrections were verified from the Desk review sites.

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.

Operational adjustment results were used from the PY2016, PY2018, and PY2019 samples. Table 4-3 details the number of sites used from each program year that were used to calculate the imputed historical operational adjustment for this study. 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 14 out of 21, and PY2019 used 11 out of 21 sampled sites, and 12 out of 12 have been used from PY2016, as shown below.

Table 4-3. Sites used for Imputed Historical Operational Adjustment Calculations (lighting + non-lighting)

Program Year	Number of Sites in Imputed Ops Adjustments	Number of Sites in Program Year
PY2016	12	12
PY2018	14	21
PY2019	11	21

Figure 4-2 & Figure 4-3 below presents bar charts of evaluated annual energy RRs for all PY2018 and PY2019 sites with Full M&V evaluations. The figure below shows seven sites in PY2018 and nine sites in PY2019 had realized energy savings greater than 100%. Two sites in PY2019 and one in PY2018 site realized zero energy savings in the evaluation.

Figure 4-2: Energy realization rates for Full M&V completed sites in the PY2018 sample (unweighted)

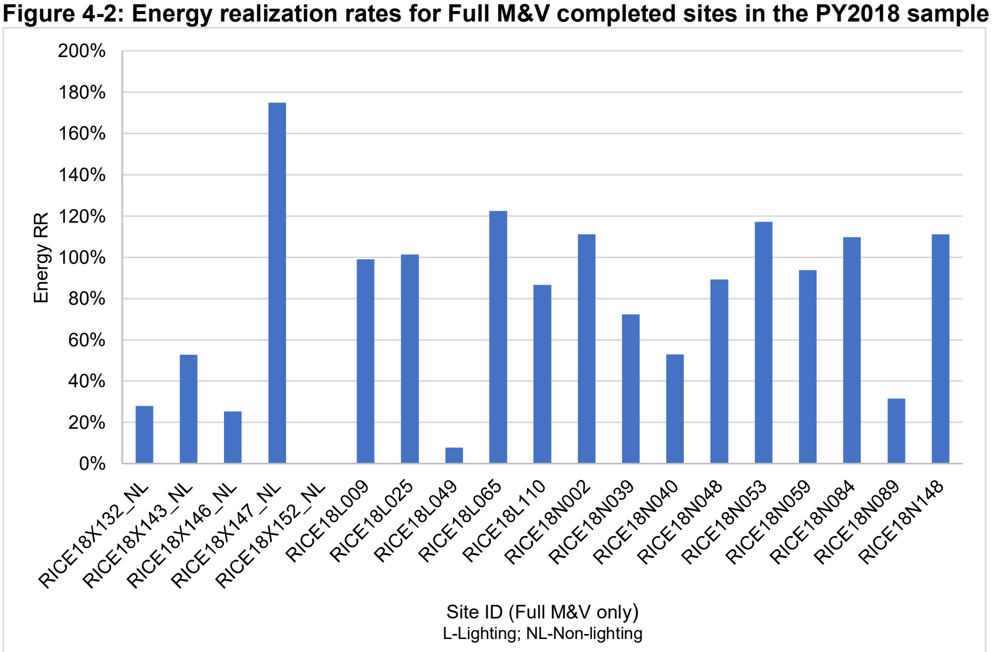
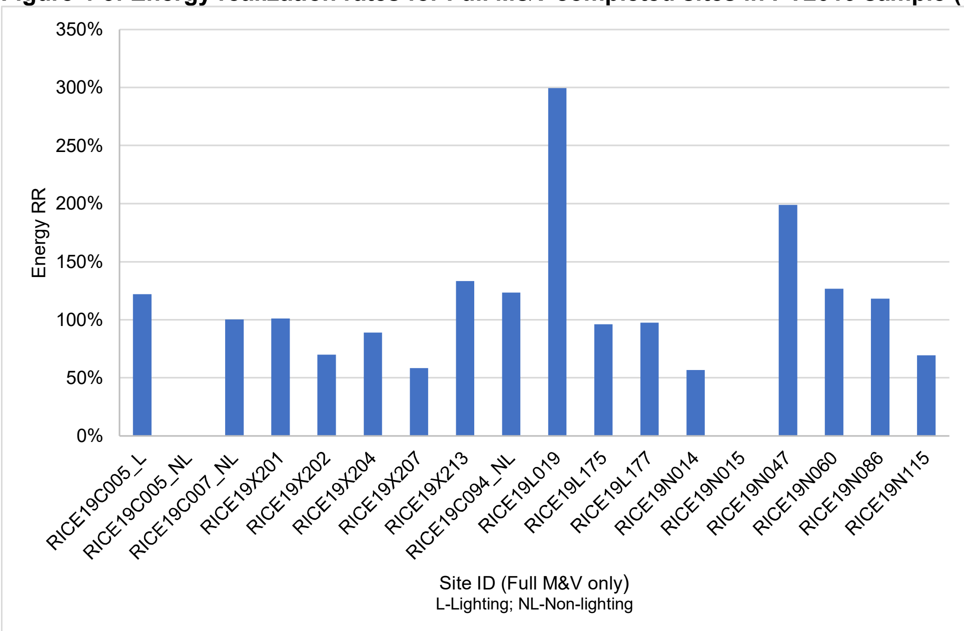


Figure 4-3: Energy realization rates for Full M&V completed sites in PY2019 sample (unweighted)



As mentioned in the previous section, two large SEMP[12] sites (one site in PY2018 and PY2019 samples) have been weighted separately in their own strata based on total savings instead of case weights to avoid over or under-representing large SEMP customers in the overall population. PY2019 sub-sampling was done during the Sample Design stage before the fieldwork began using the MBBS method, but for PY2018, the sampling was done manually (random) during the M&V planning.

4.3.1.1 Site Weight Calculation

Two sets of weights have been created for each of the 42 sites, except for the PY2018[13] SEMP site. The first set of case weights was calculated for all 42 sites by determining the total number of observations in the stratum and dividing by the number of evaluated observations, and the second set of weights was calculated similarly except for the reduction in the number of observations by removing Desk review only sites[14] to the observed sample (see site-level weighting in APPENDIX A). SEMP site weighting is explained in the following section. The final expansion analysis weights by stratum are presented in Table 4-4. Full M&V site weights have the same weight as Non-Ops; however, the final program level realization rate and error calculations are based on imputed calculations combining results from Full M&V sites from PY2016, PY2018 and PY2019 sample to sites with non-ops only adjustments. The methodology is similar to combining results from the three-year rolling sample with only operational adjustment calculations; however, APPENDIX C contains the specific algorithm followed to calculate imputed historical results.

[13] PY2019 follwed a similar weighting scheme as Non-SEMP sites (using case weights) as the SEMP sub-sample was selected using MBSS methodology during study planning stage. RICE19C036 had a total of 41 measures completed.

[14] RICE18L098, RICE18N115 and RICE19N172

Table 4-4: Stratification and Weighting

Study	Strata#	Population (N)	Sample (n)	Weight 1 (Desk Reviews)	Weight 2 (Non-Ops and Full M&V)
RICE2018(NL)	2001*	1	5	1.90	1.90
RICE2018(L)	2002*	1	4	3.37	3.37
RICE2018	1131$^{\Delta}$	26	4	6.50	8.67
RICE2018	1132	7	3	2.33	2.33
RICE2018	1231	80	5	16.00	16.00
RICE2018	1232	22	4	5.50	5.50
RICE2018	1233$^{\Delta}$	12	4	3.00	4.00
RICE2019	11	94	4	15.75	15.75
RICE2019	12	14	3	4.67	4.67
RICE2019	21	72	4	18.00	18.00
RICE2019	22	23	2	7.50	7.50
RICE2019	23	7	3	2.33	2.33
RICE2019	24$^{\Delta}$	4	3	1.00	1.50
RICE2019	101†	1	1	1.00	1.00
RICE2019	2001*	40	4	10.00	10.00
RICE2019	2002*	1	1	1.00	1.00

*SEMP sites; †Add-on site (not in the primary sample); $^{\Delta}$Desk Review only site in the stratum.

4.3.1.2 PY2018 SEMP subsampling & weighting:

PY2018 SEMP subsampling was completed by random selection manually (not MBBS statistical modeling). The field staff selected subsamples randomly during the M&V planning stage. The random sample selected had five non-lighting (stratum 2001) and four lighting (stratum 2002) measures as listed in Table 4-5 in this study. The site RICE18C013 included 52 measures with 1,458,742 kWh lighting savings and 1,189,622 kWh savings from non-lighting measures. These sites were weighted based on total measure level savings, as shown below, instead of case weights:

Total tracking savings from Non-Lighting measures from the PY2018 SEMP site = 1,189,621 kWh
Total tracking savings from the sub-sampled sites = 353,190 kWh (

Table 4-5)
Sample Weight = 1,189,621/ 353,190 = 3.37 (

Table 4-5)
A similar methodology was used for lighting measures (1,458,742/769,487 = 1.90; see

Table 4-5). PY2019 SEMP subsampling was completed using the MBBS statistical modeling, so the model also completed the weighting.

Table 4-5 Sampled PY2018 SEMP site IDs and tracking savings

Measure IDs	Measure	Tracking Savings (kWh)
RICE18X101_L	Lighting	400,612
RICE18X103_L	Lighting	48,983
RICE18X105_L	Lighting	42,030
RICE18X107_L	Lighting	277,862
	Total Lighting Savings	**769,487**
RICE18X132_NL	Non-lighting	189,275
RICE18X143_NL	Non-lighting	89,500
RICE18X146_NL	Non-lighting	11,089
RICE18X147_NL	Non-lighting	57,560
RICE18X152_NL	Non-lighting	5,766
	Total Non-lighting Savings	**353,190**

4.3.2 Lighting realization rates

The site-level evaluation results were aggregated using the final adjusted case weights. The realization rates were calculated and then applied to total tracking savings to determine their total evaluated savings. Table 4-6 illustrates the statewide lighting prospective realization rates for the custom electric program in RI. The combined RR for lighting meets the targeted relative precision (RP) of ±15% at a 90% confidence interval (CI). The combined three-year rolling-based RR is 95.4%, with an RP of ±9.7% at a 90% CI. The PY2018 and PY2019 RRs are 94.3% and 91.4%, with an RP of ±23.7% and ±18.8% at 90% CI, respectively. It is important to note the combined results presented in this section are estimated using both Full M&V, Non-Ops and Desk Reviewed site-level results. Therefore, the variability can be expected to increase as we get back to the Full M&V at all sampled sites in future evaluations.

Table 4-6. Prospective realization rates from Evaluated Energy (kWh) Savings for Lighting Measures

Lighting	RI			Combined Results
	PY2016	PY2018	PY2019	PY2016+ PY2018+PY2019
Tracking Energy Savings (kWh)	19,142,741	13,294,077	17,498,949	49,935,767
Sample Size (n)	3	10	10	23
RR	99.9%	94.3%	91.4%	95.4%
Relative precision @ 90% CI	±5.6%	±23.7%	±18.8%	±9.7%

Table 4-7 and Table 4-8 present prospective realization rates for Summer and Winter peak demand (kW) savings, and Table 4-9 presents prospective realization rates for %On-peak energy savings. The three-year rolling/combined results for both Summer and Winter peak demands met the target precision of ±20% at 80% CI.

Table 4-7. Prospective realization rates from Evaluated Summer Peak Demand (kW) Savings for Lighting Measures

Lighting	RI			Combined Results
	PY2016	PY2018	PY 2019	PY2016+ PY2018+PY2019
Tracking Summer Demand (kW)	936	1,671	1,694	4,301
Sample Size (n)	3	10	10	23
RR	107.4%	92.7%	88.4%	94.2%
Relative precision@ 80% CI	±9.0%	±21.7%	±29.3%	±13.6%

Table 4-8. Prospective realization rates from Evaluated Winter Peak Demand (kW) Savings for Lighting Measures

Lighting	RI			Combined Results
	PY2016	PY2018	PY 2019	PY2016+ PY2018+PY2019
Tracking Winter Demand (kW)	4,021	2,076	2,910	9,007
Sample Size (n)	3	10	10	23
RR	85.3%	71.2%	62.1%	74.5%
Relative precision@ 80% CI	±4.6%	±18.8%	±21.5%	±9.2%

Table 4-9. Prospective realization rates from Evaluated %On-Peak Energy Savings for Lighting Measures

Lighting	RI			Combined Results
	PY2016	PY2018	PY 2019	PY2016+ PY2018+PY2019
%On Peak Energy	19,142,741	13,294,077	17,498,949	49,935,767
Sample Size (n)	3	10	10	23
RR	106.4%	87.8%	89.4%	95.5%
Relative precision@ 80% CI	±16.2%	±13.3%	±8.4%	±9.9%

4.3.3 Non-lighting realization rates

Non-lighting realization rates are calculated similarly to lighting. The site-level evaluation results were aggregated using the final adjusted case weights. The realization rates were calculated and then applied to total tracking savings to determine their total evaluated savings. Table 4-10 presents the non-lighting prospective realization rates for the custom electric program in RI. The combined RR for non-lighting meets the targeted relative precision (RP) of ±15% at a 90% confidence interval (CI). The combined three-year rolling-based RR is 81.1%, with an RP of ±13.2% at a 90% CI. PY2018 and PY2019 RR are 77.6% and 104.1%, with an RP of ±12.3 and ±18.4% at 90% CI, respectively. The lower RRs at the site level (see seven sites <100%) have driven the PY2018 and PY2019 RRs below 100%. PY2019 RR is significantly better than the other two program years, but it is important to note the higher relative precision, implying a high variability in site-level results. The RRs for PY2019 sites varied from 0% to 199% across 15 sites, with 6 sites over 100% RR.

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 4-10. Non-lighting realization rates

Non-Lighting	RI			Combined Results
	PY2016	PY2018	PY 2019	PY2016+ PY2018+PY2019
Tracking Energy Savings (kWh)	21,044,847	12,910,679	12,804,067	46,759,593
Sample Size (n)	8	14	15	37
RR	69.3%	77.6%	104.1%	81.1%
Relative precision @ 90% CI	±23.0%	±12.3%	±18.4%	±13.2%

Table 4-11 and Table 4-12 present prospective realization rates for Summer and Winter peak demand (kW) savings, and

Table 4-13 presents prospective realization rates for %On-peak energy savings. The three-year rolling/combined results for both Summer and Winter peak demands met the target precision of ±20% at 80% CI.

Table 4-11. Prospective realization rates from Evaluated Summer Peak Demand (kW) Savings for Non-Lighting Measures

Non-Lighting	RI			Combined Results
	PY2016	PY2018	PY 2019	PY2016+ PY2018+PY2019
Tracking Summer Demand (kW)	3,799	1,634	1,754	7,187
Sample Size (n)	8	14	15	37
RR	71.0%	69.0%	72.4%	70.9%
Relative precision@ 80% CI	±19.4%	±12.1%	±24.5%	±12.2%

Table 4-12. Prospective realization rates from Evaluated Winter Peak Demand (kW) Savings for Non-Lighting Measures

Non-Lighting	RI			Combined Results
	PY2016	PY2018	PY 2019	PY2016+ PY2018+PY2019
Tracking Winter Demand (kW)	2,391	1,404	1,713	5,508
Sample Size (n)	8	14	15	37
RR	77.0%	86.5%	98.4%	86.1%
Relative precision@ 80% CI	±19.0%	±12.8%	±44.3%	±16.4%

Table 4-13. Prospective realization rates from Evaluated %On-Peak Energy Savings for Non-Lighting Measures

Non-Lighting	RI			Combined Results
	PY2016	PY2018	PY 2019	PY2016+ PY2018+PY2019
%On Peak Energy	21,044,847	12,910,679	12,804,067	46,759,593
Sample Size (n)	8	14	15	37
RR	85.7%	84.1%	68.4%	80.5%
Relative precision@ 80% CI	±9.3%	±13.0%	±40.4%	±12.4%

5 CONCLUSIONS, RECOMMENDATIONS, AND CONSIDERATIONS

5.1 Conclusions

The scope of and approach to this study differed from the previous study (PY2016) in handling operational factors. Due to the Pandemic, the study had to rely on PY2016 historical operation adjustments factors combined with the PY2018 and PY2019 operation-adjusted sampled sites in this study. This study's historical adjustment factors were calculated using twelve PY2016, fourteen in PY2018 and eleven Full M&V sites in PY2019.

The realization rates for gross annual energy savings for custom lighting saw a drop from 99.9%[15] for PY2016 to 95.4% for the rolling three-year value. For custom non-lighting, the gross annual energy savings RRs saw a net improvement over the study[15] from 65.5% from the PY2016 study to 78% from PY2018, 104% in PY2019 and 81.1% for the combined rolling three-year value. RRs for summer and winter on-peak demand followed the same path as energy, i.e., decrease in RR for lighting and improvement in 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 lighting (95.4%) and non-lighting (81.1%) realization rate results shall replace the previous realization rates used by National Grid beginning in PY2022. The results from this study should be combined with the next round of custom electric impact evaluation, which will evaluate PY2020 applications and is expected to be applied to the PY2023 tracking savings.

Recommendation 2. We continue to note that the application files are not always complete, sometimes missing significant information (see example). DNV recommends that before the incentive payment step, National Grid's review process shall include a verification step to ensure that savings values recorded in the database accurately reflect the savings supported by the calculations included with the project documentation.

Ex: In this study, Site RICE18C013 consisted of (61) non-lighting measures under one application at a large university. A summary spreadsheet of all 61 measures was included in the project documentation, whose total kWh savings for all 61 measures matched the total kWh savings found in the tracking database. However, the supporting calculations in the supplementary documentation for each measure did not match the savings values in the summary spreadsheet (and therefore database) for 34 of the 61 measures. The calculation savings differed from the summary spreadsheet by between -100% to 736% for each measure.

Recommendation 3. DNV recommends evaluating lifetime savings and reporting them at the site level in all future custom electric evaluations. This is to prepare for reporting the new lifetime savings goal as National Grid transitioned away from annual savings goals to lifetime savings goals beginning in PY2021. Reporting them in every study is critical to producing 3-year rolling-based lifetime savings results. Should lifetime savings results be available beginning with PY2020 evaluated projects, then a standard 3-year rolling reporting cycle would be available after the PY2022 evaluation

[15] PY2016 study: http://rieermc.ri.gov/wp-content/uploads/2020/08/rice2016_final_clean.pdf

5.3 Considerations

Consideration 1: DNV proposes a three-stage process to include SEMP projects in the next program year evaluation sampling for the PY2020 RI Custom Electric Impact Evaluation. Stage 1 would identify SEMP projects and categorize them separately using the line items claimed in tracking savings and creating site IDs as traditionally completed in recent evaluations. DNV will identify which SEMP projects are identified for evaluation, which leads to Stage 2. Stage 2 will require project files to disaggregate sampled SEMP projects to the measure level. DNV will sample again with the disaggregated sampling breakout at the measure level to identify measure-specific projects to evaluate that will provide results within statewide precision targets. Stage 3 is an extra step only if an identified project in Stage 2 proves to be a much larger burden on evaluators and customers than need be due to many projects and/or individual buildings. A second disaggregation would then occur at a unit needed to reduce the burden on a case-by-case basis. Sub-categories (lighting or non-lighting) will be provided for each claimed savings and measure row item as traditionally completed, and stratification will follow the same methodology as has been completed in previous evaluations.

Consideration 2: Continue to leverage the ex-ante review process for measures with large-claimed savings or for measures that are considered unique. Above the 2,000,000-kWh savings threshold, most custom measures fall into the census stratum or just below the census stratum, which effectively becomes a census stratum through recruiting attrition. By allowing the evaluation team to assess: baseline selection independently, baseline operational strategies, capture baseline operational trend data on key parameters, and estimates of kWh and kW demand on the largest and sites most likely to have variable realization rates.

Consideration 3: Similar to the study being performed in MA currently related to steam trap test and repair frequencies, National Grid should consider some research to be done into the baseline/ISP rate at which customers test for and repair leaks in their compressed air system, and based on the findings from that research, consider how that may impact program design and outreach for compressed air leak repairs, as well as to measure life for compressed air leak repairs.

Consideration 4: Consider alternate data acquisition and analysis approaches as an outcome of the pandemic to minimize customer touch. Options could include interval billing analysis, virtual audits, and remote monitoring and should include analysis of customer segments best suited for the alternate options considered.

Consideration 5: Consider implementing more frequent and rigorous post-installation commissioning for complex building management system (BMS) measures. The evaluation found several instances where Controls sequences are not operating as described in the project documentation. This has been a significant source of non-lighting operational discrepancies in most BMS-installed sites.

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	Measure ID	App	Tracking kWh	Weight 1	Weight 2	Evaluation Type	Measure	Market Event
RICE18C013*	RICE18X101_L	7307056; 7731255	400,612	1.9	1.9	NON-OPS	LED_IN-LED LIGHTING - INDOOR	Retrofit
RICE18C013*	RICE18X103_L	7307056; 7731255	48,983	1.9	1.9	NON-OPS	LED_IN-LED LIGHTING - INDOOR	Retrofit
RICE18C013*	RICE18X105_L	7307056; 7731255	42,030	1.9	1.9	NON-OPS	LED_IN-LED LIGHTING - INDOOR	Retrofit
RICE18C013*	RICE18X107_L	7307056; 7731255	277,862	1.9	1.9	NON-OPS	LED_IN-LED LIGHTING - INDOOR	Retrofit
RICE18C013*	RICE18X132_NL	7307056; 7731255	189,275	3.37	3.37	Full M&V	LED_IN-LED LIGHTING - INDOOR	Retrofit
RICE18C013*	RICE18X143_NL	7307056; 7731255	89,500	3.37	3.37	Full M&V	LED_IN-LED LIGHTING - INDOOR	Retrofit
RICE18C013*	RICE18X146_NL	7307056; 7731255	11,089	3.37	3.37	Full M&V	LED_IN-LED LIGHTING - INDOOR	Retrofit
RICE18C013*	RICE18X147_NL	7307056; 7731255	57,560	3.37	3.37	Full M&V	LED_IN-LED LIGHTING - INDOOR	Retrofit
RICE18C013*	RICE18X152_NL	7307056; 7731255	5,766	3.37	3.37	Full M&V	LED_IN-LED LIGHTING - INDOOR	Retrofit
RICE18C050	RICE18C050_L	6588264	14,941	3	4	NON-OPS	LGHP-PERFORMANCE LIGHTING	New Construction

RICE18C050	RICE18C050_NL	6588264	444,875	3	4	NON-OPS	LGHP-PERFORMANCE LIGHTING	Retrofit
RICE18C094	RICE18C094_L	7574458	14,280	16	16	NON-OPS	LGHT-LIGHTING SYSTEMS	Retrofit
RICE18C094	RICE18C094_NL	7574458	28,501	16	16	NON-OPS	LGHT-LIGHTING SYSTEMS	Retrofit
RICE18L009	RICE18L009	7404765	155,676	6.5	8.67	Full M&V	STLI-STREET LIGHTS	Retrofit
RICE18L025	RICE18L025	6911935; 7804134	2,083,156	2.33	2.33	Full M&V	LGHP-PERFORMANCE LIGHTING	New Construction
RICE18L038	RICE18L038	7467749; 8544650	778,503	2.33	2.33	NON-OPS	LED_IN-LED LIGHTING - INDOOR	Retrofit
RICE18L049	RICE18L049	7423208	156,519	6.5	8.67	Full M&V	LED_IN-LED LIGHTING - INDOOR	Retrofit
RICE18L065	RICE18L065	7353143	622,407	2.33	2.33	Full M&V	LED_IN-LED LIGHTING - INDOOR	Retrofit
RICE18L098	RICE18L098	7599855	150,913	6.5	0	Desk Review	LGHT-LIGHTING SYSTEMS	Retrofit
RICE18L110	RICE18L110	7928379	229,992	6.5	8.67	Full M&V	LGHT-LIGHTING SYSTEMS	Retrofit
RICE18N002	RICE18N002	7799073	25,780	16	16	Full M&V	OM_CAIR-OPERATION / MAINTENANCE FOR CAIR	Retrofit
RICE18N039	RICE18N039	8020501	1,700	16	16	Full M&V	HVAC-HVAC (EQUIP OR SYSTEMS)	New Construction

RICE18N040	RICE18N040	7614310	204,654	5.5	5.5	Full M&V	REFG-REFRIGERATION EQUIPMENT AND CONTROLS	Retrofit
RICE18N048	RICE18N048	6686101	156,660	5.5	5.5	Full M&V	CAIR-COMPRESSED AIR	Retrofit
RICE18N053	RICE18N053	6500330	180,699	5.5	5.5	Full M&V	OM_CAIR-OPERATION / MAINTENANCE FOR CAIR	Retrofit
RICE18N059	RICE18N059	8469852	166,970	5.5	5.5	Full M&V	OM_HVAC-OPERATION / MAINTENANCE FOR HVAC	Retrofit
RICE18N084	RICE18N084	7651168	46,467	16	16	Full M&V	HVAC-HVAC (EQUIP OR SYSTEMS)	New Construction
RICE18N089	RICE18N089	7999568	266,504	3	4	Full M&V	PROC-PROCESS EQUIPMENT/CONTROLS	New Construction
RICE18N106	RICE18N106	7185003	308,837	3	4	NON-OPS	OM_CAIR-OPERATION / MAINTENANCE FOR CAIR	Retrofit
RICE18N115	RICE18N115	7244682	541,928	3	0	Desk Review	EMSB-EMS / HVAC CONTROLS	Retrofit
RICE18N148	RICE18N148	8206773	9,635	16	16	Full M&V	REFG-REFRIGERATION EQUIPMENT AND CONTROLS	New Construction
RICE19C005	RICE19C005_L	10048840	53,433	15.75	15.75	Full M&V	EMSB-EMS / HVAC Controls	Retrofit
RICE19C005	RICE19C005_NL	10048840	3,696	15.75	15.75	Full M&V	EMSB-EMS / HVAC Controls	Retrofit

RICE19C007	RICE19C007_L	9808400 , 9926319	108,642	15.75	15.75	NON-OPS	REFG-Refrigeration Equipment and Controls	Retrofit
RICE19C007	RICE19C007_NL	9808400 , 9926319	12,580	15.75	15.75	Full M&V	REFG-Refrigeration Equipment and Controls	Retrofit
RICE19C036*	RICE19X201_L	9494449 , 9209205, 8116694, 8116694	5,141	10	10	NON-OPS	LGHT-Lighting Systems	Retrofit
RICE19C036*	RICE19X201	9494449 , 9209205, 8116694, 8116694	3,251	10	10	Full M&V	LGHT-Lighting Systems	Retrofit
RICE19C036*	RICE19X202	9494449 , 9209205, 8116694, 8116694	26,011	10	10	Full M&V	LGHT-Lighting Systems	Retrofit
RICE19C036*	RICE19X204	9494449 , 9209205, 8116694, 8116694	8,231	10	10	Full M&V	LGHT-Lighting Systems	Retrofit
RICE19C036*	RICE19X207	9494449 , 9209205, 8116694, 8116694	102,338	10	10	Full M&V	LGHT-Lighting Systems	Retrofit
RICE19C036*	RICE19X213_L	9494449 , 9209205, 8116694, 8116694	392,630	1	1	NON-OPS	LGHT-Lighting Systems	Retrofit

RICE19C036*	RICE19X213	9494449 , 9209205, 8116694, 8116694	108,166	1	1	Full M&V	LGHT-Lighting Systems	Retrofit
RICE19C072	RICE19C072_L	9764300 , 10308605 , 10309202 , 10343787 , 9897496, 8887850	539,409	1	1.5	NON-OPS	CHIL-Chiller - HVAC	Retrofit
RICE19C072	RICE19C072_NL	9764300, 10308605, 10309202, 10343787, 9897496, 8887850	866,823	1	1.5	NON-OPS	CHIL-Chiller - HVAC	Retrofit & New Construction
RICE19C094	RICE19C094_L	10587516, 9153589, 8716670	105,949	7.5	7.5	NON-OPS	LED_IN-LED Lighting - Indoor	New Construction
RICE19C094	RICE19C094_NL	10587516, 9153589, 8716670	115,641	7.5	7.5	Full M&V	LED_IN-LED Lighting - Indoor	Retrofit
RICE19L006	RICE19L006	8884147	15,124	15.75	15.75	NON-OPS	LED_IN-LED Lighting - Indoor	Retrofit
RICE19L019	RICE19L019	8425087	25,117	1	1	Full M&V	STLI-STREET LIGHTS	Retrofit
RICE19L091	RICE19L091	5387391	302,413	15.75	15.75	NON-OPS	LGHT-Lighting Systems	New Construction

RICE19L114	RICE19L114	9994194	480,921	4.67	4.67	NON-OPS	LED_OUT-LED Lighting - Outdoor	Retrofit
RICE19L175	RICE19L175	9010772, 7467071	1,070,627	4.67	4.67	Full M&V	SLCN-Strt lght + CNTRL	Retrofit
RICE19L177	RICE19L177	9020546, 7236613	450,543	4.67	4.67	Full M&V	SLCN-Strt lght + CNTRL	Retrofit
RICE19N014	RICE19N014	7864915, 9674245, 9171306, 7257791	628,289	2.33	2.33	Full M&V	DATA_C-Data Center Cooling	Retrofit
RICE19N015	RICE19N015	9511271	1,405	18	18	Full M&V	REFG-Refrigeration Equipment and Controls	New Construction
RICE19N047	RICE19N047	8662026	246,842	7.5	7.5	Full M&V	CAIR-Compressed Air	New Construction
RICE19N060	RICE19N060	8556355	64,250	18	18	Full M&V	EMSB-EMS / HVAC Controls	Retrofit
RICE19N064	RICE19N064	9505098	1,405	18	18	NON-OPS	REFG-Refrigeration Equipment and Controls	New Construction
RICE19N081	RICE19N081	9511291	1,405	18	18	NON-OPS	REFG-Refrigeration Equipment and Controls	New Construction
RICE19N083	RICE19N083	8677820, 5388014	1,458,522	1	1.5	NON-OPS	PROC-Process Equipment/Controls	New Construction
RICE19N086	RICE19N086	9310038, 9808916, 9209203, 6779649	565,957	2.33	2.33	Full M&V	OM_CAIR-Operation / Maintenance for CAIR	New Construction

RICE19N115	RICE19N115	9955597, 10471027	324,293	2.33	2.33	Full M&V	OM_CAIR-Operation / Maintenance for CAIR	Retrofit
RICE19N172	RICE19N172	10026201, 10806043, 8923824, 8038934, 8923825, 8124545	1,315,460	1	0	Desk Review	CAIR-Compressed Air	Retrofit

**SEMP site*

DNV

APPENDIX B. SITE SAVINGS SUMMARY

Site ID	Measure ID	National Grid 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)	
RICE18C013	RICE18X101_L	7307056; 7731255	400,612	47%	45	48.5	424,287	47%	51.9	49	106%
RICE18C013	RICE18X103_L	7307056; 7731255	48,983	47%	5.5	5.9	48,986	48%	5.5	5.9	100%
RICE18C013	RICE18X105_L	7307056; 7731255	42,030	47%	4.7	5.1	42,183	46%	4.7	5.1	100%
RICE18C013	RICE18X107_L	7307056; 7731255	277,862	45%	31.2	33.7	294,036	46%	35.7	33.7	106%
RICE18C013	RICE18X132_NL	7307056; 7731255	189,275	45%	41.2	10.9	52,860	24%	2.2	2.2	28%
RICE18C013	RICE18X143_NL	7307056; 7731255	89,500	45%	19.5	5.2	47,362	18%	-	-	53%
RICE18C013	RICE18X146_NL	7307056; 7731255	11,089	45%	2.4	0.6	2,803	0%	-	-	25%
RICE18C013	RICE18X147_NL	7307056; 7731255	57,560	45%	18.2	4.8	100,639	51%	11.3	1.7	175%
RICE18C013	RICE18X152_NL	7307056; 7731255	5,766	45%	0.6	0.2	-	0%	-	-	0%
RICE18C050	RICE18C050_L	6588264	14,941	88%	4.6	4.6	7,000	69%	1.9	-	47%
RICE18C050	RICE18C050_NL	6588264	444,875	43%	42.6	30.9	475,552	48%	56.4	56.4	107%
RICE18C094	RICE18C094_L	7574458	14,280	27%	0.2	3	15,137	35%	0.2	3	106%
RICE18C094	RICE18C094_NL	7574458	28,501	46%	4.3	2.6	12,946	23%	2.3	2.5	45%
RICE18L009	RICE18L009	7404765	155,676	22%	-	37.3	154,242	24%	-	1.8	99%
RICE18L025	RICE18L025	6911935; 7804134	2,083,156	49%	256	256	2,113,416	44%	228.6	237.2	101%
RICE18L038	RICE18L038	7467749; 8544650	778,503	53%	100.2	100.2	808,755	45%	114.9	100.2	104%
RICE18L049	RICE18L049	7423208	156,519	68%	25.5	25.5	12,237	57%	1.7	0.3	8%

RICE18L065	**RICE18L065**	7353143	622,468	49%	55.1	59.7	762,968	47%	89.9	88.9	123%
RICE18L098	**RICE18L098**	7599855	150,913	70%	28.8	23.9	150,913	70%	28.8	23.9	100%
RICE18L110	**RICE18L110**	7928379	229,992	48%	24.9	24.9	199,293	43%	29.2	25	87%
RICE18N002	**RICE18N002**	7799073	25,780	48%	3.1	3.1	28,676	58%	2.8	3.6	111%
RICE18N039	**RICE18N039**	8020501	1,700	46%	0.6	-	1,231	65%	0.7	-	72%
RICE18N040	**RICE18N040**	7614310	204,654	46%	23.4	23.4	108,394	48%	12.6	12.4	53%
RICE18N048	**RICE18N048**	6686101	156,660	48%	14	14	139,962	48%	16	16	89%
RICE18N053	**RICE18N053**	6500330	180,669	56%	25.1	25.1	211,703	48%	24	24.3	117%
RICE18N059	**RICE18N059**	8469852	166,970	52%	9.5	6.5	156,695	4%	18.9	17	94%
RICE18N084	**RICE18N084**	7651168	46,467	54%	3.9	5.2	51,035	75%	3.2	4.8	110%
RICE18N089	**RICE18N089**	7999568	266,504	64%	54.9	53.6	84,021	66%	16.8	16.8	32%
RICE18N106	**RICE18N106**	7185003	308,837	48%	38.6	38.6	245,041	48%	30.6	30.6	79%
RICE18N115	**RICE18N115**	7244682	541,928	45%	27.3	29.6	521,437	45%	24.2	25.9	96%
RICE18N148	**RICE18N148**	8206773	9,635	46%	0.9	0.7	10,713	46%	1.2	1.2	111%
RICE19C005	**RICE19C005_L**	10048840	53,433	72%	2	2	65,218	61%	13.7	10.2	122%
RICE19C005	**RICE19C005_NL**	10048840	3,696	46%	-	-	-	0%	-	-	0%
RICE19C007	**RICE19C007_L**	9808400, 9926319	108,642	0%	26	7.4	112,984	53%	27.2	7.4	104%
RICE19C007	**RICE19C007_NL**	9808400, 9926319	12,580	54%	1.6	1.6	12,618	54%	4.6	3.1	100%
RICE19C036	**RICE19X201**	9494449, 9209205, 8116694, 8116694	3,251	45%	0.7	0.2	3,286	36%	0.3	0.3	101%
RICE19C036	**RICE19X201_L**	9494449, 9209205, 8116694, 8116694	5,141	47%	0.6	0.6	5,467	46%	0.7	0.6	106%

RICE19C036	**RICE19X202**	9494449, 9209205, 8116694, 8116694	26,011	45%	5.7	1.5	18,195	63%	3.1	3.3	70%
RICE19C036	**RICE19X204**	9494449, 9209205, 8116694, 8116694	8,231	45%	1.8	0.5	7,328	35%	0.5	0.5	89%
RICE19C036	**RICE19X207**	9494449, 9209205, 8116694, 8116694	102,338	54%	22.3	5.9	59,667	4%	3	1.7	58%
RICE19C036	**RICE19X213**	9494449, 9209205, 8116694, 8116694	108,166	45%	23.5	98	144,049	12%	2.2	3.4	133%
RICE19C036	**RICE19X213_L**	9494449, 9209205, 8116694, 8116694	392,630	47%	44.1	47.6	416,373	48%	50.4	47.6	106%
RICE19C072	**RICE19C072_L**	9764300, 10308605, 10309202 10343787, 9897496, 8887850	539,409	65%	82.5	83.6	546,764	38%	88	82.4	101%
RICE19C072	**RICE19C072_NL**	9764300, 10308605, 10309202 10343787, 9897496, 8887850	866,823	57%	89	10	866,823	57%	68.9	30.1	100%
RICE19C094	**RICE19C094_L**	10587516, 9153589, 8716670	105,949	62%	2.8	0.9	86,434	53%	3.1	0.4	82%
RICE19C094	**RICE19C094_NL**	10587516, 9153589, 8716670	115,641	67%	19.7	19.7	142,634	23%	18	16.5	123%
RICE19L006	**RICE19L006**	8884147	15,124	54%	1.9	2.7	16,421	48%	2.7	1.7	109%
RICE19L019	**RICE19L019**	8425087	25,117	25%	-	6.2	75,188	23%	-	-	299%
RICE19L091	**RICE19L091**	5387391	302,413	66%	53.2	53.2	167,659	64%	29.5	29.5	55%

RICE19L114	**RICE19L114**	9994194	480,921	36%	24.7	108.1	494,444	65%	33.3	103.1	103%
RICE19L175	**RICE19L175**	9010772, 7467071	1,070,627	25%	-	171.3	1,029,176	17%	-	11.7	96%
RICE19L177	**RICE19L177**	9020546, 7236613	450,543	25%	-	109.7	439,643	15%	-	-	98%
RICE19N014	**RICE19N014**	7864915, 9674245, 9171306, 7257791	628,289	17%	31.1	93.8	357,224	50%	0.4	29.3	57%
RICE19N015	**RICE19N015**	9511271	1,405	48%	0.2	0.2	-	0%	-	-	0%
RICE19N047	**RICE19N047**	8662026	246,842	76%	36.1	-	490,935	29%	55.4	58.6	199%
RICE19N060	**RICE19N060**	8556355	64,250	92%	4.8	-0.9	81,308	43%	0.2	0.5	127%
RICE19N064	**RICE19N064**	9505098	1,405	48%	0.2	0.2	1,405	45%	0.1	0.1	100%
RICE19N081	**RICE19N081**	9511291	1,405	48%	-	0.2	1,405	45%	0.1	0.1	100%
RICE19N083	**RICE19N083**	8677820, 5388014	1,458,522	61%	120	120	145,852	61%	12	12	10%
RICE19N086	**RICE19N086**	9310038, 9808916, 9209203, 6779649	565,957	48%	68.9	69.3	668,896	50%	68.8	66.3	118%
RICE19N115	**RICE19N115**	9955597, 10471027	324,293	51%	41.7	41.7	225,334	39%	25.5	26	69%
RICE19N172	**RICE19N172**	1002620, 10806043, 8923824, 8038934, 8923825, 8124545	1,315,460	50%	141.1	141.1	1,315,460	50%	164.4	164.4	100%

_L: Lighting measure; _NL: Non-lighting measure; RICE18- RI Custom Electric PY2018; SiteID that includes "X" in the measure ID is part of the SEMP subsample.

APPENDIX C. RI PY2018 & PY2019 CUSTOM ELECTRIC IMPACT EVALUATION EXPANSION ANALYSIS METHODOLOGY MEMO

Memo to:		**Memo No:**	RICE_Expansion_memo_v1
Erin Crafts, National Grid		**From:**	Srikar Kaligotla, DNV
David Jacobson, Jacobson Energy		**Date:**	05/28/21
Copied to:		**Prep. By:**	Srikar Kaligotla, DNV
Olav Hegland, DNV			Benjamin Jones, DNV

Study Background

The custom electric segment includes custom projects that do not meet the criteria of National Grid's prescriptive or upstream program offerings. These projects generally use custom engineering analysis to generate ex-ante savings estimates rather than deemed savings estimates. The custom electric segment is currently evaluated each year, with end uses being segmented into lighting and non-lighting sampling categories, and results are pooled with the prior study results to achieve specific precision requirements. The most recent custom impact evaluation in RI was completed in the 2016 program year (RI PY2016 study). The RI PY2016 study[16] piggybacked with a similar study in MA[17] to achieve reliable precision targets.

Amended Scope

Due to the COVID-19 Pandemic, per National Grid's recommendation, all fieldwork was shut down in March 2020 and restarted in early 2021. Based on customer interviews completed at sampled sites, we learned that the operation at several facilities was impacted by the pandemic and ran at non-typical schedules. This impacts the energy consumption at each site. DNV, in consultation with National Grid and the EERMC Consultant Team (C-team), amended the scope for RI PY2018 to address this anomalous change in operations while evaluating to assess long-term energy savings RI PY2019 studies. Evaluated sites in each study could receive different levels of verification depending on customer access and whether customer operations were "typical" or "exceptional" during the pandemic. The levels of verification were categorized as listed below. RI PY2016 sites were completed before the pandemic and included full M&V site results for all sites. The other three studies were/are being completed during the pandemic had sites with evaluation levels split into three categories, as shown below.

[16] http://rieermc.ri.gov/wp-content/uploads/2020/08/rice2016_final_clean.pdf

[17] http://ma-eeac.org/wordpress/wp-content/uploads/MA_CIEC_Stage5_Report_P80_Custom_Impact_Evaluation_PY2016_Final.pdf

Table 5-1. Basic Structure and Sample Size

Study	Study ID	Category 1: Desk Review Results	Category 2: Verified Non-Operational Factors	Category 3: Full M&V	Total
MA PY18/19*	S1	18	18	5	18
RI PY2016	S2	12	12	12	12
RI PY2018	S3	21	19	15	21
RI PY2019	S4	20	19	11	20
Total		**71**	**68**	**43**	**71**

**Results of this study included historic operational adjustments imputed from the previous MA study (MA PY2017/18 with a sample size of 31) and will be used to inform the historic operational adjustments for RI PY2018 and RI PY2019 if needed.*

Since there are only three sites in S3 and S4 combined that have only Category 1 level verification, the expansion for the category 1 adjustment will be completed using a set of sample weights that includes all sites, while the weights for category 2 and category 3 adjustments will have weights for the sample points that completed category 2 verification. Category 3 adjustment will also require imputation across studies to calculate the final adjustment. This imputation will follow the approach used in the MA PY18/19 studies and be adjusted to incorporate information from 4 studies rather than 3 for the operational adjustment. This process will be done separately for each of the RI PY2018 and RI PY2019 samples, and we plan to use all four study results to impute for each.

Calculating the current and combined realization rates incorporating imputed operational adjustment

Notation

z = RI program year (2018 or 2019)

w_j = full-sample weight for sample site j in the study "Z" sample

S_y = population tracked savings of period y

S_T = population tracked savings for all 4 studies combined

= $S_1 + S_2 + S_3 + S_4$

q_y = period-y savings as a fraction of the 4-study total

= S_y/S_T

f_{gz} = fraction of Study-Z savings represented by "good" sites, i.e., those with operational data

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

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

= $S_1 + S_2 + f_{g3} S_3 + f_{g4} S_4$

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

Period-3, in this case, is the period for which we will only have ops adjustments for some of the samples, i.e., RI18 and separately RI19.

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

Period Z Operational realization rate RR_{oz}

1. For the portion of the population represented by sampled sites with operational adjustments ("good" sites g), RRogz is directly calculated from the sample, using the full sample weights wj. That is, RRogz is the weighted sum of verified gross savings divided by the weighted sum of tracked gross savings.
2. For sampled sites without operational adjustment ("bad" sites b), RR_{obz} is imputed as:

$RR_{obz} = (S_1 RR_{o1} + S_2 RR_{o2} + f_{g3}\, S_3 RR_{og3} + f_{g4}\, S_4 RR_{og4})/S_{Tg}$

That is, all available sites with operational data are used to impute the RR for the uncovered portion of the Study-Z population, with the RR from different periods weighted by the savings it represented.

3. Overall Operational Adjustment for Study-Z is calculated as

$RR_{oz} = f_{gz}\, RR_{ogz} + (1-f_{gz}) RR_{obz}$.

4. Standard error of Period 3 realization rate

The standard error is calculated from the individual standard errors as

$SE(RR_{oZ}) = \mathrm{sqrt}[(f_{g4}\, S_{4)}{}^2\, SE^2(RR_{og4}) +(\, f_{g3}\, S3)2\, SE^2(RR_{og3}) + S_1{}^2\, SE^2(RR_{o1}) + S_2{}^2\, SE^2(RR_{o2})]$

This is true because the 4 RRs in step 3 are from independent samples.

Period 3 combined RR

1. **The non-operational realization rate** RR_{NZ} 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

$AR_{cat2,3\ (n=68)}$ = $RR_Z = RR_{oZ}\ \ RR_{NZ}$

3. Standard Error

First calculate the relative standard error

a. $RSE(RR_Z) = \mathrm{sqrt}[RSE^2(RR_{oZ}) + RSE^2(RR_{NZ})]$

This formula is approximately correct, assuming that even though RR_o and RR_N are from a common sample, they are essentially unrelated to be treated as independent. The standard error is then calculated from the RSE.

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

3-year combined RR.

Preferred calculation

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

That is, the 3-year RR is the savings-weighted average of the 3 separately estimated RRs.

This calculation produces an overall realization rate for each period, then combines these across the period. This is the natural approach, combining the overall historical results with the most recent, consistent with our general 3-year rolling realization rate calculation method. For this reason, the method is the preferred way to produce the 3-year value.

However, because the third term, RR_3, is determined partly from the operational portions of RR_1 and RR_2, these 3 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 to approximate the standard error of the preferred calculation. The alternative calculation would be to calculate separate operational and non-operational realization rates for the 3-year period and multiply these. 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

Alternative RR calculation for SE Calculation only

1. 3-year operational realization rate

$RR_{o1\text{-}3} = q_1RR_{o1} + q_2RR_{o2} + q_3RR_{o3}$

2. 3-year non-operational realization rate

$RR_{N1\text{-}3} = q_1RR_{N1} + q_2RR_{N2} + q_3RR_{N3}$

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 3-period realization rate SE

The non-operational 3-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 3-period realization rate SE

The operational realization rate is also the savings-weighted average of the 3 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.

$RR_{o1-3} = q_1 RR_{o1} + q_2 RR_{o2} + q_3 RR_{o3}$

$= (q_1 + a_1\ q_3) RR_{o1} + (q_2 + a_2 q_3) RR_{o2} + q_3\ a_{og3} RR_{og3}$

where the factors a_x are as defined above. With this expression of the 3-period operational realization rate as a combination of independent estimates, is standard error is calculated as

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

Relative standard error of overall 3-period realization rate

Using the same argument, the relative standard errors of the two realization rate factors are combined as if they were independent estimates. This is correct, assuming that even though RR_o and RR_N are from a common sample, they are unrelated and considered independent.

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

Standard error of the 3-year realization rate

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

Level of aggregation for applying the formulas

Calculating Period-3 and 3-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 3-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.

There may be reporting categories for which there is no period-3 sample with operational data. In this case, the same formulas are used, with period-3 contributing nothing to the 3-period operational realization rate.

Calculating standard errors

In principle, we'd do all these calculations separately by reporting cells and then combining the pieces. In the interests of simplicity and recognizing it's all a bit fuzzy anyway, we can do an overall adjustment to the SE.

.

APPENDIX D. INDIVIDUAL EVALUATION SITE REPORTS

PY2018 SAMPLED SITES

RICE18C013 Lighting

Report Date: 05/28/2021

Program	RICE2018	
Application ID(s)	7307056; 7731255	
Project Type	Existing Building Retrofit	
Program Year	2018	
Evaluation Firm	DNV	DNV
Evaluation Engineer	Kristen Schleier/Khusbu Modi	
Senior Engineer	Jeff Zynda	

Evaluated Site Summary and Results

This university campus retrofitted multiple lighting and non-lighting measures at 45 different buildings using National Grid's custom electric program incentives under two applications (7307056; 7731255) with a total energy savings 2,648,364 kWh. In some cases, both lighting and non-lighting measures were completed at a single building. To reduce the customer burden and be cost-effective, the evaluator disaggregated the savings at the building level and randomly sampled them within those buildings. The sample included four buildings with lighting measures and five buildings with non-lighting measures.

To reduce the complexity and streamline reporting, lighting and non-lighting reports are separated. This site report will include lighting sites only. The total claimed lighting savings for all 45 buildings is 1,458,742 kWh per year. At these 45 buildings, 7,947 fixtures were installed to replace 8,270 fixtures and the application claims occupancy and dimming control savings for 3,247 of the program fixtures that were installed.

The applicant's project savings calculation for the four sub-sampled buildings resulted in an annual energy savings of 769,487 kWh (52% of the total lighting savings). Summer On-peak demand savings was 86.48 kW, and winter was 93.20 kW. The evaluator calculated the annual energy savings to be 809,494 kWh, summer on-peak demand savings to be 97.84 kW, and winter on-peak demand savings to be 93.64 kW; due mostly to the inclusion of interactive savings. Metering was not performed at this site due to the atypical operating conditions caused by the pandemic (lower occupancy and lighting usage due to remote/virtual learning). As such, the operation in the applicant savings calculations was assumed in the evaluation savings calculations. See Section 2.3 for further details.

The evaluation results are presented in Table 5-2.

Table 5-2. Evaluation Results Summary

Building ID		Annual Electric Energy (kWh)	Summer On-Peak Demand (kW)	Winter On-Peak Demand (kW)
Building 1	Tracked	48,983	5.5	5.9
	Evaluated	48,986	5.5	5.9
	Realization Rate	100%	100%	100%
Building 2	Tracked	400,612	45	49
	Evaluated	424,287	52	49
	Realization Rate	106%	115%	101%
Building 3	Tracked	42,030	4.72	5.09
	Evaluated	42,183	4.74	5.11
	Realization Rate	100%	100%	100%
Building 4	Tracked	277,862	31	34
	Evaluated	294,036	36	34
	Realization Rate	106%	114%	100%
Evaluation Totals	Tracked	769,487	86.5	93.2
	Evaluated	809,492	97.8	93.6
	Realization Rate	105%	113%	100%

Explanation of Deviations from Tracking

Savings increases are due primarily to the inclusion of interactive savings in buildings one, two, and four, which were not accounted for in the applicant savings calculations. Building three consisted entirely of exterior fixture installations, which are not affected by HVAC interaction.

Recommendations for Program Designers & Implementers

There are no recommendations currently.
Customer Alert
There are no customer alerts for this site.

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 interior and exterior LED fixtures and controls in the four sub-sampled buildings.

Application Information and Applicant Savings Methodology

This section describes the applicant's application information, savings methodology, and evaluation assessment of the applicant's savings calculation algorithm. Project savings were generated from a reduction in fixture wattage and reduced hours from controls.

Applicant Description of Baseline

The four sub-sampled sites in this project are classified as a lighting retrofit project in the application. The majority (95.0%) of the baseline fixtures/lamps are categorized as T8 fluorescents (81.4%) and CFLs (13.6%). The remaining baseline fixtures/lamps are categorized as halogens, high-pressure sodium, incandescent, LEDs, metal halides, T5s, and T12s. The site documentation reported that the baseline consisted of 4,400 fixtures that operated varying watts from 12 to 455 watts. Application baseline usage hours ranged from 760 to 8,760 annual hours. The key applicant baseline parameters are summarized in Table 5-3.

Table 5-3. Applicant baseline key parameters

		BASELINE		
Measure	Parameter	Value(s)	Source of Parameter Value	Note
Lighting Retrofit	Fixture Wattage	Varies from 12 to 455	Project Files	None
Lighting Retrofit	Fixture Quantity	4,000	Project Files	None
Lighting Retrofit	Operating Hours	Varies from 760 to 8,760	Project Files	None

Applicant Description of Installed Equipment and Operation

The facility upgraded its lighting system by retrofitting older fixtures with LEDs of varying wattages. Operating schedules and fixture counts observed in the baseline description are maintained for the installed fixtures. Project savings were generated from the installation of LED fixtures and controls. The installed equipment consisted of 4,311 fixtures that operated varying watts from 5 to 230 watts. Some fixtures had controls installed.

Table 5-4. Application proposed key parameters

		PROPOSED		
Measure	Parameter	Value(s)	Source of Parameter Value	Note
Lighting Retrofit	Fixture Wattage	Varies from 5 to 230 Watts	Project Files	None
Lighting Retrofit	Fixture Quantity	4,311 fixtures	Project Files	None
Lighting Controls	Reduction in Operating Hours	Varies from 18% to 24% reduction in assumed baseline hours.	Project Files	None
Lighting Controls	Reduction in Wattage due to Dimming Controls	Varies from 31% to 86% reduction in fixture wattage.	Project Files	None

Applicant Energy Savings Algorithm

Savings were calculated using a custom lighting savings excel workbook using the following equations. The primary driver for this measure's energy savings is a reduction in fixture/lamp wattage. Energy savings algorithms are as follows:

$Baseline\ Fixture\ kWh = \frac{Quantity_B * Wattage_B}{1000} * Baseline\ Operating\ Hours$ without controls

$Proposed\ Fixture\ kWh = \frac{Quantity_P * Wattage_P}{1000} * Baseline\ Operating\ Hours$ without controls

$Fixture\ kWh\ Savings = Baseline\ Fixture\ kWh - Proposed\ Fixture\ kWh$

$Dimming\ Control\ kWh\ Savings$ = Proposed Fixture kWh * Applicant assumed % dimming reduction

$\mathrm{ProposedFixturekW} * (\mathrm{ApplicantPreControlOperatingHours} - \sum \mathrm{ProposedFixturekWineachdimminglevel} \times \mathrm{OperationHoursineachdimminglevel})$

$Occupancy\ Sensor\ Control\ kWh\ Savings$ = Proposed Fixture kWh * Applicant assumed % occupancy sensor HOU reduction $Proposed\ Fixture\ kW * (Applicant\ PreControl\ Operating\ Hours - Applicant\ PostControl\ Operating\ Hours)$

$Total\ kWh\ Savings = Fixture\ kWh\ Savings + Dimming\ Control\ kWh\ Savings + Occupancy\ Sensor\ Control\ kWh\ Savings$

Table 5-5 through Table 5-8 below show the savings calculations for each building.

Table 5-5. Applicant Savings Calculations for Building 1

	A	B	C	D	E	F=A*B*E /1000	G=C*D*E/1000	H	T=F-G
Space Type	Baseline Quantity	Baseline Watts per Fixture	Installed Quantity	Installed Watts per Fixture	Annual Hours	Baseline kWh	Installed kWh	Control kWh Savings	kWh Fixture Savings
24/7	7	455	7	230	6,132	19,530	9,873	2,370	9,658
24/7	132	60	132	31	6,132	48,565	25,092	6,023	23,473
24/7	4	52	4	31	6,132	1,275	760	183	515
24/7	13	88	13	47	6,132	7,015	3,747	899	3,268
24/7	1	28	1	11	6,132	172	67	0	104
24/7	1	90	1	19	6,132	552	117	0	435
24/7	1	26	1	14	6,132	159	86	21	74
24/7	5	32	5	9	6,132	981	276	0	705
24/7	1	46	1	14	6,132	282	86	0	196
Office	3	60	3	31	2,800	504	260	62	244
Office - Central Heating Plant	2	60	2	39	4,000	480	312	75	168
Office - Central Heating Plant	2	52	4	14	4,000	416	224	54	192
Office - Central Heating Plant	3	52	3	42	2,584	403	326	0	78
Office - Central Heating Plant	3	52	6	14	2,584	403	217	0	186
Total	178		183			80,739	41,442	9,687	39,296

Table 5-6. Applicant Savings Calculations for Building 2

	A	B	C	D	E	F=A*B*E/1000	G=C*D*E/1000	H	H=F-G
Space Type	Baseline Quantity	Baseline Watts per Fixture	Installed Quantity	Installed Watts per Fixture	Annual Hours	Baseline kWh	Installed kWh	Control kWh Savings	kWh Fixture Savings
Hallway	19	60	19	29	8,760	9,986	4,827	1,834	5,160
Hallway	1	24	1	10	8,760	210	88	0	123
Hallway	8	30	8	15	8,760	2,102	1,051	426	1,051
Hallway	7	37	7	23	8,760	2,269	1,410	497	858
Hallway	97	72	97	23	8,760	61,180	19,544	7,257	41,636
Hallway	5	48	5	24	8,760	2,102	1,051	0	1,051
Hallway	4	63	4	31	8,760	2,208	1,086	413	1,121
Hallway	4	24	4	10	3,500	336	140	0	196
Hallway	1	60	1	24	5,000	300	120	0	180
Hallway	64	37	64	23	6,658	15,766	9,801	1,372	5,966
Closet	1	60	1	10	1,500	90	15	0	75
Closet	1	30	1	15	1,500	45	23	0	23
Closet	1	75	1	10	1,500	113	15	0	98
Closet	1	17	1	8	1,500	26	12	0	14
Elec room	12	60	12	29	1,500	1,080	522	0	558
Elec room	2	60	2	30	1,500	180	90	0	90
Elec room	10	60	10	24	1,500	900	360	0	540

Elec room	6	30	6	16	1,500	270	144	0	126
Elec room	4	145	4	29	1,500	870	174	0	696
Elec room	2	37	2	23	1,500	111	69	24	42
Elec room	3	130	3	12	1,500	585	54	0	531
Classroom	3	60	3	30	8,760	1,577	788	0	788
Classroom	4	60	4	10	3,500	840	140	30	700
Classroom	1	24	1	10	3,500	84	35	0	49
Classroom	1	75	1	10	3,500	263	35	0	228
Classroom	17	60	17	29	5,000	5,100	2,465	592	2,635
Classroom	17	60	17	10	5,000	5,100	850	119	4,250
Classroom	146	60	146	30	5,000	43,800	21,900	5,256	21,900
Classroom	5	60	5	23	5,000	1,500	575	138	925
Classroom	4	75	4	11	5,000	1,500	220	53	1,280
Classroom	9	72	9	31	5,000	3,240	1,395	335	1,845
Classroom	3	46	1	30	3,000	414	90	0	324
Classroom	4	46	2	24	3,000	552	144	0	408
Classroom	11	75	11	11	4,700	3,878	569	102	3,309
Classroom	36	60	36	30	3,800	8,208	4,104	0	4,104
Classroom	4	94	4	24	3,800	1,429	365	0	1,064
Classroom	6	32	6	8	3,800	730	182	0	547

Lab	23	60	23	30	8,760	12,089	6,044	0	6,044
Lab	6	53	6	30	8,760	2,786	1,577	0	1,209
Lab	2	117	2	45	8,760	2,050	788	0	1,261
Lab	2	60	2	24	4,000	480	192	46	288
Lab	1	30	1	23	4,000	120	92	0	28
Lab	8	37	8	23	4,000	1,184	736	268	448
Lab	4	32	4	15	4,000	512	240	0	272
Lab	2	60	2	29	3,000	360	174	42	186
Lab	12	75	12	11	3,000	2,700	396	95	2,304
Lab	132	60	132	29	6,000	47,520	22,968	5,512	24,552
Lab	91	60	91	30	6,000	32,760	16,380	3,715	16,380
Lab	1	60	1	23	6,000	360	138	32	222
Lab	12	60	12	24	6,000	4,320	1,728	415	2,592
Lab	2	60	4	16	6,000	720	384	0	336
Lab	4	60	2	72	6,000	1,440	864	202	576
Lab	3	60	3	36	6,000	1,080	648	151	432
Lab	8	60	2	143	6,000	2,880	1,716	403	1,164
Lab	5	37	5	23	6,000	1,110	690	251	420
Lab	6	112	12	30	6,000	4,032	2,160	518	1,872
Lab	7	112	7	58	6,000	4,704	2,436	585	2,268

Lab	3	112	3	72	6,000	2,016	1,296	202	720
Lab	14	53	14	30	6,000	4,452	2,520	605	1,932
Lab	9	34	9	10	6,000	1,836	540	0	1,296
Lab	7	88	7	31	6,000	3,696	1,302	363	2,394
Lab	1	94	1	29	6,000	564	174	42	390
Lab	6	126	12	30	6,000	4,536	2,160	518	2,376
Lab	9	126	9	68	6,000	6,804	3,672	881	3,132
Lab	9	117	9	45	6,000	6,318	2,430	583	3,888
Lab	4	234	8	45	6,000	5,616	2,160	518	3,456
Lab	9	63	9	30	6,000	3,402	1,620	389	1,782
Lab	16	69	16	29	6,000	6,624	2,784	668	3,840
Lab	581	60	581	30	4,560	158,962	79,481	0	79,481
Lab	62	60	62	24	4,560	16,963	6,785	0	10,178
Lab	5	60	1	179	4,560	1,368	816	0	552
Lab	19	72	19	23	4,560	6,238	1,993	0	4,245
Lab	5	112	5	72	4,560	2,554	1,642	0	912
Lab	1	88	1	31	4,560	401	141	0	260
Lab	7	117	7	45	4,560	3,735	1,436	0	2,298
Lab	3	234	6	45	4,560	3,201	1,231	0	1,970
Lab	3	64	3	24	4,560	876	328	0	547

Conf room	5	60	5	30	3,500	1,050	525	126	525
Conf room	10	60	10	24	3,500	2,100	840	202	1,260
Conf room	6	60	2	107	3,500	1,260	749	176	511
Conf room	4	24	4	11	3,500	336	154	37	182
Conf room	32	37	32	23	3,500	4,144	2,576	936	1,568
Conf room	12	75	12	11	3,500	3,150	462	111	2,688
Conf room	12	53	12	23	3,500	2,226	966	222	1,260
Conf room	6	50	6	8	3,290	987	158	28	829
Conf room	3	60	3	24	2,660	479	192	0	287
Conf room	6	60	2	107	2,660	958	569	0	388
Conf room	6	50	6	8	2,660	798	128	0	670
Corridor	3	24	3	10	4,000	288	120	0	168
Storage	5	60	5	29	1,500	450	218	31	233
Storage	5	60	5	24	1,500	450	180	17	270
Storage	1	72	1	29	1,500	108	44	0	65
Storage	2	72	2	24	1,500	216	72	0	144
Storage	2	112	2	45	1,500	336	135	0	201
Storage	4	88	4	31	1,500	528	186	0	342
Storage	2	60	2	24	2,500	300	120	29	180
Storage	8	37	8	23	2,500	740	460	167	280

Storage	8	54	8	10	2,500	1,080	200	67	880
Storage	4	60	4	24	1,140	274	109	0	164
Mech room	14	60	14	29	1,500	1,260	609	0	651
Mech room	2	60	2	24	1,500	180	72	0	108
Mech room	4	94	4	29	1,500	564	174	0	390
Mech room	7	60	7	29	1,000	420	203	0	217
Mech room	13	30	13	16	1,000	390	208	0	182
Office	29	60	28	30	4,000	6,960	3,360	806	3,600
Office	1	60	1	23	4,000	240	92	21	148
Office	9	60	9	24	4,000	2,160	864	207	1,296
Office	8	60	4	58	4,000	1,920	928	223	992
Office	8	60	2	143	4,000	1,920	1,144	269	776
Office	9	60	6	45	4,000	2,160	1,080	199	1,080
Office	10	37	10	23	4,000	1,480	920	285	560
Office	1	37	1	17	4,000	148	68	15	80
Office	3	112	3	45	4,000	1,344	540	130	804
Office	18	34	18	10	4,000	2,448	720	242	1,728
Office	4	34	4	12	4,000	544	192	46	352
Office	3	88	3	31	4,000	1,056	372	104	684
Office	2	94	1	45	4,000	752	180	43	572

Office	6	50	6	8	4,000	1,200	192	0	1,008
Office	1	144	1	45	4,000	576	180	43	396
Office	2	15	2	6	3,000	90	36	0	54
Office	8	60	8	30	3,040	1,459	730	0	730
Office	36	60	36	24	3,040	6,566	2,627	0	3,940
Office	20	60	10	72	3,040	3,648	2,189	0	1,459
Office	8	60	2	143	3,040	1,459	869	0	590
Office	2	72	2	23	3,040	438	140	0	298
Office	1	112	1	72	3,040	340	219	0	122
Office	10	63	10	30	3,040	1,915	912	0	1,003
Office	2	60	2	24	2,800	336	134	32	202
Bathroom	1	30	1	16	8,760	263	140	0	123
Bathroom	3	37	3	23	8,760	972	604	220	368
Bathroom	7	60	7	24	4,200	1,764	706	169	1,058
Bathroom	13	30	13	16	4,200	1,638	874	145	764
Bathroom	3	37	3	23	4,200	466	290	105	176
Bathroom	2	72	2	23	4,200	605	193	44	412
Bathroom	1	88	1	31	4,200	370	130	31	239
Bathroom	1	17	1	8	4,200	71	34	8	38
Bathroom	2	37	2	23	3,192	236	147	21	89

Docking Area	3	60	3	30	2,500	450	225	54	225
Docking Area	3	30	3	16	2,500	225	120	29	105
Exterior	1	120	1	12	4,400	528	53	0	475
Vestibule	10	60	6	29	8,760	5,256	1,524	0	3,732
Office	2	60	2	30	4,000	480	240	58	240
Open Office	4	60	4	23	5,000	1,200	460	106	740
Open Office	6	60	3	45	5,000	1,800	675	162	1,125
Open Office	5	37	5	23	5,000	925	575	209	350
Open Office	2	120	2	10	5,000	1,200	100	34	1,100
Open Office	12	37	12	23	4,000	1,776	1,104	401	672
Open Office	3	17	3	10	4,000	204	120	0	84
Open Office	3	60	3	24	3,040	547	219	0	328
Open Office	4	60	4	36	3,040	730	438	0	292
Open Office	10	60	10	24	3,800	2,280	912	0	1,368
Open Office	2	60	1	72	3,800	456	274	0	182
Open Office	20	60	5	143	3,800	4,560	2,717	0	1,843
Open Office	20	60	4	179	3,800	4,560	2,721	0	1,839
Open Office	10	60	2	215	3,800	2,280	1,634	0	646
Open Office	2	37	2	23	3,800	281	175	24	106

Office	2	112	2	45	4,000	896	360	86	536
Lounge	4	75	4	11	3,500	1,050	154	0	896
Lounge	1	72	1	29	3,500	252	102	0	151
Lounge	2	72	2	30	3,500	504	210	0	294
Lounge	2	60	2	24	2,660	319	128	0	192
Lounge	4	60	2	72	2,660	638	383	0	255
mailroom	6	72	6	23	3,040	1,313	420	0	894
Lobby	28	48	28	24	8,760	11,773	5,887	0	5,887
Kitchen	1	37	1	23	3,500	130	81	29	49
Kitchen	1	37	1	23	4,000	148	92	33	56
Kitchen	3	37	3	23	2,660	295	184	26	112
Locker room	1	30	1	16	3,500	105	56	0	49
Locker room	1	30	1	16	4,200	126	67	0	59
Locker room	2	37	2	23	2,660	197	122	17	74
Total	2,228		2,145			662,411	304,078	42,279	358,333

Table 5-7. Applicant Savings Calculations for Building 3

	A	B	C	D	E	F=A*B*E/1000	G=C*D*E/1000	H	H=F-G
Space Type	Baseline Quantity	Baseline Watts per Fixture	Installed Quantity	Installed Watts per Fixture	Annual Hours	Baseline kWh	Installed kWh	Control kWh Savings	kWh Fixture Savings
North	2	455	2	129	4,380	3,986	1,130	0	2,856
North	2	295	2	37	4,380	2,584	324	0	2,260
North	1	120	1	26	4,380	526	114	0	412
North	1	25	1	9.5	4,380	110	42	0	68
North	8	25	8	12	4,380	876	421	0	456
North	1	12	1	12	4,380	53	53	0	0
North	6	205	6	37	4,380	5,388	972	0	4,415
North	1	190	1	37	4,380	832	162	0	670
North	2	190	2	40	4,380	1,664	350	0	1,314
North	1	90	1	18	4,380	394	79	0	315
North	3	15	3	9.5	1,040	47	30	0	17
South	2	455	2	129	4,380	3,986	1,130	0	2,856
South	2	455	2	455	4,380	3,986	3,986	0	0
South	2	295	2	57	4,380	2,584	499	0	2,085
South	1	120	1	26	4,380	526	114	0	412
South	1	65	1	18	4,380	285	79	0	206

South	1	130	1	26	4,380	569	114	0	456
South	1	205	1	37	4,380	898	162	0	736
South	1	48	1	20	4,380	210	88	0	123
South	1	190	1	40	4,380	832	175	0	657
South	9	95	9	18	4,380	3,745	710	0	3,035
South	1	100	1	20	8,760	876	175	0	701
South Lot Shed	2	455	2	57	4,380	3,986	499	0	3,487
West	1	295	1	57	4,380	1,292	250	0	1,042
West	1	180	1	26	4,380	788	114	0	675
West	4	25	4	12	4,380	438	210	0	228
West	1	12	1	12	4,380	53	53	0	0
East	2	455	2	129	4,380	3,986	1,130	0	2,856
East	1	295	1	37	4,380	1,292	162	0	1,130
East	4	15	4	15	4,380	263	263	0	0
East	1	65	1	20	4,380	285	88	0	197
East	4	205	4	37	4,380	3,592	648	0	2,944
East	3	48	3	20	4,380	631	263	0	368
East	1	48	1	18	4,380	210	79	0	131
East	1	48	1	26	4,380	210	114	0	96
East	3	190	3	40	4,380	2,497	526	0	1,971

East	4	63	4	63	4,380	1,104	1,104	0	0
North (Pole)	2	455	2	129	4,380	3,986	1,130	0	2,856
Total	85		85			59,570	17,540	-	42,030

Table 5-8. Applicant Savings Calculations for Building 4

	A	B	C	D	E	F=A*B*E/1000	G=C*D*E/1000	H	H=F-G
Space Type	Baseline Quantity	Baseline Watts per Fixture	Installed Quantity	Installed Watts per Fixture	Annual Hours	Baseline kWh	Installed kWh	Control kWh Savings	kWh Fixture Savings
Undercabinet	316	24	316	15	3,000	22,752	14,220	0	8,532
Mech room	1	45	1	29	1,140	51	33	0	18
Mech room	2	30	2	14	1,140	68	32	0	36
Mech room	4	60	4	29	1,140	274	132	0	141
Mech room	4	45	4	29	8,760	1,577	1,016	0	561
Mech room	25	60	25	29	4,000	6,000	2,900	1,102	3,100
Mech room	30	112	30	58	4,000	13,440	6,960	2,645	6,480
Mech room	8	45	8	29	1,900	684	441	0	243
Mech room	1	60	1	29	760	46	22	0	24
Hallway	4	24	2	25	7,008	673	350	0	322
Hallway	1	45	1	26	7,008	315	182	0	133
Hallway	2	27	2	21	7,008	378	294	106	84
Hallway	4	45	4	29	6,000	1,080	696	264	384
Hallway	2	45	2	25	6,000	540	300	165	240
Hallway	1	45	1	26	6,000	270	156	0	114

Hallway	60	27	60	21	6,000	9,720	7,560	2,722	2,160
Hallway	5	39	5	24	6,000	1,170	720	259	450
Hallway	7	34	7	14	6,000	1,428	588	0	840
Hallway	5	45	5	29	8,760	1,971	1,270	483	701
Hallway	4	45	4	25	8,760	1,577	876	166	701
Hallway	55	27	55	21	8,760	13,009	10,118	3,642	2,891
Lobby	2	27	2	21	8,760	473	368	132	105
Conf room	3	45	1	76	3,040	410	231	0	179
Conf room	4	89	4	51	3,040	1,082	620	0	462
Conf room	3	34	3	14	3,040	310	128	0	182
Conf room	3	47	1	76	3,040	429	231	0	198
Auditorium	4	34	4	18	4,000	544	288	0	256
Storage	4	45	4	29	1,140	205	132	0	73
Storage	2	45	2	24	1,140	103	55	0	48
Storage	3	45	3	29	1,500	203	131	0	72
Storage	1	27	1	21	1,500	41	32	11	9
Storage	1	34	1	14	1,500	51	21	0	30
Storage	1	60	1	29	1,500	90	44	0	47
Vestibule	1	45	1	29	8,760	394	254	97	140
lab	3	68	3	30	6,000	1,224	540	297	684

lab	11	136	22	30	6,000	8,976	3,960	2,178	5,016
lab	17	45	17	25	8,760	6,701	3,723	0	2,978
lab	4	68	4	30	8,760	2,383	1,051	0	1,332
lab	19	45	19	25	4,560	3,899	2,166	671	1,733
lab	55	89	55	45	4,560	22,321	11,286	3,499	11,035
Lab Hood	23	80	23	17	4,000	7,360	1,564	0	5,796
Lab Storage	4	45	2	58	3,000	540	348	84	192
Lab Storage	12	27	12	21	3,000	972	756	272	216
Lab Storage	2	60	2	24	3,000	360	144	0	216
Lab Storage	6	68	6	26	3,000	1,224	468	0	756
Lab Storage	1	145	1	30	3,000	435	90	0	345
Lab	2	45	2	29	6,000	540	348	84	192
Lab	1	45	1	25	6,000	270	150	83	120
Lab	8	45	4	58	6,000	2,160	1,392	167	768
Lab	4	68	4	24	6,000	1,632	576	0	1,056
Lab	4	68	4	26	6,000	1,632	624	225	1,008
Lab	6	68	6	33	6,000	2,448	1,188	285	1,260
Lab	5	88	5	26	6,000	2,640	780	0	1,860
Lab	2	53	2	24	6,000	636	288	0	348
Lab	137	45	137	25	8,760	54,005	30,003	0	24,002

Lab	2	72	2	24	8,760	1,261	420	0	841
Lab	5	52	5	25	8,760	2,278	1,095	0	1,183
Lab	163	45	163	25	4,560	33,448	18,582	5,442	14,866
Lab	113	45	113	24	4,560	23,188	12,367	0	10,821
Lab	335	89	335	45	4,560	135,956	68,742	21,310	67,214
Lab	3	89	3	58	4,560	1,218	793	0	424
Lab	26	68	26	24	4,560	8,062	2,845	0	5,217
Lab	6	68	6	33	4,560	1,860	903	0	958
Lab	4	88	4	24	4,560	1,605	438	136	1,167
Lab	16	72	16	24	4,560	5,253	1,751	0	3,502
Lab	12	52	12	25	4,560	2,845	1,368	424	1,477
Office	3	45	3	26	8,760	1,183	683	0	499
Office	7	27	7	21	8,760	1,656	1,288	0	368
Office	5	72	5	24	8,760	3,154	1,051	0	2,102
Office	27	45	27	24	3,040	3,694	1,970	0	1,724
Office	20	45	20	26	3,040	2,736	1,581	0	1,155
Office	19	27	19	21	3,040	1,560	1,213	0	347
Office	1	34	1	14	3,040	103	43	0	61
Office	21	68	21	24	3,040	4,341	1,532	0	2,809
Office	69	72	69	24	3,040	15,103	5,034	0	10,068

Office	5	45	5	24	4,000	900	480	46	420
Office	3	68	3	26	4,000	816	312	75	504
Office	3	72	3	24	4,000	864	288	69	576
Office	8	17	8	6	4,000	544	192	0	352
Bathroom	2	34	2	18	8,760	596	315	0	280
Bathroom	56	45	56	25	3,192	8,044	4,469	0	3,575
Bathroom	4	54	4	18	3,192	689	230	0	460
Bathroom	4	34	4	18	4,200	571	302	73	269
Elec room	1	45	1	29	8,760	394	254	0	140
Elec room	9	45	9	29	1,500	608	392	0	216
Elec room	1	45	1	21	1,500	68	32	0	36
Elec room	20	45	10	58	1,500	1,350	870	0	480
Computer lab	5	72	5	24	3,263	1,175	392	0	783
Computer lab	7	72	7	24	3,800	1,915	638	0	1,277
Exterior	3	20	3	7	4,400	264	92	0	172
Exterior	2	95	2	27	4,400	836	238	0	598
Mail Room	3	45	3	29	8,760	1,183	762	290	420
Mail Room	9	45	9	29	5,000	2,025	1,305	496	720
Dark Room	2	34	2	14	2,000	136	56	0	80
Dark Room	2	15	2	5	2,000	60	20	0	40

Dark Room	2	200	2	23	2,000	800	92	0	708
Dark Room	2	28	2	7	2,000	112	28	0	84
Total	1,909		1,898			478,167	248,304	47,999	229,863

Evaluation Assessment of Applicant Methodology

The evaluator agrees with the analysis approach used by the applicant.

Onsite Inspection

The evaluators conducted a site visit after confirming the following criteria:
The site was safe to visit, and the site contact with knowledge of the project was available to assist with the evaluation site visit.
COVID-19 impacted the site's operations, so metering equipment was not installed.
This section provides details on the tasks performed during the site visit.

Summary of Site Visit Findings and Metering

With the facility manager's assistance, the site visit was completed on April 29, 2021. While visiting the customer's facility, the evaluator confirmed the lighting control types being utilized, fixture counts, wattages, and HVAC information. While onsite, the evaluators did not observe any differences in the fixture counts in any of the four buildings. Differences were also not observed in the counts of controlled fixtures in any of the buildings except building one. For this building the site documentation revealed that 166 fixtures also received controls through the program. During the site visit, the evaluators found controls on 164 fixtures. Two fixtures that were reported as having controls in the site documentation were found to be manually controlled during the site visit.
Differences in wattages were not observed in buildings one and four, but some differences were found in buildings two and three. In building two, differences were found in the wattages of 246 of the fixtures that had controls installed on them through the program18. These wattage differences were initially found during a post audit performed by National Grid and the tracking system fixture savings were corrected to reflect them. However, the controls savings for these fixtures were not updated with the wattages found during this audit. In building three wattage differences were found for 39 of the fixtures installed through the program[19].
Table 5-9 below provides a quick summary of the evaluator's findings.
Table 5-9. Measure Verification

Building ID	Measure Name	Verification Method	Verification Result
1	Lighting Controls	Onsite Visit	Two of the fixtures reported to have had controls in the site documentation were found to be manually controlled during the site visit.
2	Lighting Controls	Onsite Visit	Changes were observed with the wattage of 246 of the fixtures installed with controls. These changes were reflected in the tracking system fixture savings but not in the tracking system controls savings.
3	Lighting Fixtures	Onsite Visit	Changes were observed with the wattage of 39 of the installed fixtures.

18 Fifteen of these fixtures were reported to be 9-watt fixtures but were found to be 10-watt fixtures, 28 were reported to be 14-watt fixtures but were found to be 10-watt fixtures, eight were reported to be 16-watt fixtures but were found to be 15-watt fixtures, one was reported to be a 16-watt fixture but was found to be a 17-watt fixture, 168 were reported to be 22-watt fixtures but were found to be 23-watt fixtures, three were reported to be 24-watt fixtures but were found to be 45-watt fixtures, three were reported to be 35-watt fixtures but were found to be 36-watt fixtures, ten were reported to be 36-watt fixtures but were found to be 31-watt fixtures, four were reported to be 70-watt fixtures but were found to be 72-watt fixtures, two were reported to be 105-watt fixtures but were found to be 107-watt fixtures, and four were reported to be 140-watt fixtures but were found to be 143-watt fixtures.

19 Three of these fixtures were reported to be 18-watt fixtures but were reported to be 20-watt fixtures, six were reported to be 20-watt fixtures but were found to be 22-watt fixtures, five were reported to be 26-watt fixtures but were found to be 30-watt fixtures, 14 were reported to be 37-watt fixtures but were found to be 35-watt fixtures, six were reported to be 40-watt fixtures but were found to be 38-watt fixtures, and five were reported to be 57-watt fixtures but were found to be 50-watt fixtures.

Measured and Logged Data

Metering was not performed at this site due to the atypical operating conditions caused by the COVID-19 pandemic (lower occupancy and lighting usage due to remote/virtual learning), as the evaluator felt that any metering data collected would not be representative of normal operations. As such, the operation in the applicant savings calculations was assumed in the evaluation savings calculations.

Evaluation Methods and Findings

This section describes the evaluator methods and findings.

Evaluation Description of Baseline

The baseline condition for this retrofit project consisted of T8 fluorescents (81.4%) and CFLs (13.6%). The remaining baseline fixtures/lamps are categorized as halogens, high-pressure sodium, incandescent, LEDs, metal halides, T5s, and T12s. The application does not include savings due to HVAC interactive effects. Additionally, the application documentation does not list pre-existing lighting controls. The evaluator reviewed the project files and interviewed the site contact and conducted a site visit to confirm the baseline information provided in the application.

Evaluation Metered Data and Analysis Methodology

The evaluators conducted a site visit to verify equipment technology, quantities and gather HVAC information. Metering was not performed at this site due to the atypical operating conditions caused by the COVID-19 pandemic
The evaluator used the equations highlighted below to calculate the energy savings associated with this measure.

Baseline Fixture kWh = $\frac{Quantity_B * Wattage_{\boldsymbol{B}}}{1000} * Evaluated\ Operating\ Hours\ without\ controls$

Proposed Fixture kWh = $\frac{Quantity_P * Wattage_{\boldsymbol{P}}}{1000} * Evaluated\ Operating\ Hours\ without\ controls$

Fixture kWh Savings = $Baseline\ Fixture\ kWh\ - Proposed\ Fixture\ kWh$

Control kWh Savings = $Proposed\ Fixture\ kW\ * (Evaluated\ Operating\ Hours\ without\ controls - Evaluated\ EFL\ Operating\ Hours\ with\ controls)$

HVAC Interactive Fixture Savings = $(pre\ connected\ kW - post\ connected\ kW) * Coincident\ Occupied\ Cooling\ Hours * \frac{0.8}{Cooling\ COP}$

HVAC Interactive Control Savings = (post conn kW * (pre coincident occupied cooling hours-post coincident cooling hours) *0.8)/(Cooling COP)

Total kWh Savings = $Fixture\ kWh\ Savings + Control\ kWh\ Savings\ + HVAC\ Interactive\ Fixture\ Savings\ + HVAC\ Interactive\ Control\ Savings$

Final Results

This section will summarize the evaluation results determined in the analysis above. The evaluator's estimated savings values result from observed changes to the applicant's pre- and post-cases.

Table 5-10 to Table 5-16 below show the evaluation inputs and savings calculations for each building.

Table 5-10. Evaluation Fixture Inputs and kWh Savings Building 1

	A	B	C	D	E	F	G=A*B*E /1000	H=C*D*E/ 1000	I=G-H	J	K	L	M=F*J*K* 0.8/L	N=I+M
Space Type	Baseline Quantity	Baseline Watts per Fixture	Installed Quantity	Installed Watts per Fixture	Annual Hours	Connected kW Savings	Baseline kWh	Installed kWh	kWh Fixture Savings	% of Space Cooled	Annual Cooling Hours	Cooling COP	Interactive Cooling Savings	Total kWh Fixture Savings
24/7	7	455	7	230	6,132	1.575	19,530	9,873	9,658	0%	N/A	N/A	0	9,658
24/7	132	60	132	31	6,132	3.828	48,565	25,092	23,473	0%	N/A	N/A	0	23,473
24/7	4	52	4	31	6,132	0.084	1,275	760	515	0%	N/A	N/A	0	515
24/7	13	88	13	47	6,132	0.533	7,015	3,747	3,268	0%	N/A	N/A	0	3,268
24/7	1	28	1	11	6,132	0.017	172	67	104	0%	N/A	N/A	0	104
24/7	1	90	1	19	6,132	0.071	552	117	435	0%	N/A	N/A	0	435
24/7	1	26	1	14	6,132	0.012	159	86	74	0%	N/A	N/A	0	74
24/7	5	32	5	9	6,132	0.115	981	276	705	0%	N/A	N/A	0	705

24/7	1	46	1	14	6,132	0.032	282	86	196	0%	N/A	N/A	0	196
Office	3	60	3	31	2,800	0.087	504	260	244	0%	N/A	N/A	0	244
Office - Central Heating Plant	2	60	2	39	4,000	0.042	480	312	168	100%	1,662	2.9	19	187
Office - Central Heating Plant	2	52	4	14	4,000	0.048	416	224	192	100%	1,662	2.9	22	214
Office - Central Heating Plant	3	52	3	42	2,584	0.030	403	326	78	100%	1,117	2.9	9	87
Office - Central Heating Plant	3	52	6	14	2,584	0.072	403	217	186	100%	1,117	2.9	22	208
Total	178		183			6.546	80,739	34,965	39,296				72	39,368

Table 5-11. Evaluation Fixture Inputs and kWh Savings for Building 2

	A	B	C	D	E	F	G=A*B*E/1000	H=C*D*E/1000	I=G-H	J	K	L	M=F*J*K*0.8/L	N=I+M
Space Type	Baseline Quantity	Baseline Watts per Fixture	Installed Quantity	Installed Watts per Fixture	Annual Hours	Connected kW Savings	Baseline kWh	Installed kWh	kWh Fixture Savings	Percent of Space Cooled	Annual Cooling Hours	Cooling COP	Interactive Cooling Savings	Total kWh Fixture Savings
Hallway	19	60	19	29	8,760	0.589	9,986	4,827	5,160	100%	3,467	5.5	296	5,455
Hallway	1	24	1	10	8,760	0.014	210	88	123	100%	3,467	5.5	7	130
Hallway	8	30	8	15	8,760	0.120	2,102	1,051	1,051	100%	3,467	5.5	60	1,111
Hallway	7	37	7	23	8,760	0.098	2,269	1,410	858	100%	3,467	5.5	49	908
Hallway	97	72	97	23	8,760	4.753	61,180	19,544	41,636	100%	3,467	5.5	2,385	44,021
Hallway	5	48	5	24	8,760	0.120	2,102	1,051	1,051	100%	3,467	5.5	60	1,111
Hallway	4	63	4	31	8,760	0.128	2,208	1,086	1,121	100%	3,467	5.5	64	1,186
Hallway	4	24	4	10	3,500	0.056	336	140	196	100%	1,444	5.5	12	208

Hallway	1	60	1	24	5,000	0.036	300	120	180	100%	2,015	5.5	10	190
Hallway	64	37	64	23	6,658	0.896	15,766	9,801	5,966	100%	2,646	5.5	343	6,309
Closet	1	60	1	10	1,500	0.050	90	15	75	100%	679	5.5	5	80
Closet	1	30	1	15	1,500	0.015	45	23	23	100%	679	5.5	1	24
Closet	1	75	1	10	1,500	0.065	113	15	98	100%	679	5.5	6	104
Closet	1	17	1	8	1,500	0.009	26	12	14	100%	679	5.5	1	14
Elec room	12	60	12	29	1,500	0.372	1,080	522	558	100%	679	5.5	37	595
Elec room	2	60	2	30	1,500	0.060	180	90	90	100%	679	5.5	6	96
Elec room	10	60	10	24	1,500	0.360	900	360	540	100%	679	5.5	35	575
Elec room	6	30	6	16	1,500	0.084	270	144	126	100%	679	5.5	8	134
Elec room	4	145	4	29	1,500	0.464	870	174	696	100%	679	5.5	46	742
Elec room	2	37	2	23	1,500	0.028	111	69	42	100%	679	5.5	3	45

Elec room	3	130	3	12	1,500	0.354	585	54	531	100%	679	5.5	35	566
Classroom	3	60	3	30	8,760	0.090	1,577	788	788	100%	3,467	5.5	45	834
Classroom	4	60	4	10	3,500	0.200	840	140	700	100%	1,444	5.5	42	742
Classroom	1	24	1	10	3,500	0.014	84	35	49	100%	1,444	5.5	3	52
Classroom	1	75	1	10	3,500	0.065	263	35	228	100%	1,444	5.5	14	241
Classroom	17	60	17	29	5,000	0.527	5,100	2,465	2,635	100%	2,015	5.5	154	2,789
Classroom	17	60	17	10	5,000	0.850	5,100	850	4,250	100%	2,015	5.5	248	4,498
Classroom	146	60	146	30	5,000	4.380	43,800	21,900	21,900	100%	2,015	5.5	1,277	23,177
Classroom	5	60	5	23	5,000	0.185	1,500	575	925	100%	2,015	5.5	54	979
Classroom	4	75	4	11	5,000	0.256	1,500	220	1,280	100%	2,015	5.5	75	1,355
Classroom	9	72	9	31	5,000	0.369	3,240	1,395	1,845	100%	2,015	5.5	108	1,953
Classroom	3	46	1	30	3,000	0.108	414	90	324	100%	1,253	5.5	20	344

Classroom	4	46	2	24	3,000	0.136	552	144	408	100%	1,253	5.5	25	433
Classroom	11	75	11	11	4,700	0.704	3,878	569	3,309	100%	1,902	5.5	194	3,503
Classroom	36	60	36	30	3,800	1.080	8,208	4,104	4,104	100%	1,557	5.5	243	4,347
Classroom	4	94	4	24	3,800	0.280	1,429	365	1,064	100%	1,557	5.5	63	1,127
Classroom	6	32	6	8	3,800	0.144	730	182	547	100%	1,557	5.5	32	580
Lab	23	60	23	30	8,760	0.690	12,089	6,044	6,044	100%	3,467	5.5	346	6,391
Lab	6	53	6	30	8,760	0.138	2,786	1,577	1,209	100%	3,467	5.5	69	1,278
Lab	2	117	2	45	8,760	0.144	2,050	788	1,261	100%	3,467	5.5	72	1,334
Lab	2	60	2	24	4,000	0.072	480	192	288	100%	1,633	5.5	17	305
Lab	1	30	1	23	4,000	0.007	120	92	28	100%	1,633	5.5	2	30
Lab	8	37	8	23	4,000	0.112	1,184	736	448	100%	1,633	5.5	26	474
Lab	4	32	4	15	4,000	0.068	512	240	272	100%	1,633	5.5	16	288

Lab	2	60	2	29	3,000	0.062	360	174	186	100%	1,253	5.5	11	197
Lab	12	75	12	11	3,000	0.768	2,700	396	2,304	100%	1,253	5.5	139	2,443
Lab	132	60	132	29	6,000	4.092	47,520	22,968	24,552	100%	2,395	5.5	1,418	25,970
Lab	91	60	91	30	6,000	2.730	32,760	16,380	16,380	100%	2,395	5.5	946	17,326
Lab	1	60	1	23	6,000	0.037	360	138	222	100%	2,395	5.5	13	235
Lab	12	60	12	24	6,000	0.432	4,320	1,728	2,592	100%	2,395	5.5	150	2,742
Lab	2	60	4	16	6,000	0.056	720	384	336	100%	2,395	5.5	19	355
Lab	4	60	2	72	6,000	0.096	1,440	864	576	100%	2,395	5.5	33	609
Lab	3	60	3	36	6,000	0.072	1,080	648	432	100%	2,395	5.5	25	457
Lab	8	60	2	143	6,000	0.194	2,880	1,716	1,164	100%	2,395	5.5	67	1,231
Lab	5	37	5	23	6,000	0.070	1,110	690	420	100%	2,395	5.5	24	444
Lab	6	112	12	30	6,000	0.312	4,032	2,160	1,872	100%	2,395	5.5	108	1,980

Lab	7	112	7	58	6,000	0.378	4,704	2,436	2,268	100%	2,395	5.5	131	2,399
Lab	3	112	3	72	6,000	0.120	2,016	1,296	720	100%	2,395	5.5	42	762
Lab	14	53	14	30	6,000	0.322	4,452	2,520	1,932	100%	2,395	5.5	112	2,044
Lab	9	34	9	10	6,000	0.216	1,836	540	1,296	100%	2,395	5.5	75	1,371
Lab	7	88	7	31	6,000	0.399	3,696	1,302	2,394	100%	2,395	5.5	138	2,532
Lab	1	94	1	29	6,000	0.065	564	174	390	100%	2,395	5.5	23	413
Lab	6	126	12	30	6,000	0.396	4,536	2,160	2,376	100%	2,395	5.5	137	2,513
Lab	9	126	9	68	6,000	0.522	6,804	3,672	3,132	100%	2,395	5.5	181	3,313
Lab	9	117	9	45	6,000	0.648	6,318	2,430	3,888	100%	2,395	5.5	225	4,113
Lab	4	234	8	45	6,000	0.576	5,616	2,160	3,456	100%	2,395	5.5	200	3,656
Lab	9	63	9	30	6,000	0.297	3,402	1,620	1,782	100%	2,395	5.5	103	1,885
Lab	16	69	16	29	6,000	0.640	6,624	2,784	3,840	100%	2,395	5.5	222	4,062

Lab	581	60	581	30	4,560	17.430	158,962	79,481	79,481	100%	1,848	5.5	4,662	84,143
Lab	62	60	62	24	4,560	2.232	16,963	6,785	10,178	100%	1,848	5.5	597	10,775
Lab	5	60	1	179	4,560	0.121	1,368	816	552	100%	1,848	5.5	32	584
Lab	19	72	19	23	4,560	0.931	6,238	1,993	4,245	100%	1,848	5.5	249	4,494
Lab	5	112	5	72	4,560	0.200	2,554	1,642	912	100%	1,848	5.5	53	965
Lab	1	88	1	31	4,560	0.057	401	141	260	100%	1,848	5.5	15	275
Lab	7	117	7	45	4,560	0.504	3,735	1,436	2,298	100%	1,848	5.5	135	2,433
Lab	3	234	6	45	4,560	0.432	3,201	1,231	1,970	100%	1,848	5.5	116	2,085
Lab	3	64	3	24	4,560	0.120	876	328	547	100%	1,848	5.5	32	579
Conf room	5	60	5	30	3,500	0.150	1,050	525	525	100%	1,444	5.5	31	556
Conf room	10	60	10	24	3,500	0.360	2,100	840	1,260	100%	1,444	5.5	75	1,335
Conf room	6	60	2	107	3,500	0.146	1,260	749	511	100%	1,444	5.5	31	542

Conf room	4	24	4	11	3,500	0.052	336	154	182	100%	1,444	5.5	11	193
Conf room	32	37	32	23	3,500	0.448	4,144	2,576	1,568	100%	1,444	5.5	94	1,662
Conf room	12	75	12	11	3,500	0.768	3,150	462	2,688	100%	1,444	5.5	161	2,849
Conf room	12	53	12	23	3,500	0.360	2,226	966	1,260	100%	1,444	5.5	75	1,335
Conf room	6	50	6	8	3,290	0.252	987	158	829	100%	1,362	5.5	50	879
Conf room	3	60	3	24	2,660	0.108	479	192	287	100%	1,123	5.5	18	305
Conf room	6	60	2	107	2,660	0.146	958	569	388	100%	1,123	5.5	24	412
Conf room	6	50	6	8	2,660	0.252	798	128	670	100%	1,123	5.5	41	711
Corridor	3	24	3	10	4,000	0.042	288	120	168	100%	1,633	5.5	10	178
Storage	5	60	5	29	1,500	0.155	450	218	233	100%	679	5.5	15	248
Storage	5	60	5	24	1,500	0.180	450	180	270	100%	679	5.5	18	288
Storage	1	72	1	29	1,500	0.043	108	44	65	100%	679	5.5	4	69

Storage	2	72	2	24	1,500	0.096	216	72	144	100%	679	5.5	9	153
Storage	2	112	2	45	1,500	0.134	336	135	201	100%	679	5.5	13	214
Storage	4	88	4	31	1,500	0.228	528	186	342	100%	679	5.5	22	364
Storage	2	60	2	24	2,500	0.072	300	120	180	100%	1,061	5.5	11	191
Storage	8	37	8	23	2,500	0.112	740	460	280	100%	1,061	5.5	17	297
Storage	8	54	8	10	2,500	0.352	1,080	200	880	100%	1,061	5.5	54	934
Storage	4	60	4	24	1,140	0.144	274	109	164	100%	542	5.5	11	175
Mech room	14	60	14	29	1,500	0.434	1,260	609	651	100%	679	5.5	43	694
Mech room	2	60	2	24	1,500	0.072	180	72	108	100%	679	5.5	7	115
Mech room	4	94	4	29	1,500	0.260	564	174	390	100%	679	5.5	26	416
Mech room	7	60	7	29	1,000	0.217	420	203	217	100%	486	5.5	15	232
Mech room	13	30	13	16	1,000	0.182	390	208	182	100%	486	5.5	13	195

Office	29	60	28	30	4,000	0.900	6,960	3,360	3,600	100%	1,633	5.5	213	3,813
Office	1	60	1	23	4,000	0.037	240	92	148	100%	1,633	5.5	9	157
Office	9	60	9	24	4,000	0.324	2,160	864	1,296	100%	1,633	5.5	77	1,373
Office	8	60	4	58	4,000	0.248	1,920	928	992	100%	1,633	5.5	59	1,051
Office	8	60	2	143	4,000	0.194	1,920	1,144	776	100%	1,633	5.5	46	822
Office	9	60	6	45	4,000	0.270	2,160	1,080	1,080	100%	1,633	5.5	64	1,144
Office	10	37	10	23	4,000	0.140	1,480	920	560	100%	1,633	5.5	33	593
Office	1	37	1	17	4,000	0.020	148	68	80	100%	1,633	5.5	5	85
Office	3	112	3	45	4,000	0.201	1,344	540	804	100%	1,633	5.5	48	852
Office	18	34	18	10	4,000	0.432	2,448	720	1,728	100%	1,633	5.5	102	1,830
Office	4	34	4	12	4,000	0.088	544	192	352	100%	1,633	5.5	21	373
Office	3	88	3	31	4,000	0.171	1,056	372	684	100%	1,633	5.5	40	724

Office	2	94	1	45	4,000	0.143	752	180	572	100%	1,633	5.5	34	606
Office	6	50	6	8	4,000	0.252	1,200	192	1,008	100%	1,633	5.5	60	1,068
Office	1	144	1	45	4,000	0.099	576	180	396	100%	1,633	5.5	23	419
Office	2	15	2	6	3,000	0.018	90	36	54	100%	1,253	5.5	3	57
Office	8	60	8	30	3,040	0.240	1,459	730	730	100%	1,267	5.5	44	774
Office	36	60	36	24	3,040	1.296	6,566	2,627	3,940	100%	1,267	5.5	238	4,177
Office	20	60	10	72	3,040	0.480	3,648	2,189	1,459	100%	1,267	5.5	88	1,547
Office	8	60	2	143	3,040	0.194	1,459	869	590	100%	1,267	5.5	36	625
Office	2	72	2	23	3,040	0.098	438	140	298	100%	1,267	5.5	18	316
Office	1	112	1	72	3,040	0.040	340	219	122	100%	1,267	5.5	7	129
Office	10	63	10	30	3,040	0.330	1,915	912	1,003	100%	1,267	5.5	61	1,064
Office	2	60	2	24	2,800	0.072	336	134	202	100%	1,177	5.5	12	214

Bathroom	1	30	1	16	8,760	0.014	263	140	123	100%	3,467	5.5	7	130
Bathroom	3	37	3	23	8,760	0.042	972	604	368	100%	3,467	5.5	21	389
Bathroom	7	60	7	24	4,200	0.252	1,764	706	1,058	100%	1,709	5.5	62	1,121
Bathroom	13	30	13	16	4,200	0.182	1,638	874	764	100%	1,709	5.5	45	809
Bathroom	3	37	3	23	4,200	0.042	466	290	176	100%	1,709	5.5	10	187
Bathroom	2	72	2	23	4,200	0.098	605	193	412	100%	1,709	5.5	24	436
Bathroom	1	88	1	31	4,200	0.057	370	130	239	100%	1,709	5.5	14	254
Bathroom	1	17	1	8	4,200	0.009	71	34	38	100%	1,709	5.5	2	40
Bathroom	2	37	2	23	3,192	0.028	236	147	89	100%	1,326	5.5	5	95
Docking Area	3	60	3	30	2,500	0.090	450	225	225	100%	1,061	5.5	14	239
Docking Area	3	30	3	16	2,500	0.042	225	120	105	100%	1,061	5.5	6	111
Exterior	1	120	1	12	4,400	0.108	528	53	475	0%	N/A	N/A	0	475

Vestibule	10	60	6	29	8,760	0.426	5,256	1,524	3,732	100%	3,467	5.5	214	3,946
Office	2	60	2	30	4,000	0.060	480	240	240	100%	1,633	5.5	14	254
Open Office	4	60	4	23	5,000	0.148	1,200	460	740	100%	2,015	5.5	43	783
Open Office	6	60	3	45	5,000	0.225	1,800	675	1,125	100%	2,015	5.5	66	1,191
Open Office	5	37	5	23	5,000	0.070	925	575	350	100%	2,015	5.5	20	370
Open Office	2	120	2	10	5,000	0.220	1,200	100	1,100	100%	2,015	5.5	64	1,164
Open Office	12	37	12	23	4,000	0.168	1,776	1,104	672	100%	1,633	5.5	40	712
Open Office	3	17	3	10	4,000	0.021	204	120	84	100%	1,633	5.5	5	89
Open Office	3	60	3	24	3,040	0.108	547	219	328	100%	1,267	5.5	20	348
Open Office	4	60	4	36	3,040	0.096	730	438	292	100%	1,267	5.5	18	309
Open Office	10	60	10	24	3,800	0.360	2,280	912	1,368	100%	1,557	5.5	81	1,449
Open Office	2	60	1	72	3,800	0.048	456	274	182	100%	1,557	5.5	11	193

Open Office	20	60	5	143	3,800	0.485	4,560	2,717	1,843	100%	1,557	5.5	109	1,952
Open Office	20	60	4	179	3,800	0.484	4,560	2,721	1,839	100%	1,557	5.5	109	1,948
Open Office	10	60	2	215	3,800	0.170	2,280	1,634	646	100%	1,557	5.5	38	684
Open Office	2	37	2	23	3,800	0.028	281	175	106	100%	1,557	5.5	6	113
Office	2	112	2	45	4,000	0.134	896	360	536	100%	1,633	5.5	32	568
Lounge	4	75	4	11	3,500	0.256	1,050	154	896	100%	1,444	5.5	54	950
Lounge	1	72	1	29	3,500	0.043	252	102	151	100%	1,444	5.5	9	159
Lounge	2	72	2	30	3,500	0.084	504	210	294	100%	1,444	5.5	18	312
Lounge	2	60	2	24	2,660	0.072	319	128	192	100%	1,123	5.5	12	203
Lounge	4	60	2	72	2,660	0.096	638	383	255	100%	1,123	5.5	16	271
mailroom	6	72	6	23	3,040	0.294	1,313	420	894	100%	1,267	5.5	54	948
Lobby	28	48	28	24	8,760	0.672	11,773	5,887	5,887	100%	3,467	5.5	337	6,224

Kitchen	1	37	1	23	3,500	0.014	130	81	49	100%	1,444	5.5	3	52
Kitchen	1	37	1	23	4,000	0.014	148	92	56	100%	1,633	5.5	3	59
Kitchen	3	37	3	23	2,660	0.042	295	184	112	100%	1,123	5.5	7	119
Locker room	1	30	1	16	3,500	0.014	105	56	49	100%	1,444	5.5	3	52
Locker room	1	30	1	16	4,200	0.014	126	67	59	100%	1,709	5.5	3	62
Locker room	2	37	2	23	2,660	0.028	197	122	74	100%	1,123	5.5	5	79
Total	2,228		2,145			72.727	662,411	304,078	358,333				20,910	379,243

Table 5-12. Evaluation Fixture Inputs and kWh Savings for Building 3

	A	B	C	D	E	F	G=A*B*E	H=C*D*E/1000	I=G-H	J	K	L	M=F*J*K*0.8/L	N=I+M
							/1000							
Space Type	Baseline Quantity	Baseline Watts per Fixture	Installed Quantity	Installed Watts per Fixture	Annual Hours	Connected kW Savings	Baseline kWh	Installed kWh	kWh Fixture Savings	Percent of Space Cooled	Annual Cooling Hours	Cooling COP	Interactive Cooling Savings	Total kWh Fixture Savings
North	2	295	2	35	4,380	0.520	2,584	307	2,278	0%	N/A	N/A	0	2,278
North	1	120	1	30	4,380	0.090	526	131	394	0%	N/A	N/A	0	394
North	2	455	2	129	4,380	0.652	3,986	1,130	2,856	0%	N/A	N/A	0	2,856
North	1	25	1	9.5	4,380	0.016	110	42	68	0%	N/A	N/A	0	68
North	8	25	8	12	4,380	0.104	876	421	456	0%	N/A	N/A	0	456
North	1	12	1	12	4,380	0.000	53	53	0	0%	N/A	N/A	0	0
North	6	205	6	35	4,380	1.020	5,388	920	4,468	0%	N/A	N/A	0	4,468
North	2	190	2	38	4,380	0.304	1,664	333	1,332	0%	N/A	N/A	0	1,332
North	1	190	1	37	4,380	0.153	832	162	670	0%	N/A	N/A	0	670
North	1	90	1	20	4,380	0.070	394	88	307	0%	N/A	N/A	0	307
North	3	15	3	9.5	1,040	0.017	47	30	17	0%	N/A	N/A	0	17
South	2	295	2	50	4,380	0.490	2,584	438	2,146	0%	N/A	N/A	0	2,146
South	1	120	1	30	4,380	0.090	526	131	394	0%	N/A	N/A	0	394

South	2	455	2	129	4,380	0.652	3,986	1,130	2,856	0%	N/A	N/A	0	2,856
South	2	455	2	455	4,380	0.000	3,986	3,986	0	0%	N/A	N/A	0	0
South	1	65	1	20	4,380	0.045	285	88	197	0%	N/A	N/A	0	197
South	1	130	1	30	4,380	0.100	569	131	438	0%	N/A	N/A	0	438
South	1	205	1	35	4,380	0.170	898	153	745	0%	N/A	N/A	0	745
South	1	48	1	22	4,380	0.026	210	96	114	0%	N/A	N/A	0	114
South	1	190	1	38	4,380	0.152	832	166	666	0%	N/A	N/A	0	666
South	9	95	9	18	4,380	0.693	3,745	710	3,035	0%	N/A	N/A	0	3,035
South	1	100	1	22	8,760	0.078	876	193	683	0%	N/A	N/A	0	683
South Lot Shed	2	455	2	50	4,380	0.810	3,986	438	3,548	0%	N/A	N/A	0	3,548
West	1	295	1	50	4,380	0.245	1,292	219	1,073	0%	N/A	N/A	0	1,073
West	1	180	1	30	4,380	0.150	788	131	657	0%	N/A	N/A	0	657
West	4	25	4	12	4,380	0.052	438	210	228	0%	N/A	N/A	0	228
West	1	12	1	12	4,380	0.000	53	53	0	0%	N/A	N/A	0	0
East	1	295	1	35	4,380	0.260	1,292	153	1,139	0%	N/A	N/A	0	1,139
East	2	455	2	129	4,380	0.652	3,986	1,130	2,856	0%	N/A	N/A	0	2,856
East	4	15	4	15	4,380	0.000	263	263	0	0%	N/A	N/A	0	0
East	1	65	1	22	4,380	0.043	285	96	188	0%	N/A	N/A	0	188
East	4	205	4	35	4,380	0.680	3,592	613	2,979	0%	N/A	N/A	0	2,979
East	1	48	1	30	4,380	0.018	210	131	79	0%	N/A	N/A	0	79

East	3	48	3	22	4,380	0.078	631	289	342	0%	N/A	N/A	0	342
East	1	48	1	20	4,380	0.028	210	88	123	0%	N/A	N/A	0	123
East	3	190	3	38	4,380	0.456	2,497	499	1,997	0%	N/A	N/A	0	1,997
East	4	63	4	63	4,380	0.000	1,104	1,104	0	0%	N/A	N/A	0	0
North (Pole)	2	455	2	129	4,380	0.652	3,986	1,130	2,856	0%	N/A	N/A	0	2,856
Total	85		85			9.565	59,570	17,386	42,183				-	42,183

Table 5-13. Evaluation Fixture Inputs and kWh Savings for Building 4

	A	B	C	D	E	F	G=A*B*E/1000	H=C*D*E/1000	I=G-H	J	K	L	M=F*J*K*0.8/L	N=I+M
Space Type	Baseline Quantity	Baseline Watts per Fixture	Installed Quantity	Installed Watts per Fixture	Annual Hours	Connected kW Savings	Baseline kWh	Installed kWh	kWh Fixture Savings	Percent of Space Cooled	Annual Cooling Hours	Cooling COP	Interactive Cooling Savings	Total kWh Fixture Savings
Undercabinet	316	24	316	15	3,000	2.844	22,752	14,220	8,532	100%	1,243	5.5	512	9,044
Mech room	4	45	4	29	8,760	0.064	1,577	1,016	561	100%	3,434	5.5	32	592
Mech room	1	45	1	29	1,140	0.016	51	33	18	100%	534	5.5	1	19
Mech room	2	30	2	14	1,140	0.032	68	32	36	100%	534	5.5	2	39
Mech room	4	60	4	29	1,140	0.124	274	132	141	100%	534	5.5	10	151
Mech room	25	60	25	29	4,000	0.775	6,000	2,900	3,100	100%	1,625	5.5	182	3,282
Mech room	30	112	30	58	4,000	1.620	13,440	6,960	6,480	100%	1,625	5.5	381	6,861
Mech room	8	45	8	29	1,900	0.128	684	441	243	100%	824	5.5	15	258

Mech room	1	60	1	29	760	0.031	46	22	24	100%	389	5.5	2	25
Hallway	5	45	5	29	8,760	0.080	1,971	1,270	701	100%	3,434	5.5	40	741
Hallway	4	45	4	25	8,760	0.080	1,577	876	701	100%	3,434	5.5	40	741
Hallway	55	27	55	21	8,760	0.330	13,009	10,118	2,891	100%	3,434	5.5	164	3,055
Hallway	4	24	2	25	7,008	0.046	673	350	322	100%	2,772	5.5	18	341
Hallway	1	45	1	26	7,008	0.019	315	182	133	100%	2,772	5.5	8	141
Hallway	2	27	2	21	7,008	0.012	378	294	84	100%	2,772	5.5	5	89
Hallway	4	45	4	29	6,000	0.064	1,080	696	384	100%	2,389	5.5	22	406
Hallway	2	45	2	25	6,000	0.040	540	300	240	100%	2,389	5.5	14	254
Hallway	1	45	1	26	6,000	0.019	270	156	114	100%	2,389	5.5	7	121
Hallway	60	27	60	21	6,000	0.360	9,720	7,560	2,160	100%	2,389	5.5	124	2,284
Hallway	5	39	5	24	6,000	0.075	1,170	720	450	100%	2,389	5.5	26	476

Hallway	7	34	7	14	6,000	0.140	1,428	588	840	100%	2,389	5.5	48	888
Lobby	2	27	2	21	8,760	0.012	473	368	105	100%	3,434	5.5	6	111
Conf room	3	45	1	76	3,040	0.059	410	231	179	100%	1,260	5.5	11	190
Conf room	4	89	4	51	3,040	0.152	1,082	620	462	100%	1,260	5.5	28	490
Conf room	3	34	3	14	3,040	0.060	310	128	182	100%	1,260	5.5	11	193
Conf room	3	47	1	76	3,040	0.065	429	231	198	100%	1,260	5.5	12	209
Auditorium	4	34	4	18	4,000	0.064	544	288	256	100%	1,625	5.5	15	271
Storage	4	45	4	29	1,140	0.064	205	132	73	100%	534	5.5	5	78
Storage	2	45	2	24	1,140	0.042	103	55	48	100%	534	5.5	3	51
Storage	3	45	3	29	1,500	0.048	203	131	72	100%	671	5.5	5	77
Storage	1	27	1	21	1,500	0.006	41	32	9	100%	671	5.5	1	10
Storage	1	34	1	14	1,500	0.020	51	21	30	100%	671	5.5	2	32

Storage	1	60	1	29	1,500	0.031	90	44	47	100%	671	5.5	3	50
Vestibule	1	45	1	29	8,760	0.016	394	254	140	100%	3,434	5.5	8	148
lab	17	45	17	25	8,760	0.340	6,701	3,723	2,978	100%	3,434	5.5	169	3,147
lab	4	68	4	30	8,760	0.152	2,383	1,051	1,332	100%	3,434	5.5	76	1,407
lab	3	68	3	30	6,000	0.114	1,224	540	684	100%	2,389	5.5	39	723
lab	11	136	22	30	6,000	0.836	8,976	3,960	5,016	100%	2,389	5.5	289	5,305
lab	19	45	19	25	4,560	0.380	3,899	2,166	1,733	100%	1,839	5.5	101	1,834
lab	55	89	55	45	4,560	2.420	22,321	11,286	11,035	100%	1,839	5.5	644	11,679
Lab Hood	23	80	23	17	4,000	1.449	7,360	1,564	5,796	100%	1,625	5.5	341	6,137
Lab Storage	4	45	2	58	3,000	0.064	540	348	192	100%	1,243	5.5	12	204
Lab Storage	12	27	12	21	3,000	0.072	972	756	216	100%	1,243	5.5	13	229
Lab Storage	2	60	2	24	3,000	0.072	360	144	216	100%	1,243	5.5	13	229

Lab Storage	6	68	6	26	3,000	0.252	1,224	468	756	100%	1,243	5.5	45	801
Lab Storage	1	145	1	30	3,000	0.115	435	90	345	100%	1,243	5.5	21	366
Lab	137	45	137	25	8,760	2.740	54,005	30,003	24,002	100%	3,434	5.5	1,362	25,364
Lab	2	72	2	24	8,760	0.096	1,261	420	841	100%	3,434	5.5	48	889
Lab	5	52	5	25	8,760	0.135	2,278	1,095	1,183	100%	3,434	5.5	67	1,250
Lab	2	45	2	29	6,000	0.032	540	348	192	100%	2,389	5.5	11	203
Lab	1	45	1	25	6,000	0.020	270	150	120	100%	2,389	5.5	7	127
Lab	8	45	4	58	6,000	0.128	2,160	1,392	768	100%	2,389	5.5	44	812
Lab	4	68	4	24	6,000	0.176	1,632	576	1,056	100%	2,389	5.5	61	1,117
Lab	4	68	4	26	6,000	0.168	1,632	624	1,008	100%	2,389	5.5	58	1,066
Lab	6	68	6	33	6,000	0.210	2,448	1,188	1,260	100%	2,389	5.5	73	1,333
Lab	5	88	5	26	6,000	0.310	2,640	780	1,860	100%	2,389	5.5	107	1,967

Lab	2	53	2	24	6,000	0.058	636	288	348	100%	2,389	5.5	20	368
Lab	163	45	163	25	4,560	3.260	33,448	18,582	14,866	100%	1,839	5.5	868	15,733
Lab	113	45	113	24	4,560	2.373	23,188	12,367	10,821	100%	1,839	5.5	632	11,453
Lab	335	89	335	45	4,560	14.740	135,956	68,742	67,214	100%	1,839	5.5	3,924	71,139
Lab	3	89	3	58	4,560	0.093	1,218	793	424	100%	1,839	5.5	25	449
Lab	26	68	26	24	4,560	1.144	8,062	2,845	5,217	100%	1,839	5.5	305	5,521
Lab	6	68	6	33	4,560	0.210	1,860	903	958	100%	1,839	5.5	56	1,014
Lab	4	88	4	24	4,560	0.256	1,605	438	1,167	100%	1,839	5.5	68	1,236
Lab	16	72	16	24	4,560	0.768	5,253	1,751	3,502	100%	1,839	5.5	204	3,707
Lab	12	52	12	25	4,560	0.324	2,845	1,368	1,477	100%	1,839	5.5	86	1,564
Office	3	45	3	26	8,760	0.057	1,183	683	499	100%	3,434	5.5	28	528
Office	7	27	7	21	8,760	0.042	1,656	1,288	368	100%	3,434	5.5	21	389

Office	5	72	5	24	8,760	0.240	3,154	1,051	2,102	100%	3,434	5.5	119	2,222
Office	27	45	27	24	3,040	0.567	3,694	1,970	1,724	100%	1,260	5.5	103	1,827
Office	20	45	20	26	3,040	0.380	2,736	1,581	1,155	100%	1,260	5.5	69	1,224
Office	19	27	19	21	3,040	0.114	1,560	1,213	347	100%	1,260	5.5	21	367
Office	1	34	1	14	3,040	0.020	103	43	61	100%	1,260	5.5	4	64
Office	21	68	21	24	3,040	0.924	4,341	1,532	2,809	100%	1,260	5.5	169	2,977
Office	69	72	69	24	3,040	3.312	15,103	5,034	10,068	100%	1,260	5.5	604	10,672
Office	5	45	5	24	4,000	0.105	900	480	420	100%	1,625	5.5	25	445
Office	3	68	3	26	4,000	0.126	816	312	504	100%	1,625	5.5	30	534
Office	3	72	3	24	4,000	0.144	864	288	576	100%	1,625	5.5	34	610
Office	8	17	8	6	4,000	0.088	544	192	352	100%	1,625	5.5	21	373
Bathroom	2	34	2	18	8,760	0.032	596	315	280	100%	3,434	5.5	16	296

Bathroom	56	45	56	25	3,192	1.120	8,044	4,469	3,575	100%	1,317	5.5	213	3,788
Bathroom	4	54	4	18	3,192	0.144	689	230	460	100%	1,317	5.5	27	487
Bathroom	4	34	4	18	4,200	0.064	571	302	269	100%	1,701	5.5	16	285
Elec room	1	45	1	29	8,760	0.016	394	254	140	100%	3,434	5.5	8	148
Elec room	9	45	9	29	1,500	0.144	608	392	216	100%	671	5.5	14	230
Elec room	1	45	1	21	1,500	0.024	68	32	36	100%	671	5.5	2	38
Elec room	20	45	10	58	1,500	0.320	1,350	870	480	100%	671	5.5	31	511
Computer lab	5	72	5	24	3,263	0.240	1,175	392	783	100%	1,343	5.5	47	830
Computer lab	7	72	7	24	3,800	0.336	1,915	638	1,277	100%	1,549	5.5	75	1,352
Exterior	3	20	3	7	4,400	0.039	264	92	172	0%	0	0.0	0	172
Exterior	2	95	2	27	4,400	0.136	836	238	598	0%	0	0.0	0	598
Mail Room	3	45	3	29	8,760	0.048	1,183	762	420	100%	3,434	5.5	24	444

Mail Room	9	45	9	29	5,000	0.144	2,025	1,305	720	100%	2,007	5.5	42	762
Dark Room	2	34	2	14	2,000	0.040	136	56	80	100%	862	5.5	5	85
Dark Room	2	15	2	5	2,000	0.020	60	20	40	100%	862	5.5	2	42
Dark Room	2	200	2	23	2,000	0.354	800	92	708	100%	862	5.5	44	752
Dark Room	2	28	2	7	2,000	0.042	112	28	84	100%	862	5.5	5	89
Total	1909		1898			50.427	478,167	248,304	229,863				13,370	243,233

Table 5-14. Evaluation Controls Inputs and kWh Savings for Building 1

	A	**B**	**C**	**D=A*B/1000**	**E=C*D**	**F**	**G**	**H**	**I=D*F*G*0.8/H**	**J=E+I**
Space Type	Installed Quantity	Installed Watts per Fixture	Annual Hours Reduction	Connected kW	kWh Controls Savings	Percent of Space Cooled	Annual Cooling Hours Reduction	Cooling COP	Interactive Cooling Savings	Total kWh Controls Savings
24/7	13	47	1,472	0.61	899	0%	594	N/A	0	899
24/7	132	31	1,472	4.09	6,023	0%	594	N/A	0	6,023

24/7	7	230	1,472	1.61	2,370	0%	594	N/A	0	2,370
24/7	4	31	1,472	0.12	183	0%	594	N/A	0	183
24/7	1	14	1,472	0.01	21	0%	594	N/A	0	21
Office	3	31	672	0.09	62	0%	289	N/A	0	62
Office - Central Heating Plant	4	14	960	0.06	54	100%	402	2.9	6	60
Total	164			6.60	9,612				6	9,618

Table 5-15. Evaluation Controls Inputs and kWh Savings for Building 2

	A	B	C	D=A*B/1000	E=C*D	F	G	H	I=D*F*G*0.8/H	J=E+I
Space Type	Installed Quantity	Installed Watts per Fixture	Annual Hours Reduction	Connected kW	kWh Controls Savings	Percent of Space Cooled	Annual Cooling Hours Reduction	Cooling COP	Interactive Cooling Savings	Total kWh Controls Savings
Hallway	97	23	3,329	2.23	7,427	100%	1,350	5.5	436	7,863
Hallway	4	31	3,329	0.12	413	100%	1,350	5.5	24	437
Hallway	19	29	3,329	0.55	1,834	100%	1,350	5.5	108	1,942
Hallway	8	15	3,329	0.12	399	100%	1,350	5.5	23	423
Hallway	3	23	3,329	0.07	230	100%	1,350	5.5	13	243
Hallway	4	23	3,154	0.09	290	100%	1,286	5.5	17	307
Hallway	64	23	932	1.47	1,372	100%	434	5.5	92	1,464

Elec room	2	23	540	0.05	25	100%	272	5.5	2	27
Classroom	4	10	840	0.04	34	100%	346	5.5	2	36
Classroom	9	31	1,200	0.28	335	100%	482	5.5	19	354
Classroom	17	29	1,200	0.49	592	100%	482	5.5	34	626
Classroom	11	10	1,200	0.11	132	100%	482	5.5	8	140
Classroom	146	30	1,200	4.38	5,256	100%	482	5.5	305	5,561
Classroom	5	23	1,200	0.12	138	100%	482	5.5	8	146
Classroom	4	11	1,200	0.04	53	100%	482	5.5	3	56
Classroom	11	11	846	0.12	102	100%	341	5.5	6	108
Lab	8	23	1,520	0.18	280	100%	643	5.5	17	297
Lab	2	24	960	0.05	46	100%	389	5.5	3	49
Lab	2	29	720	0.06	42	100%	300	5.5	3	44
Lab	12	11	720	0.13	95	100%	300	5.5	6	101
Lab	8	45	1,440	0.36	518	100%	572	5.5	30	548
Lab	7	31	1,440	0.22	312	100%	572	5.5	18	330
Lab	12	30	1,440	0.36	518	100%	572	5.5	30	548
Lab	9	68	1,440	0.61	881	100%	572	5.5	51	932
Lab	9	45	1,440	0.41	583	100%	572	5.5	34	617
Lab	9	30	1,440	0.27	389	100%	572	5.5	22	411
Lab	12	24	1,440	0.29	415	100%	572	5.5	24	439

Lab	2	72	1,440	0.14	207	100%	572	5.5	12	219
Lab	3	36	1,440	0.11	156	100%	572	5.5	9	164
Lab	132	29	1,440	3.83	5,512	100%	572	5.5	317	5,829
Lab	86	30	1,440	2.58	3,715	100%	572	5.5	214	3,929
Lab	1	23	1,440	0.02	33	100%	572	5.5	2	35
Lab	2	143	1,440	0.29	412	100%	572	5.5	24	436
Lab	2	72	1,440	0.14	207	100%	572	5.5	12	219
Lab	12	30	1,440	0.36	518	100%	572	5.5	30	548
Lab	7	58	1,440	0.41	585	100%	572	5.5	34	618
Lab	14	30	1,440	0.42	605	100%	572	5.5	35	640
Lab	1	29	1,440	0.03	42	100%	572	5.5	2	44
Lab	16	29	1,440	0.46	668	100%	572	5.5	38	707
Lab	5	23	2,280	0.12	262	100%	931	5.5	16	278
Conf room	32	23	1,330	0.74	979	100%	574	5.5	61	1,040
Conf room	10	24	840	0.24	202	100%	346	5.5	12	214
Conf room	5	30	840	0.15	126	100%	346	5.5	8	134
Conf room	2	107	840	0.21	180	100%	346	5.5	11	190
Conf room	4	11	840	0.04	37	100%	346	5.5	2	39
Conf room	12	11	840	0.13	111	100%	346	5.5	7	117
Conf room	12	23	840	0.28	232	100%	346	5.5	14	246

Conf room	6	8	592	0.05	28	100%	242	5.5	2	30
Storage	2	24	360	0.05	17	100%	162	5.5	1	18
Storage	3	29	360	0.09	31	100%	162	5.5	2	33
Storage	8	23	950	0.18	175	100%	425	5.5	11	186
Storage	2	24	600	0.05	29	100%	252	5.5	2	31
Storage	8	10	600	0.08	48	100%	252	5.5	3	51
Office	6	23	1,520	0.14	210	100%	643	5.5	13	223
Office	3	31	960	0.09	89	100%	389	5.5	5	95
Office	9	24	960	0.22	207	100%	389	5.5	12	220
Office	28	30	960	0.84	806	100%	389	5.5	47	854
Office	1	23	960	0.02	22	100%	389	5.5	1	23
Office	4	58	960	0.23	223	100%	389	5.5	13	236
Office	2	143	960	0.29	275	100%	389	5.5	16	291
Office	6	45	960	0.27	259	100%	389	5.5	15	274
Office	4	23	960	0.09	88	100%	389	5.5	5	94
Office	1	17	960	0.02	16	100%	389	5.5	1	17
Office	3	45	960	0.14	130	100%	389	5.5	8	137
Office	4	12	960	0.05	46	100%	389	5.5	3	49
Office	18	10	960	0.18	173	100%	389	5.5	10	183
Office	1	45	960	0.05	43	100%	389	5.5	3	46

Office	1	45	960	0.05	43	100%	389	5.5	3	46
Office	2	24	672	0.05	32	100%	281	5.5	2	34
Bathroom	3	23	3,329	0.07	230	100%	1,350	5.5	13	243
Bathroom	1	31	1,008	0.03	31	100%	409	5.5	2	33
Bathroom	2	23	1,008	0.05	46	100%	409	5.5	3	49
Bathroom	7	24	1,008	0.17	169	100%	409	5.5	10	179
Bathroom	9	16	1,008	0.14	145	100%	409	5.5	9	154
Bathroom	1	8	1,008	0.01	8	100%	409	5.5	0	9
Bathroom	3	23	1,596	0.07	110	100%	672	5.5	7	117
Bathroom	2	23	447	0.05	21	100%	251	5.5	2	22
Docking Area	3	30	600	0.09	54	100%	252	5.5	3	57
Docking Area	3	16	600	0.05	29	100%	252	5.5	2	31
Office	2	30	960	0.06	58	100%	389	5.5	3	61
Open Office	4	23	1,200	0.09	110	100%	482	5.5	6	117
Open Office	3	45	1,200	0.14	162	100%	482	5.5	9	171
Open Office	2	10	1,200	0.02	24	100%	482	5.5	1	25
Open Office	5	23	1,900	0.12	219	100%	786	5.5	13	232
Open Office	12	23	1,520	0.28	420	100%	643	5.5	26	445
Open Office	2	23	532	0.05	24	100%	283	5.5	2	26
Office	2	45	960	0.09	86	100%	389	5.5	5	91

Kitchen	1	23	1,330	0.02	31	100%	574	5.5	2	33
Kitchen	1	23	1,520	0.02	35	100%	643	5.5	2	37
Kitchen	3	23	372	0.07	26	100%	223	5.5	2	28
Locker room	2	23	372	0.05	17	100%	223	5.5	1	19
Total	1,053			28.84	42,546				2,498	45,044

Table 5-16. Evaluation Controls Inputs and kWh Savings for Building 4

	A	**B**	**C**	**D=A*B/1000**	**E=C*D**	**F**	**G**	**H**	**I=D*F*G*0.8/H**	**J=E+I**
Space Type	Installed Quantity	Installed Watts per Fixture	Annual Hours Reduction	Connected kW	kWh Controls Savings	Percent of Space Cooled	Annual Cooling Hours Reduction	Cooling COP	Interactive Cooling Savings	Total kWh Controls Savings
Office	3	24	960	0.07	69	100%	393	5.5	4	73
Office	2	24	960	0.05	46	100%	393	5.5	3	49
Office	3	26	960	0.08	75	100%	393	5.5	4	79
Mech room	25	29	1,520	0.73	1,102	100%	620	5.5	65	1,167
Mech room	30	58	1,520	1.74	2,645	100%	620	5.5	156	2,801
Hallway	55	21	3,154	1.16	3,642	100%	1,235	5.5	206	3,849
Hallway	5	29	3,329	0.15	483	100%	1,304	5.5	27	510

Hallway	2	25	3,329	0.05	166	100%	1,304	5.5	9	176
Hallway	2	21	2,523	0.04	106	100%	1,001	5.5	6	112
Hallway	5	24	2,160	0.12	259	100%	863	5.5	15	274
Hallway	60	21	2,160	1.26	2,722	100%	863	5.5	157	2,879
Hallway	2	25	3,300	0.05	165	100%	1,318	5.5	10	175
Hallway	4	29	2,280	0.12	264	100%	912	5.5	15	280
Lobby	2	21	3,154	0.04	132	100%	1,235	5.5	8	140
Storage	1	21	540	0.02	11	100%	244	5.5	1	12
Vestibule	1	29	3,329	0.03	97	100%	1,304	5.5	5	102
lab	3	30	3,300	0.09	297	100%	1,318	5.5	17	314
lab	22	30	3,300	0.66	2,178	100%	1,318	5.5	126	2,304
lab	19	25	1,414	0.48	671	100%	574	5.5	39	711
lab	55	45	1,414	2.48	3,499	100%	574	5.5	205	3,704
Lab Storage	2	58	720	0.12	84	100%	298	5.5	5	89
Lab Storage	12	21	1,080	0.25	272	100%	449	5.5	16	289
Lab	4	26	2,160	0.10	225	100%	863	5.5	13	238
Lab	1	25	3,300	0.03	82	100%	1,318	5.5	5	87
Lab	2	29	1,440	0.06	84	100%	577	5.5	5	88
Lab	2	58	1,440	0.12	167	100%	577	5.5	10	177

Lab	6	33	1,440	0.20	285	100%	577	5.5	17	302
Lab	4	24	1,414	0.10	136	100%	574	5.5	8	144
Lab	154	25	1,414	3.85	5,442	100%	574	5.5	320	5,762
Lab	335	45	1,414	15.08	21,310	100%	574	5.5	1,251	22,561
Lab	12	25	1,414	0.30	424	100%	574	5.5	25	449
Bathroom	4	18	1,008	0.07	73	100%	410	5.5	4	77
Mail Room	3	29	3,329	0.09	290	100%	1,304	5.5	16	306
Mail Room	9	29	1,900	0.26	496	100%	765	5.5	29	525
Total	851			30.00	47,999				2,804	50,803

Explanation of Differences

The primary factor that affects this project's energy-saving is the inclusion of HVAC interactive savings for buildings one, two, and four. Building three consisted entirely of exterior fixture installations, which are not affected by HVAC interaction.

Table 5-17 and Table 5-18 summarize the differences between the application and evaluation savings. Table 5-17 summarizes the quantity and fixture wattage differences that were found. It is important to note that the wattage differences found in building two were initially found during a post audit performed by National Grid and the tracking system fixture savings were corrected to reflect them but the controls savings were not updated. Table 5-18 summarizes the impact of the discrepancies between the application and evaluation savings.

Table 5-17. Summary of Key Parameters

		Applicant		Evaluation	
Building ID	Discrepancy - Measure	Controlled Fixture Quantity	Proposed Watts per Fixture	Controlled Fixture Quantity	Proposed Watts per Fixture
1	Quantity – Lighting Controls	2	39	0	N/A
2	Technology – Lighting Controls	15	9	15	10
2	Technology – Lighting Controls	28	14	28	10
2	Technology – Lighting Controls	8	16	8	15
2	Technology – Lighting Controls	1	16	1	17
2	Technology – Lighting Controls	168	22	168	23
2	Technology – Lighting Controls	3	24	3	45
2	Technology – Lighting Controls	3	35	3	36
2	Technology – Lighting Controls	10	36	10	31
2	Technology – Lighting Controls	4	70	4	72
2	Technology – Lighting Controls	2	105	2	107
2	Technology – Lighting Controls	4	140	4	143
Total	Lighting Controls	248	-	246	-

3	Technology – Lighting Fixtures	3	18	3	20
3	Technology – Lighting Fixtures	6	20	6	22
3	Technology – Lighting Fixtures	5	26	5	30
3	Technology – Lighting Fixtures	14	37	14	35
3	Technology – Lighting Fixtures	6	40	6	38
3	Technology – Lighting Fixtures	5	57	5	50
Total	Lighting Fixtures	39	-	39	-

Table 5-18. Summary of Deviations

Building ID	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
Building 1	HVAC Interaction	Electric Cooling	+0.01%	Increased savings – Inclusion of HVAC interactive cooling savings for program installed fixtures.
Building 1	Quantity	Quantity	-0.01%	Decreased savings – Changes in the quantity of fixtures with controls.
Building 1	HVAC Interaction	Electric Cooling	+0.001%	Increased savings – Inclusion of HVAC interactive cooling savings for program installed controls.
Building 2	HVAC Interaction	Electric Cooling	+2.7%	Increased savings – Inclusion of HVAC interactive cooling savings for program installed fixtures.
Building 2	Technology	Wattage	+0.03%	Increased savings – Changes to the fixture wattages on program installed controls.
Building 2	HVAC Interaction	Electric Cooling	+0.3%	Increased savings – Inclusion of HVAC interactive cooling savings for program installed controls
Building 3	Technology	Wattage	+0.02%	Increased savings – Changes to the program installed fixture wattages.

Building 4	HVAC Interaction	Electric Cooling	+1.7%	Increased savings –Inclusion of HVAC interactive cooling savings for program installed fixtures.
Building 4	HVAC Interaction	Electric Cooling	+0.4%	Increased savings – Inclusion of HVAC interactive cooling savings for program installed controls

Ancillary impacts

There are no fuel-based ancillary impacts associated with this project.

RICE18C013 Non-Lighting

Report Date: 7/27/21

Application ID(s)	7307056; 7731255	
Project Type	C&I Retrofit	
Program Year	2018	
Evaluation Firm	DNV	DNV
Evaluation Analysis Type	Full M&V	
Evaluation Engineer	Joe St. John	
Senior Engineer	Olav Hegland	

Evaluated Site Summary and Results

This evaluation report describes findings from evaluating 5 sampled non-lighting custom electric measures across 5 buildings at a university campus. These 5 sampled measures were drawn from a list of 47 energy efficiency measures installed across 34 buildings at this university that were claimed by the utility program in 2018.

DNV reviewed available data for these 5 sampled measures and determined that coupled with recent on-site spot measurements and verification, that sufficient data existed from before the pandemic to justify full EM&V analysis. For some of the measures, the evaluators collected data through short-term meters including spot measurements to further support the longer-term data found in the supporting documentation that was associated with the tracking estimates.

The evaluation results are presented in Table 5-19. The overall realization rate for these 5 measures was found to be 57.7%.

Table 5-19. Evaluation Results Summary

Measure Number	PA Application ID	Measure Name		Annual Electric Energy (kWh)	% of Energy Savings On-Peak	Summer On-Peak Demand (kW)	Winter On-Peak Demand (kW)
1	7307056; 7731255	Building 1, Laboratory Building - New Occ Sensors and Scheduling Controls	Tracked	189,275	45.00%	41.15	10.92
			Evaluated - ops	52,860	23.60%	2.22	2.10
			Realization Rate	27.9%	52.4%	5.4%	19.2%
2	7307056; 7731255	Building 2, Laboratory Building - Condenser Water Reset	Tracked	57,560	45.00%	18.16	4.82
			Evaluated - ops	100,639	51.44%	11.31	1.68
			Realization Rate	174.8%	114.3%	62.3%	34.8%
3	7307056; 7731255	Building 3, Medical Education Building - Reduce Supply and Exhaust Fan Airflow During Unoccupied Hours	Tracked	89,500	45.00%	19.46	5.16
			Evaluated - ops	47,362	17.85%	0.00	0.00
			Realization Rate	52.9%	39.7%	0%	0%
4	7307056; 7731255	Building 4, Dining Hall - Add Scheduling Controls to AHU-1	Tracked	11,089	45.00%	2.41	0.64
			Evaluated - ops	2,803	0.00%	0	0.00
			Realization Rate	25.3%	0.0%	0%	0%
5	7307056; 7731255	Building 5, Office Building - Integrate VRF with BAS for Scheduling Control	Tracked	5,766	45.00%	0.59	0.16
			Evaluated - ops	0	0.00%	0.00	0.00
			Realization Rate	0%	0.0%	0%	0%
	Totals Evaluated		**Tracked**	353,190	45.00%	81.76	21.70
			Evaluated - ops	203,664	35.70%	13.54	3.77
			Realization Rate	57.7%	79.3%	16.6%	17.4%

Table 5-20 shows the evaluation results for the evaluated measures, as well as the non-evaluated measures. While an engineering analysis was not completed for the non-evaluated measures, admin/tracking discrepancies were evaluated for all 47 measures. The reason that the realization rate for non-sampled measures for each stratum is different from the realization rate for the sampled measures is due to differences in the tracking/admin realization rates. The “operational” realization rates (evaluated savings / tracking calculator savings) are equivalent for the sampled and non-sampled measures for each stratum.

Table 5-20. Evaluation Results Summary of Sampled and Non-Sampled Measures By Stratum

Measure #	Tracking Database Savings	Tracking Calculator Savings	Evaluated Savings	Realization Rate
1 (large stratum, sampled)	189,275	189,275	52,860	27.9%
2 (large stratum, sampled)	57,560	83,540	100,639	174.8%
3 (large stratum, sampled)	89,500	85,900	47,362	52.9%
1,2,3 (large stratum, sampled) Total	**336,335**	**358,715**	**200,861**	**59.7%**
25 (small stratum, sampled)	11,089	7,075	2,803	25.3%
36 (small stratum, sampled)	5,766	2,711	0	0.0%
25, 36 (small stratum, sampled) Total	**16,855**	**9,786**	**2,803**	**16.6%**
2,4,5 (large stratum, non-sampled)	240,123	293,530	164,361	68.4%
6-24, 26-35, 37-46 (small stratum, non-sampled)	596,308	563,694	161,435	27.1%
Total	**1,189,622**	**1,225,725**	**529,460**	**44.5%**

Explanation of Deviations from Tracking

The measure which contributed most significantly to the low realization rate is measure 1 in Table 5-19, which is a measure which involves restoring scheduling controls for the terminal boxes served by supply and exhaust fans in a laboratory building, as well as installing occupancy sensors in non-lab spaces. The primary reason for the discrepancy for this measure is that 44% of the savings associated with tracking calculations inadvertantly omitted the post-retrofit usage of ~75 kW associated with the supply fans going into “standby” for 1,095 hours of the year. The realization rate for the peak savings for this measure are low because the majority of savings for this measure occur during unoccupied hours, while the tracking peak savings were estimated by assuming that the summer peak savings (for all measures) are simply equal to the total kWh savings multiplied by 30%, and divided by 1,380 hours. The calculations appear to have intended to include some non-zero kW for these hours, but the calculations erroneosly did not incorporate the non-zero kW values for these hours. Since this is a laborotory building that requires continuous fresh air for safety reasons, it is not possible for the supply fan kW to drop to zero. The trend data from the BAS that was reviewed confirmed that the entire supply and exhaust fan airflow, and therefore kW, does not ever reduce to zero. Additional details on differences between tracking and evaluator savings values can be found in Section 0.

Recommendations for Program Designers & Implementers

There are no recommendations.

Customer Alert

During the evaluation it was determined that measure 5 (integrate VRF with BAS for scheduling control) was not found to be scheduled to go into unoccupied times. The customer was made aware of this issue, and indicated they would look into this, but the customer service representative may want to follow up.

Evaluated Measures

The measures evaluated as part of this report are described below:

1. **Building 1, Laboratory Building - New Occ Sensors and Scheduling Controls**

   The measure involves restoring scheduling controls for the terminal boxes associated with AHU-1 and EAHUs-1&2 that were found to have lost their scheduling parameters and were, therefore, running in occupied mode 24/7. The measure also involves installing new occupancy sensor controls on all or a portion of the non-laboratory terminal units served by AHU-1 and EAHUs-1&2. The new occupancy controls allow the terminal units to go into unoccupied mode (which requires lower airflow rates) during scheduled “occupied” hours when no occupancy is detected. The retro-commissioning found that there were 17 terminal unit boxes that were in occupied mode 24/7.

2. **Building 2, Laboratory Building - Condenser Water Reset**

   This measure consisted of 5 measures affecting a chilled water plant, but only the condenser water reset measure was in scope for the evaluation. The identified RCx opportunity that was identified and fixed was that the condenser water supply temperature setpoint was 75° F, even though the programming had condenser water supply temperature setpoint calculation of CWST = max(min(OA WB + 7° F, 85° F), 65° F). The measure involves rewriting the programming to ensure condenser water reset is occurring. The chiller plant consists of (3) chillers.

3. **Building 3, Medical Education Building - Reduce Supply and Exhaust Fan Airflow During Unoccupied Hours**

   This measure involves putting the supply fans and exhaust fans into standby mode during unoccupied hours. The tracking calculations assume a 15% reduction in airflow during the eight hours per day that the building is unoccupied. The measure description states that there are four 20 HP supply fans in a fan wall configuration that are rated at 8,000 CFM each, and two 50 HP, 32,000 CFM exhaust fans. All the fans are controlled by VFDs.

4. **Building 4, Dining Hall - Add Scheduling Controls to AHU-1**

   The tracking calculations indicate that the 3 HP supply fan ran in occupied mode 8760 hours/year in the baseline and runs during occupied hours for 5,904 hours/year in the post-case.

5. **Building 5, Office Building - Integrate VRF with BAS for Scheduling Control**

   The tracking documentation indicates that this measure involves connecting the variable refrigerant flow (VRF) unit at this building to the campus BAS, which allows scheduling and setback controls. There are (2) 4-ton VRF units that serve this small 2-story, 6,640 ft^2 office building, of which 5,030 ft^2 is cooled.

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.

Applicant Baseline and Installed Key Parameters

The applicant classified all the measures as a retrofit with a single baseline.

Building 1, Laboratory Building - New Occ Sensors and Scheduling Controls

Table 5-21 and Table 5-22 show the key variables used in the tracking calculations for the fan reduction portion of the measure. The fan reduction portion of the measure accounts for 94% of the claimed savings, while the cooling portion makes up 6% of the claimed savings for this measure. Because the cooling savings are much lower,only the key parameters for the fan portion of the claimed savings are shown. More detail and discussion of the values shown in Table 5-21 and Table 5-22 are provided below these tables.

Table 5-21. Baseline and proposed key values used in tracking calculations

Parameter Name	Baseline Value	Proposed Value
AHU-1, EAHU1&2, EF 1-4 Fan Occupied Hours	5,475	4,380
AHU-1, EAHU1&2, EF 1-4 Fan Unoccupied Hours	3,285	3,285
AHU-1, EAHU1&2, EF 1-4 Fan Standby Hours	0	1,095

AHU-1 Fan Occupied Weighted Average kW	75.6	75.6
AHU-1 Fan Unoccupied Weighted Average kW	56.5	47
AHU-1 Fan Standby Weighted Average kW	0	0
EAHU1&2 Fan Occupied Weighted Average kW	2.9	2.9
EAHU1&2 Fan Unoccupied Weighted Average kW	3.1	3.1
EAHU1&2 Fan Standby Weighted Average kW	0	0
EF 1-4 Fan Occupied Weighted Average kW	56	56
EF 1-4 Fan Unoccupied Weighted Average kW	56	56
EF 1-4 Fan Standby Weighted Average kW	0	0
AHU-1 Fan Occupied Weighted Average CFM	58,586	58,586
AHU-1 Fan Unoccupied Weighted Average CFM	51,731	47,612
AHU-1 Fan Standby Weighted Average CFM	0	0
EAHU1&2 Fan Occupied Weighted Average CFM	66,602	66,602
EAHU1&2 Fan Unoccupied Weighted Average CFM	66,602	66,602
EAHU1&2 Fan Standby Weighted Average CFM	0	0
EF 1-4 Fan Occupied Weighted Average CFM	66,602	66,602
EF 1-4 Fan Unoccupied Weighted Average CFM	66,602	66,602
EF 1-4 Fan Standby Weighted Average CFM	0	0
AHU-1 Fan Total Static Pressure (in. w.c)	7.2	7.2
EAHU1&2 Total Static Pressure (in. w.c.)	0.4	0.4
EF 1-4 Total Static Pressure	4	4
Fan Efficiency (AHU-1, EAHU1&2, EF1-4)	0.6	0.6
Motor Efficiency (AHU-1, EAHU1&2, EF1-4)	0.93	0.93

Table 5-22. Baseline and proposed energy use by occupancy mode and fan according to tracking calculations

Parameter Name	Baseline Value	Proposed Value
AHU-1 Fan Occupied Annual kWh	413,656	330,925
AHU-1 Fan Unoccupied Annual kWh	185,678	154,428
AHU-1 Fan Standby Annual kWh	0	0

AHU-1 Fan kWh	**599,334**	**485,352**
EAHU1&2 Fan Occupied Annual kWh	15,606	12,485
EAHU1&2 Fan Unoccupied Annual kWh	10,210	10,210
EAHU1&2 Fan Standby Annual kWh	0	0
EAHU1&2 Fan kWh	**25,816**	**22,695**
EF 1-4 Fan Occupied Annual kWh	306,798	245,438
EF 1-4 Fan Unoccupied Annual kWh	184,079	184,079
EF 1-4 Fan Standby Annual kWh	0	0
EF 1-4 Fan kWh	**490,876**	**429,517**
Total kWh	**1,116,026**	**937,564**
Total Fan Savings	**-**	**178,462**

The tracking calculations split the fan-saving calculations associated with the exhaust fans into two groups, one group represented by what they call "EAHU1&2", and another group by what they call "EF 1-14". However, this is all the same equipment. There are two exhaust fans (EF-1 and EF-2) that move air through EAHU-1 and two exhaust fans (EF-3 and EF-4) that move air through EAHU-2. Evidently the tracking calculations stated, "EF 1-14", when they really meant "EF 1-4", since other documentation clearly states that EF 1-4 are associated with EAHU1&2.

The tracking calculations also used the term "standby hours" to identify hours in the baseline "occupied" hours of 7 AM to 10 PM that could potentially be classified as "unoccupied hours" once occupancy sensors are installed. There appears to be an inconsistency however with their introduction of this term that caused an overestimation of the savings for this measure. In neither the baseline nor proposed calculations does the bin spreadsheet assume that the kW associated with the supply and exhaust fans goes to zero during unoccupied hours. This makes sense because laboratories generally store chemicals that still require mechanical ventilation even when no one is present to ensure that the concentration of hazardous gasses never reaches a critical toxicity level. The calculations, however, introduce the term standby hours as 20% of the baseline occupied hours and show that for these 1,095 standby hours in the post-case, the entire ~75 kW of supply fan kW goes to zero, which does not seem likely to the evaluator based on this preliminary review. Forty-four percent of the savings for this measure come from this portion of the calculations for this measure.

Building 2, Laboratory Building - Condenser Water Reset

Table 5-23 shows a summarized list of the key baseline and post tracking values. For chillers 1 and 2, the savings are being driven by the assumption that for every 1° F decrease in the LCWT, there is a 1% decrease in kW consumption. For chiller 3, the reduction of the savings is based on the chiller performance data from the manufacturer, who provides chiller efficiency data at various loading values, and various condenser water temperature values.

Table 5-23. Key base and post tracking values

Variable	Base value	Post value	Savings %
Chiller 1 average power consumption (kW)	166	157	5.0%
Chiller 2 average power consumption (kW)	156	148	5.2%
Chiller 3 average power consumption (kW)	51	46	9.5%
Chiller 1 annual runtime (hours)	4,381	4,381	0.0%
Chiller 2 annual runtime (hours)	4,556	4,556	0.0%
Chiller 3 annual runtime (hours)	2,054	2,054	0.0%

Chiller 1 annual energy use (kWh)	725,741	689,428	5.0%
Chiller 2 annual energy use (kWh)	711,981	674,647	5.2%
Chiller 3 annual energy use (kWh)	104,484	94,591	9.5%
Total annual energy use (kWh)	1,542,205	1,458,665	5.4%
Total annual energy savings (kWh)		83,540	5.4%

Building 3, Medical Education Building - Reduce Supply and Exhaust Fan Airflow During Unoccupied Hours

Table 5-24, Table 5-25, and Table 5-26 show the key baseline and post-case parameters for the “reduce supply fan and exhaust fan airflow rate by 15% during unoccupied hours” measure.

Table 5-24. Key base and post tracking values for supply fan portion of savings

Variable	Base value	Post value
Supply fan quantity	4	4
Supply fan nameplate airflow per fan (CFM)	8,000	8,000
Supply fan nameplate horsepower per fan (hp)	20	20
Suppply fan occupied brake horsepower per fan (hp)	13.2	13.2
Suppply fan unoccupied brake horsepower per fan (hp)	13.2	8.1
Supply fan occupied input power per fan (kW)	9.85	9.85
Supply fan unoccupied input power per fan (kW)	9.85	6.04
Supply fan occupied annual runtime (hours)	8760	5840
Supply fan unoccupied annual runtime (hours)	0	2920
Supply fan annual energy use (kWh)	115,054	70,601
Supply fan energy savings (kWh)		44,453

Table 5-25. Key base and post tracking values for exhaust fan portion of savings

Variable	Base value	Post value
Exhaust fan quantity	2	2
Exhaust fan nameplate airflow per fan (CFM)	32,000	32,000
Exhaust fan nameplate horsepower per fan (hp)	50	50
Exhaust fan occupied brake horsepower per fan (hp)	41.2	41.2
Exhaust fan unoccupied brake horsepower per fan (hp)	41.2	25.3
Exhaust fan occupied input power per fan (kW)	30.74	30.74

Exhaust fan unoccupied input power per fan (kW)	30.74	18.88
Exhaust fan occupied annual runtime (hours)	8760	5840
Exhaust fan unoccupied annual runtime (hours)	0	2920
Exhaust fan annual energy use (kWh)	89,765	55,130
Exhaust fan annual energy savings (kWh)		34,635

Table 5-26. Key base and post tracking values for cooling portion of savings

Variable	Base value	Post value
Supply fan total outdoor airflow rate during unoccupied hours (CFM)	32,000	27,200
Average outdoor air enthalpy (Btu/lb)	27.472	27.472
Average supply air enthalpy during cooling mode (Btu/lb)	21.5	21.5
Cooling system efficiency (kW/ton)	0.80	0.80
Annual cooling hours during unoccupied hours (hours)	792	792
Air density (lb/ft^3)	0.075	0.075
Minutes per hour conversion factor	60	60
Btus per ton conversion factor	12,000	12,000
Annual cooling energy usage (kWh)	45,406	38,595
Annual cooling savings		6,811

Building 4, Dining Hall - Add Scheduling Controls to AHU-1

Table 5-27 shows the key baseline and post tracking values for the “add scheduling to 3 HP supply fan” measure. Note the difference between the 3 HP cited in the name of the measure, and the 5 HP used in the calculations, which was attributed to a 2-hp return fan. A photo in the project documentation indicated that the supply fan was indeed 3 HP but there was no evidence of a return fan. The evaluation will confirmed there was noreturn fan which was scheduled along with this 3 HP supply fan.

Table 5-27. Key base and post tracking values for add scheduling to 3 HP supply fan measure

Variable	Base value	Post value
Supply and Return Fan HP	5	5
Occupied Fan kW	3.41	3.41
Unoccupied Fan kW	3.41	1.02
Occupied Fan Annual Hours	8760	5,904
Unoccupied Fan Annual Hours	0	2,856
Fan Occupied Energy Use (kWh)	29,874	20,134
Fan Unoccupied Energy Use (kWh)	0	2922
Fan Total Energy Use (kWh)	29,874	23,056
Fan Energy Savings (kWh)		6,818

Cooling System Efficiency (kW/ton)	1.2	1
Cooling System Annual Operating Hours	1,449	1,142
Cooling Weighted Average Outdoor Air Temperature (°F) During Operating Hours	77	79
Cooling Supply Air Temperature (°F)	58	58
Cooling System Average ∆T (°F)	19	21
Cooling Outdoor Airflow (CFM)	600	600
Cooling System Energy Use (kWh)	1,807	1,550
Cooling System Savings (kWh)		257
Fan and Cooling Energy Use (kWh)	31,681	24,606
Fan and Cooling Energy Savings (kWh)		7,075

Building 5, Office Building - Integrate VRF with BAS for Scheduling Control

The key parameters for this measure are shown in Table 5-28.

Table 5-28. Key variables for Integrate VRF with BAS for scheduling control measure

Variable	Value
Area of space served by VRF (ft^2)	5,030
Energy Savings per ft^2 (kWh/ft^2)	0.539
Energy Savings (kWh)	2,711

Applicant Energy Savings Algorithm

This section provides algorithms used in the applicant savings analysis files.

Building 1, Laboratory Building - New Occ Sensors and Scheduling Controls

Table 5-29 and Table 5-30 show the applicant baseline and post-case bin calculations for the fan savings portion of this measure, which makes up 94% of the total savings for this measure. Applicant algorithms for the cooling portion of the savings are not shown here due to budget considerations, and because the cooling portion makes up only 6% of the savings for this measure.

Table 5-29. Baseline applicant bin calculations for fan savings portion of project

OAT Average F (db)	Occupied Total Supply cfm	Occupied Exhaust Air cfm	Unoccupied Total Supply cfm	Unoccupied Exhaust Air cfm	Fans Occupied hrs/yr	Fans Occupied Supply Air kW	Fans Occupied EAHU-1&2 kW	Fans Occupied EF-1thru14 Air kW total	Fans Occupied kWH	Fans Unoccupied hrs/yr	Fans Unoccupied Supply Air kW	Fans Unoccupied EAHU-1&2 kW	Fans Unoccupied EF-1thru14 Air kW total	Fans Unoccupied Total kW	Fans Unoccupied kWH
	58,586	58,586	51,731			413,656	15,606	306,798			185,678	10,210	184,079		
AHU-1 a VAV Sched					AHU-1 & EAHU-1&2										
90	66,602	66,602	66,602	66,602	44	101.54	5.6	56.0	7,180	0	101.54	5.6	56.0	163.18	-
85	66,602	66,602	66,602	66,602	76	101.54	5.6	56.0	12,402	0	101.54	5.6	56.0	163.18	-
80	66,602	66,602	66,602	66,602	289	101.54	5.6	56.0	47,159	9	101.54	5.6	56.0	163.18	1,469
75	66,602	66,602	66,602	66,602	403	101.54	-	56.0	63,504	72	101.54	-	56.0	157.58	11,346
70	66,602	66,602	66,602	66,602	394	101.54	-	56.0	62,085	162	101.54	-	56.0	157.58	25,527
65	64,421	64,421	53,623	53,623	500	93.37	-	56.0	74,703	313	59.70	-	56.0	115.74	36,226
60	59,218	59,218	52,198	52,198	523	75.78	-	56.0	68,940	381	56.05	-	56.0	112.09	42,706
55	55,285	55,285	50,955	50,955	420	64.18	-	56.0	50,493	227	53.01	-	56.0	109.05	24,754
50	52,624	52,624	49,892	49,892	450	57.13	-	56.0	50,923	308	50.52	-	56.0	106.55	32,818
45	51,232	51,232	49,011	49,011	369	53.68	5.6	56.0	42,553	247	48.52	5.6	56.0	110.16	27,209
40	51,112	51,112	48,312	48,312	419	53.39	5.6	56.0	48,197	321	46.98	5.6	56.0	108.61	34,865
35	52,262	52,262	47,793	47,793	534	56.21	5.6	56.0	62,934	387	45.86	5.6	56.0	107.50	41,602
30	54,684	54,684	47,456	47,456	467	62.53	5.6	56.0	57,989	338	45.14	5.6	56.0	106.78	36,093
25	58,375	58,375	47,301	47,301	230	73.18	5.6	56.0	31,007	157	44.82	5.6	56.0	106.46	16,714
20	63,338	63,338	47,326	47,326	188	89.49	5.6	56.0	28,412	187	44.87	5.6	56.0	106.51	19,917
15	66,602	66,602	66,602	66,602	117	101.54	5.6	56.0	19,092	107	101.54	5.6	56.0	163.18	17,460
10	66,602	66,602	66,602	66,602	40	101.54	5.6	56.0	6,527	56	101.54	5.6	56.0	163.18	9,138
5	66,602	66,602	66,602	66,602	11	101.54	5.6	56.0	1,795	13	101.54	5.6	56.0	163.18	2,121
0	66,602	66,602	66,602	66,602	1	101.54	5.6	56.0	163	0	101.54	5.6	56.0	163.18	-
					5,475				736,060	3,285					379,966

Table 5-30 shows post-case applicant bin calculations for the fan savings portion of the project. While Table 5-30 shows some kW associated with the 1,095 "standby" hours, the final roll-up of the savings do not include this term, which essentially makes the kW associated with these 1,095 hours equal to zero.

Table 5-30. Post-case applicant bin calculations for fan savings portion of project

OAT Average Temp F (db)	Occupied Total Supply cfm	Occupied Exhaust Air cfm	Unoccupied Total Supply cfm	Unoccupied Exhaust Air cfm	Fans Occupied hrs/yr	Fans Occupied Supply Air kW	Fans Occupied EAHU-1&2 kW	Fans Occupied EF-1thru14 Air kW total	Fans Occupied kWH	Fans Unoccupied hrs/yr	Fans Unoccupied Supply Air kW	Fans Unoccupied EAHU-1&2 kW	Fans Unoccupied EF-1thru14 Air kW total	Fans Unoccupied kWH	Occ Sensor STBY hrs/yr	Occ Sensor STBY Supply Air kW	Occ Sensor STBY EAHU 1&2 kW	Occ Sensor STBY EF-1thru14 BHP total	Occ Sensor STBY EF-1thru14 Air kW total	Occ Sensor STBY kWH
	58,586		47,612			330,925	12,485	245,438			154,428	10,210	184,079			57,826	3,121		61,360	
AHU-1 VAV Sched					AHU-1 & EAHU-1&2															
90	66,602	66,602	62,483	62,483	35	101.54	5.6	56.0	5,744	0	86.51	5.6	56.0	-	9	86.51	5.6	69.9	56.0	1,304
85	66,602	66,602	62,483	62,483	61	101.54	5.6	56.0	9,921	0	86.51	5.6	56.0	-	15	86.51	5.6	69.9	56.0	2,252
80	66,602	66,602	62,483	62,483	231	101.54	5.6	56.0	37,727	9	86.51	5.6	56.0	1,333	58	86.51	5.6	69.9	56.0	8,563
75	66,602	66,602	62,483	62,483	322	101.54	-	56.0	50,803	72	86.51	-	56.0	10,263	81	86.51	-	69.9	56.0	11,489
70	66,602	66,602	62,483	62,483	315	101.54	-	56.0	49,668	162	86.51	-	56.0	23,092	79	86.51	-	69.9	56.0	11,233
65	64,421	64,421	49,504	49,504	400	93.37	-	56.0	59,763	313	49.63	-	56.0	33,073	100	49.63	-	69.9	56.0	10,566
60	59,218	59,218	48,079	48,079	418	75.78	-	56.0	55,152	381	46.47	-	56.0	39,056	105	46.47	-	69.9	56.0	10,722
55	55,285	55,285	46,836	46,836	336	64.18	-	56.0	40,394	227	43.85	-	56.0	22,675	84	43.85	-	69.9	56.0	8,391
50	52,624	52,624	45,773	45,773	360	57.13	-	56.0	40,738	308	41.71	-	56.0	30,106	90	41.71	-	69.9	56.0	8,797
45	51,232	51,232	44,892	44,892	295	53.68	5.6	56.0	34,042	247	40.00	5.6	56.0	25,105	74	40.00	5.6	69.9	56.0	7,501
40	51,112	51,112	44,193	44,193	335	53.39	5.6	56.0	38,558	321	38.69	5.6	56.0	32,205	84	38.69	5.6	69.9	56.0	8,407
35	52,262	52,262	43,674	43,674	427	56.21	5.6	56.0	50,347	387	37.74	5.6	56.0	38,459	107	37.74	5.6	69.9	56.0	10,613
30	54,684	54,684	43,337	43,337	374	62.53	5.6	56.0	46,391	338	37.13	5.6	56.0	33,384	93	37.13	5.6	69.9	56.0	9,225
25	58,375	58,375	43,182	43,182	184	73.18	5.6	56.0	24,806	157	36.85	5.6	56.0	15,463	46	36.85	5.6	69.9	56.0	4,531
20	63,338	63,338	43,207	43,207	150	89.49	5.6	56.0	22,730	187	36.90	5.6	56.0	18,427	38	36.90	5.6	69.9	56.0	3,705
15	66,602	66,602	62,483	62,483	94	101.54	5.6	56.0	15,274	107	86.51	5.6	56.0	15,852	23	86.51	5.6	69.9	56.0	3,467
10	66,602	66,602	62,483	62,483	32	101.54	5.6	56.0	5,222	56	86.51	5.6	56.0	8,296	8	86.51	5.6	69.9	56.0	1,185
5	66,602	66,602	62,483	62,483	9	101.54	5.6	56.0	1,436	13	86.51	5.6	56.0	1,926	2	86.51	5.6	69.9	56.0	326
0	66,602	66,602	62,483	62,483	1	101.54	5.6	56.0	131	0	86.51	5.6	56.0	-	0	86.51	5.6	69.9	56.0	30
					4,380				588,848	3,285				348,716	1,095					122,307

From Table 5-29 and Table 5-30 the savings for this measure are calculated using the formulas below:

$$Fan\ Energy\ Savings = Baseline\ Energy - Post\ Energy$$

$Baseline\ Fan\ Energy = Baseline\ Occupied\ Fan\ kWh + Baseline\ Unoccupied\ Fan\ kWh$

$Post\ Fan\ Energy = Post\ Occupied\ Fan\ kWh + Post\ Unoccupied\ Fan\ kWh$

Where,

$Baseline\ Occupied\ Fan\ kWh = 736{,}060\ kWh$

$Baseline\ Unoccupied\ Fan\ kWh = 379{,}966\ kWh$

$Post\ Occupied\ Fan\ kWh = 588{,}848\ kWh$

$Post\ Unoccupied\ Fan\ kWh = 348{,}716\ kWh$

And,

$Baseline\ Fan\ Energy = 736{,}060\ kWh +\ 379{,}966\ kWh = 1{,}116{,}026\ kWh$

$Post\ Fan\ Energy =\ 588{,}848\ kWh +\ 348{,}716\ kWh = 937{,}564$

And,

$Fan\ Energy\ Savings = 1{,}116{,}026\ kWh -\ 937{,}564 = 178{,}468\ kWh$

$Cooling\ Energy\ Savings = 10{,}813\ kWh$

$Total\ Energy\ Savings = 178{,}468\ kWh + 10{,}813\ kWh = 189{,}275\ kWh$

Building 2, Laboratory Building - Condenser Water Reset

The tracking savings used a 5° bin calculation for this measure. The following formulas describe the algorithms used in the tracking calculations. The regression equations for base chiller kW was based on trended kW data for chillers 1 and 2, and on trended tonnage data for chiller 3, combined with chiller efficiency values from the manufacturer. For chillers 1 and 2, the tracking calculations assumed a 1% chiller kW reduction improvement for each 1°F lower that the leaving condenser water temperature (LCWT) could be made, with the minimum LCWT set at 65° F. For chiller 3, the chiller efficiency values from the manufacturer at the lower LCWT values were used for the post case. The chiller on% values at each bin temperature was based on trended chiller status data.

$Annual\ Energy\ Savings = Baseline\ Energy - Post\ Energy$

$Baseline\ Energy = Chiller\ 1\ Base\ Energy + Chiller\ 2\ Base\ Energy + Chiller\ 3\ Base\ Energy$

$$Chiller\ 1\ Base\ Energy = \sum_{i=5°\ OA\ temp\ bin=30°}^{n=5°\ OA\ temp\ bin=\quad °} Chiller\ 1\ Base\ kW_i \times Chiller\ 1\ \%\ On_i \times Hours_i$$

$$Chiller\ 2\ Base\ Energy = \sum_{i=5°\ OA\ temp\ bin=\quad °}^{n=5°\ OA\ temp\ bin=95°} Chiller\ 2\ Base\ kW_i \times Chiller\ 1\ \%\ On_i \times Hours_i$$

$$Chiller\ 3\ Base\ Energy = \sum_{i=5°\ OA\ temp\ bin=25°}^{n=5°\ OA\ temp\ bin=65°} Chiller\ 3\ Base\ kW_i \times Chiller\ 1\ \%\ On_i \times Hours_i$$

$$Chiller\ 1\ Base\ kW_i = \begin{matrix} if\ OA\ temp\ bin \leq 45\ \rightarrow Chiller\ 1\ Base\ kW_i = 150\ kW \\ if\ OA\ temp\ bin > 45 \rightarrow\ Chiller\ 1\ Base\ kW_i = .6243 *\ OAT^2 - 5.6243 * OAT + 254.64 \end{matrix}$$

$$Chiller\ 2\ Base\ kW_i = \begin{matrix} if\ OA\ temp\ bin \leq 45\ \rightarrow Chiller\ 2\ Base\ kW_i = 150\ kW \\ if\ OA\ temp\ bin > 45 \rightarrow\ Chiller\ 2\ Base\ kW_i = 0.0147 * OAT^2 + 1.1237 * OAT + 13.268 \end{matrix}$$

$$Chiller\ 3\ Base\ kW_i = \begin{array}{l} if\ OA\ temp\ bin \leq 30\ \rightarrow Chiller\ 3\ Post\ kW_i = 16.2\ kW \\ if\ OA\ temp\ bin \leq 45\ \rightarrow Chiller\ 3\ Post\ kW_i = 0.4092 * OAT + 3.906 \\ if\ OA\ temp\ bin \leq 30\ \rightarrow Chiller\ 3\ Post\ kW_i = 10.066 * OAT - 273.58 \end{array}$$

$$Post\ Energy = Chiller\ 1\ Post\ Energy + Chiller\ 2\ Post\ Energy + Chiller\ 3\ Post\ Energy$$

$$Chiller\ 1\ Post\ Energy = \sum_{i=5°\ OA\ temp\ bin=35°}^{n=5°\ OA\ temp\ bin=\quad °} Chiller\ 1\ Post\ kW_i \times Chiller\ 1\ \%\ On_i \times Hours_i$$

$$Chiller\ 2\ Post\ Energy = \sum_{i=5°\ OA\ temp\ bin=3\quad °}^{n=5°\ OA\ temp\ bin=95°} Chiller\ 2\ Post\ kW_i \times Chiller\ 1\ \%\ On_i \times Hours_i$$

$$Chiller\ 3\ Post\ Energy = \sum_{i=5°\ OA\ temp\ bin=\quad °}^{n=5°\ OA\ temp\ bin=\quad °} Chiller\ 3\ Post\ kW_i \times Chiller\ 1\ \%\ On_i \times Hours_i$$

$$Chiller\ 1\ Post\ kW_i = \begin{array}{l} if\ OA\ temp\ bin \leq 45\ \rightarrow Chiller\ 1\ Post\ kW_i = 150\ kW \\ if\ OA\ temp\ bin > 45 \rightarrow\ Chiller\ 1\ Post\ kW_i = Chiller\ 1\ Base\ kW_i \times (1 - Chiller\ Factor_i) \end{array}$$

$$Chiller\ 2\ Post\ kW_i = \begin{array}{l} if\ OA\ temp\ bin \leq 45\ \rightarrow Chiller\ 2\ Post\ kW_i = 150\ kW \\ if\ OA\ temp\ bin > 45 \rightarrow\ Chiller\ 2\ Post\ kW_i = Chiller\ 2\ Base\ kW_i \times (1 - Chiller\ Factor_i) \end{array}$$

$$Chiller\ 3\ Post\ kW_i = \begin{array}{l} if\ OA\ temp\ bin \leq 30\ \rightarrow Chiller\ 3\ Post\ kW_i = 14.8\ kW \\ if\ OA\ temp\ bin \leq 45\ \rightarrow Chiller\ 3\ Post\ kW_i = 0.3751 * OAT + 3.5805 \\ if\ OA\ temp\ bin \leq 30\ \rightarrow Chiller\ 3\ Post\ kW_i = 9.0596 * OAT - 246.22 \end{array}$$

$$Chiller\ Factor_i = 0.01\ \times (Existing\ LCWT\ -\ Post\ LCWT)$$

$$Existing\ LCWT = \begin{array}{l} if\ OA\ dry\ bulb\ \ Temp\ bin < 85 \rightarrow Existing\ LCWT = 75°\ F \\ if\ OA\ dry\ bulb\ \ Temp\ bin\ \geq 85 \rightarrow Existing\ LCWT = OA\ Wet\ Bulb\ Temp + 7°\ F \end{array}$$

$$Post\ LCWT = \begin{array}{l} if\ OA\ dry\ bulb\ \ Temp\ bin < 70 \rightarrow Existing\ LCWT = 65°\ F \\ if\ OA\ dry\ bulb\ \ Temp\ bin\ \geq 70 \rightarrow Existing\ LCWT = OA\ Wet\ Bulb\ Temp + 7°\ F \end{array}$$

Table 5-31 shows the $Hours_i$ and Chiller $On\%_i$ Values by 5° F dry-bulb temperature bin that were used in the tracking calculations. The hours column is based on the local TMY3 file, and the chiller on% columns are based on trended data. The trended data that this table was developed from was not included in the documentation provided.

Table 5-31. $Hours_i$ and Chiller $On\%_i$ Values by 5° F dry-bulb temperature bin

OAT (°F)	Hours	Ch1 On%	Ch2 On%	Ch3 On%
95	44	100%	100%	0%
90	76	98%	98%	0%
85	298	97%	93%	0%
80	475	90%	93%	0%
75	556	93%	94%	0%
70	813	83%	90%	0%
65	904	82%	92%	1%
60	647	87%	93%	5%
55	758	79%	85%	12%
50	616	62%	60%	22%
45	740	3%	1%	34%
40	921	2%	0%	53%
35	805	2%	0%	54%
30	387	1%	0%	53%
25	375	0%	0%	60%
20	224	0%	0%	56%

15	96	0%	0%	47%
10	24	0%	0%	47%
5	1	0%	0%	47%
Total	**8,415**			

Table 5-32 shows the chiller base and post kW values, and the total kWh savings by 5° F dry-bulb temperature bin as calculated using the algorithms described above. The raw trended data that was used to develop the regression relationships shown in the algorithms above, and used to produce the values in Table 5-32 were not included in the tracking documentation made available to the evaluator.

Table 5-32. Chiller base and post kW values, and total kWh savings by 5° F dry-bulb temperature bin

OAT (°F)	Ch1 Base kW	Ch2 Base kW	Ch3 Base kW	Ch1 Post kW	Ch2 Post kW	Ch3 Post kW	kWh Savings
95	283.8	252.7	0.0	283.8	252.7	0.0	0
90	254.1	233.5	0.0	254.1	233.5	0.0	0
85	227.6	215.0	0.0	227.6	215.0	0.0	0
80	204.2	197.2	0.0	203.3	196.3	0.0	817
75	184.0	180.2	0.0	179.5	175.8	0.0	4,614
70	166.8	164.0	0.0	157.7	155.0	0.0	12,776
65	152.8	148.4	380.7	137.5	133.6	342.7	24,133
60	141.9	133.6	330.4	127.7	120.2	297.4	17,141
55	134.2	119.5	280.1	120.7	107.6	252.1	18,219
50	129.5	106.2	229.7	129.5	106.2	206.8	3,063
45	150.0	150.0	22.3	150.0	150.0	20.5	466
40	150.0	150.0	20.3	150.0	150.0	18.6	825
35	150.0	150.0	18.2	150.0	150.0	16.7	656
30	150.0	0.0	16.2	150.0	0.0	14.8	278
25	0.0	0.0	16.2	0.0	0.0	14.8	305
20	0.0	0.0	16.2	0.0	0.0	14.8	170
15	0.0	0.0	16.2	0.0	0.0	14.8	61
10	0.0	0.0	16.2	0.0	0.0	14.8	15
5	0.0	0.0	16.2	0.0	0.0	14.8	1
						Total	**83,540**

Table 5-33 shows the base and post LCWT values, delta LCWT, and the chiller kW factor for chillers 1 and 2 for the outdoor air temperature bins where chillers 1 and 2 operate. These values are calculated per the algorithms above. The Chiller kW Factor is essentially the savings factor that gets applied and is based on the assumption of there being a 1% efficiency improvement for every 1° F decrease in LCWT.

Table 5-33. Base and post LCWT values, delta, and the chiller kW Factor for chillers 1 and 2

OA DB Temp °F	OA WB Temp °F	Base LCWT	Post LCWT	[Base LCWT] - [Post LCWT]	Chiller kW Factor
95	74	81	81	0	0%
90	73	80	80	0	0%
85	69	76	76	0	0%
80	68	75	75	0	0%
75	66	75	73	2	2%

70	63	75	70	5	5%
65	57	75	65	10	10%
60	52	75	65	10	10%
55	48	75	65	10	10%

Building 3, Medical Education Building - Reduce Supply and Exhaust Fan Airflow During Unoccupied Hours

The tracking savings calculations were described in a word document. The formulas used to develop the tracking savings are described here. The calculations show that the supply and exhaust fan speed is being reduced from 100% speed to 85% speed for 2920 hours per year.

AHU-1

1. 4 supply fans in the fan wall are currently operating at ~4200 cfm each and the common VFD output is ~50%. 4 x 4200 = 16,800 cfm; total fan capacity is rated at 32,000 cfm.
2. Each SF motor is 20 hp, 13.2 max bhp.
3. Design DA-T is 52F, unit is currently set to operate at 55F
4. The operational sequence states that the use of the heat recovery coil (HRC) during the summer is "unless cooling recovery is desired." (If not desired, then the flow is bypassed around the HRC in both the OA and EA ducts). Trends indicate that it does operate in the summer. However, the bypass damper position is not stable. They are capable of modulation. The sequence states that the bypass damper position is controlled by the DA-T. When HR-T < 35F, the bypasses fully open to prevent frosting the coil.

EAHU-1

1. Two Strobic exhaust fans, each rated 32,000 cfm, each 50 hp and 41.2 bhp.
2. Current trends indicate that EFs are manually rotated. Lead-lag is not automatically implemented. When either fan runs, VFD-O is at 100%. Trends indicate airflow is ~32,500cfm. Note: total SF indicates 16,800 cfm ≠ total EF of 32,500 cfm

SAVINGS AND ASSUMPTIONS

1. Total savings = supply fan electrical + exhaust fan electrical + OA cooling
2. Assuming we can reduce fan speed at least 15% during unoccupied periods, and that unoccupied periods are at least 8 hours/day (average).
3. Assuming Δh = average enthalpy above 25 Btu/lb over 2376 hrs/yr cooling season = 6 Btu/lb air. Assuming cooling plant efficiency of 0.8 kW/ton.

<u>Supply Fan Electrical</u>
$P_1 / P_2 = (N_1 / N_2)^3$ where P_1 = 13.2 bhp and $N_2 = N_1 \times 0.85$, then
P_2 = 8.1 hp, a savings of (13.2 – 8.1) = 5.1 hp
(5.1 hp) (0.746 kW/hp) (8 hrs/day) (365 days/yr) = 11,113 kWh/yr
There are 4 supply fans, so total is **44,454 kWh/yr**
<u>Exhaust Fan Electrical</u>
$P_1 / P_2 = (N_1 / N_2)^3$ where P_1 = 41.2 bhp and $N_2 = N_1 \times 0.85$, then
P_2 = 25.3 hp, a savings of (41.2 – 25.3) = 15.9 hp
(15.9 hp) (0.746 kW/hp) (8 hrs/day) (365 days/yr) = **34,635 kWh/yr**
Only one exhaust fan operates at a time,

<u>OA Cooling</u>
Q = 4.5 CFM Δh = 4.5 (32,000 x .15) x (6 Btu/lb air) = 129,600 Btu/hr
(2376 hrs/yr) x (8 hrs/24 hrs) = 792 hrs/yr
129,600 Btu/hr x 792 hrs/yr x (ton/12,000 Btu/hr) x (0.8 kW/ton) = **6811 kWh/yr**

SUMMARY
44,454 + 34635 + 6811 = **85,900 kWh/yr** (fan electrical and cooling)

This is for a 15% reduction in OA during unoccupied periods.

Building 4, Dining Hall - Add Scheduling Controls to AHU-1

The applicant equations and key parameters for this measure are as follows:

Baseline Occupied Fan kW = 3.41 kW

Baseline Occupied Fan Operating hours = 8,760 hours/year

Baseline Occupied Fan Energy = 29,874 kWh

Post Occupied Fan kW = 3.41 kW

Post Occupied Fan Operating hours = 5,904 hours/year

Post Occupied Fan kWh = 20,134 kWh

Post Unoccupied Fan kW = 1.02 kW

Post Unoccupied Fan Operating Hours = 2,856 hours/year

Post Unoccupied Fan kWh = 2,922 kWh

Fan Energy Savings = 29,874 kWh - (20,134 kWh + 2,922 kWh) = 6,818 kWh

Baseline Cooling Energy = (1.08 x OA CFM x (OAT - SAT) x 1.2 kW/ton / 12,000 Btuh/ton x 1,449 hours/year = 1,807 kWh

Post Cooling Energy = 1.08 x OA CFM x (OAT - SAT) x 1.2 kW/ton / 12,000 Btuh/ton x 1,142 hours/year = 1,550 kWh

Cooling Energy Savings = 1,807 kWh - 1,505 kWh = 257 kWh

Total Savings = 6,818 Fan kWh Savings + 257 Cooling kWh Savings = 7,075 kWh

OAT is based on an 8,760 TMY3 file

SAT is set at 58° F

OA CFM is 10% of 6,000 CFM (indicated as rated CFM of fan), which is 600 CFM. It is 600 CFM during occupied times (8,760 hours/year in baseline, and 0 CFM during unoccupied times (in the post-case).

Building 5, Office Building - Integrate VRF with BAS for Scheduling Control

The tracking calculations referred to the RI TRM to estimate the savings for this measure based on the “HVAC – Programable Thermostat” measure.

The algorithm used was:

Energy Savings = 5,030 ft^2 x 0.539 kWh/ft^2

Where the 5,030 ft^2 is the area of the conditioned space served by the VRF unit, and the 0.539 kWh/ft^2 comes from the RI TRM. Figure 5-1 shows a screenshot from the RI TRM where the 0.539 kWh/ft^2 value came from.

Figure 5-1. Screenshot from RI TRM, the source of the 0.539 kWh/ft^2 value

Savings Factors (Save)[531]

Equipment Type	$SAVE_{kWh}$ (kWh/SQFT)	$SAVE_{kW}$ (kW/SQFT)
Cool Only No Existing Control	0.539	0.00
Cool Only Erratic Existing Control	0.154	0.00
Heat Only No Existing Control	0.418	0.00
Heat Only Erratic Existing Control	0.119	0.00
Cool and Heat No Existing Control	0.957	0.00
Cool and Heat Erratic Existing Control	0.273	0.00
Heat Pump No Existing Control	0.848	0.00
Heat Pump Erratic Existing Control	0.242	0.00

Evaluation Assessment of Applicant Methodology

The evaluator assessment of the applicant methodology described below for each measure:

1. **Building 1, Laboratory Building - New Occ Sensors and Scheduling Controls**

The tracking calculations use the term "standby hours" to identify hours in the baseline "occupied" hours of 7 AM to 10 PM that could potentially be classified as "unoccupied hours" once occupancy sensors are installed. The introduction of this term caused an overestimation of the savings for this measure. In neither the baseline nor proposed calculations does the bin spreadsheet assume that the kW associated with the supply and exhaust fans goes to zero during unoccupied hours. This makes sense because laboratories generally store chemicals that still require mechanical ventilation even when no one is present to ensure that the concentration of hazardous gasses never reaches a critical toxicity level. The calculations introduce the term "standby hours" which are estimated at 20% of the baseline occupied hours the tracking calculations erroneously did not roll-up the kW associated with these hours, even though estimates had been made for the kW usage draw during this time period. Sixty percent of the claimed savings for this measure come from this error.

2. **Building 2, Laboratory Building - Condenser Water Reset**

The evaluator finds that the calculation method used to estimate the claimed tracking savings are acceptable.

3. **Building 3, Medical Education Building - Reduce Supply and Exhaust Fan Airflow During Unoccupied Hours**

The evaluator finds that the calculation method used to estimate the claimed tracking fan savings are acceptable. The evaluator finds that the tracking cooling savings may have overstated the number of hours that cooling savings may have occurred.

4. **Building 4, Dining Hall - Add Scheduling Controls to AHU-1**

The evaluator finds that the calculation method used to estimate the claimed tracking savings are adequate. The tracking savings only capture sensible cooling savings, and not latent cooling savings, so that is one small area for improvement.

5. **Building 5, Office Building - Integrate VRF with BAS for Scheduling Control**

The claimed tracking savings used a one line calculation based on a TRM savings factor for programmable thermostats, that gets applied to a building square footage. This approach is very rough and does not take into account any information about capacity, efficiency, or scheduling of the affected equipment.

Onsite Metering

This section provides details on the tasks performed during the onsite visit. DNV installed meters and conducted an onsite verification of the system installed. The following section provides a summary of the findings.

Summary of Onsite Findings

DNV interviewed the facility staff and verified the equipment installed onsite. DNV completed an initial site visit on 4/8/21 to visually verify and collect data on select measures.

Table 5-34 shows the verification method and result for each of the ten measures evaluated within this report.

Table 5-34. Measure Verification

Measure Name	Verification Method	Verification Result
1) Building 1, Laboratory Building - New Occ Sensors and Scheduling Controls	Take kW measurement of fans while simultaneously collecting trend data on speed and/or CFM from BAS to gather motor load factor data, and speed/cfm to kW relationship. Review baseline and post trend data available prior to COVID pandemic to see if fan usage	kW measurements were not possible due to not being able to turn off the fans since they served laboratory spaces, and the site contact would not allow installing the meters while "hot" because this equipment was large, and critical. The review of baseline and post case trended CFM data did show that CFM usage decreased significantly in the post case during unoccupied times and did not decrease significantly in the baseline case during unoccupied

	decreased after project during unoccupied times. Confirm installation of occupancy sensors. Confirm motor horsepower.	times, confirming the scheduling component of this measure. The occupancy sensors were confirmed through a review of the tracking documentation and from the interview with the site-contact. The motor HP values were confirmed.
2) Building 2, Laboratory Building - Condenser Water Reset	Install temperature loggers to collect condenser water supply and return temperatures, as well as outdoor air temperature/humidity sensor to confirm whether temperature reset measure is occurring.	The temperature data collected using the evaluator's temperature loggers was inconclusive. The temperature data from the BAS confirmed that the condenser water reset was occurring.
3) Building 3, Medical Education Building - Reduce Supply and Exhaust Fan Airflow During Unoccupied Hours	Take kW measurement of fans while simultaneously collecting trend data on speed and/or CFM from BAS to gather motor load factor data, and speed/cfm to kW relationship. Review baseline and post trend data available prior to COVID pandemic to see if fan usage decreased after project during unoccupied times. Confirm motor horsepower.	kW measurements were not possible due to not being able to turn off the fans since they served laboratory spaces, and the site contact would not allow installing the meters while "hot" because this equipment was large, and critical. The review of baseline and post case trended exhaust fan speed data did show that speed decreased significantly in the post case during unoccupied times, and did not decrease significantly in the baseline case during unoccupied times, confirming the scheduling component for the exhaust fans. The initial data reviewed had errors, but the site contact provided updated BAS trend data on the exhaust fans showing reduction from pre to post during unoccupied times. The updated data from the site contact on the supply fan did not show a similar reduction however for the month of September of 2017 (for which the exhaust fan data did show a reduction). The site contact provided data on the supply fan from July of 2017 which did show a reduction, however. Based on a review of all the available data, this measure is operating as indented.
4) Building 4, Dining Hall - Add Scheduling Controls to AHU-1	Take spot kW measurement of fan to gather motor load factor on this constant volume fan. Review baseline and post runtime data available from BMS from before pandemic. Confirm motor horsepower.	AHU-1 was found to have a 3 HP motor, as indicated in the tracking documentation. We took spot measurements and found that the average kW of the fan motor was 1.73 kW, which corresponds 2.1 HP. This corresponds to a motor load factor on the 3 HP motor of 70%. The tracking calculations show that there is a 3HP supply fan motor, along with a 2 HP return fan motor. We did not notice a 2 HP return fan motor during the site visit. We did however measure kW that fed the entire unit, when the DX compressors were off, so if there were a return fan, it would have been included in the 1.73 measured kW. A review of the trend data confirmed that the unit was shutting off during unoccupied times in the post-case.
5) Building 5, Office Building - Integrate VRF with BAS for	Install kW or amp loggers on VRF equipment. Review trend data in BMS to see if unit is being scheduled to go into unoccupied mode.	Found that there were two 4-ton (cooling) 4.5-ton (heating) VRF heat pump units serving this building, one serving the first floor, one serving the second floor. Installed amp logger on one unit, and kW logger on other unit, and temperature loggers on each floor. Review of the measured Amp data found that setback was not occurring. The site contact

Scheduling Control		reviewed the scheduling in the BAS and stated that "There are schedules in the system, but they appear to be scheduled as occupied 24/7", even though this building is not actually occupied 24/7.

Table 5-35 shows the loggers installed by the evaluators, the metering period, and the parameters they monitored.

Table 5-35. Evaluator Logger Information

Measure #	Data Logger Type	Parameter	Time Interval	Duration
2	HOBO Microstation	Condenser Water Supply Temperature, Return Temperature, Outdoor Air Temperature and Humidity	5-minutes	4/8/21 – 5/13/21
4	DENT ELITEPro XC	Fan Motor kW	1-second	~2 minutes
5	HOBO Energy Logger Pro	VRF 1 Amps	5-minutes	4/8/21 – 5/13/21
5	DENT ELITEPro XC	VRF 2 Amps, kW	5-minutes	4/8/21 – 5/13/21
5	HOBO Microstation	Indoor air temperature, floor 1	5-minutes	4/8/21 – 5/13/21
5	HOBO Microstation	Indoor air temperature, floor 2	5-minutes	4/8/21 – 5/13/21

Table 5-36 shows the trend data from the facility's BAS that was from before the COVID pandemic which were incorporated into the evaluator analyses and measure verifications.

Table 5-36. Trend Data Incorporated from Tracking Documentation

Measure #	Data Type	Parameter	Time Interval	Duration
1	BAS	AHU-1 Supply CFM	10-mintute	Baseline data from 9/9/12 – 12/1/12 Post data from 1/1/17 -7/21/17
1	BAS	AHU-1 Supply Amps	10-mintute	Post data from 1/1/17 -7/21/17
1	BAS	EAHU1&2 Exhaust CFM	10-mintute	Baseline data from 9/9/12 – 12/1/12 Post data from 1/1/17 -7/21/17
1	BAS	EAHU1&2 Exhaust Amps	10-mintute	Post data from 1/1/17 -7/21/17
2	BAS	CWST, CWRT, Cooling Tower 1-3 Status, Chiller 1-3 Status	10-mintute	Post data from 1/23/17 – 8/31/17
3	BAS	EF1&EF2 % Speed	10-mintute	Baseline Data from 9/1/16 – 9/31/16 Post data from 9/1/17-9/31/17
3	BAS	SF1-4 % Speed	10-mintute	Baseline Data from 9/1/16 – 9/31/16 Post data from 9/1/17-9/31/17
4	BAS	Supply Fan Status	Change of variable (COV)	Baseline data from 4/5/17 – 5/31/17

				Post data from 8/1/17 – 9/30/17

Building 1, Laboratory Building - New Occ Sensors and Scheduling Controls

Figure 5-2 shows the baseline occupied and unoccupied supply CFM data plotted against outdoor air temperature. This chart shows that in the baseline, there was not a large difference in CFM usage between occupied and unoccupied times. This means that there was hardly any unoccupied CFM setback in the baseline.

Figure 5-2. Baseline Occupied and Unoccupied Supply CFM vs. Outdoor Air Temperature

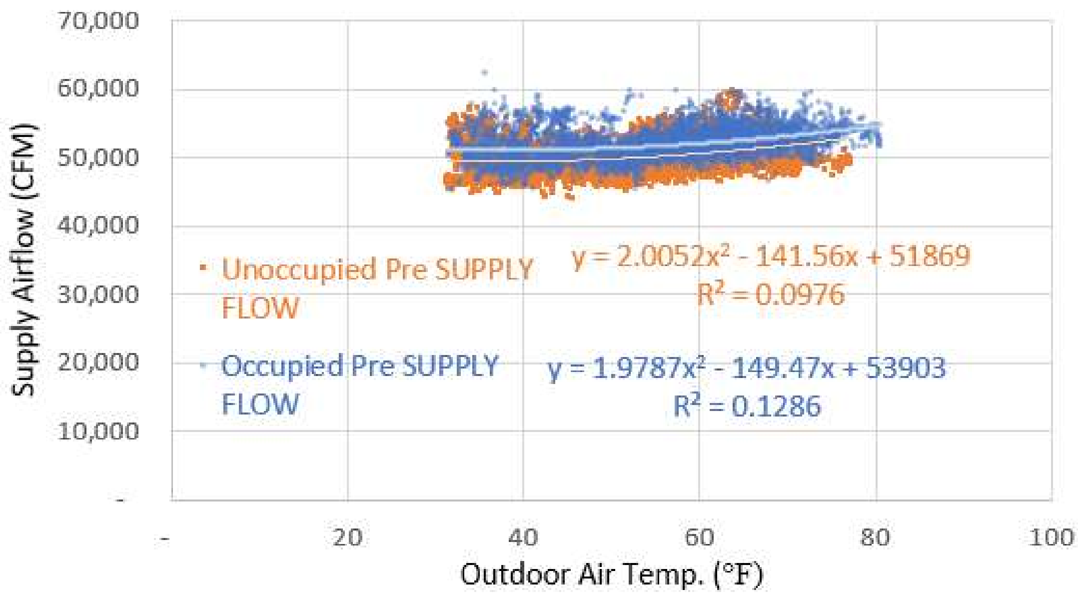


Figure 5-3 shows the post-case occupied and unoccupied supply CFM data plotted against outdoor air temperature. This chart shows that in the post-case, there was a large difference in CFM usage between occupied and unoccupied times. This is expected, and shows that the measure appears to have been effective at reducing airflow during unoccupied hours.

Figure 5-3. Post-case Occupied and Unoccupied Supply CFM vs. Outdoor Air Temperature

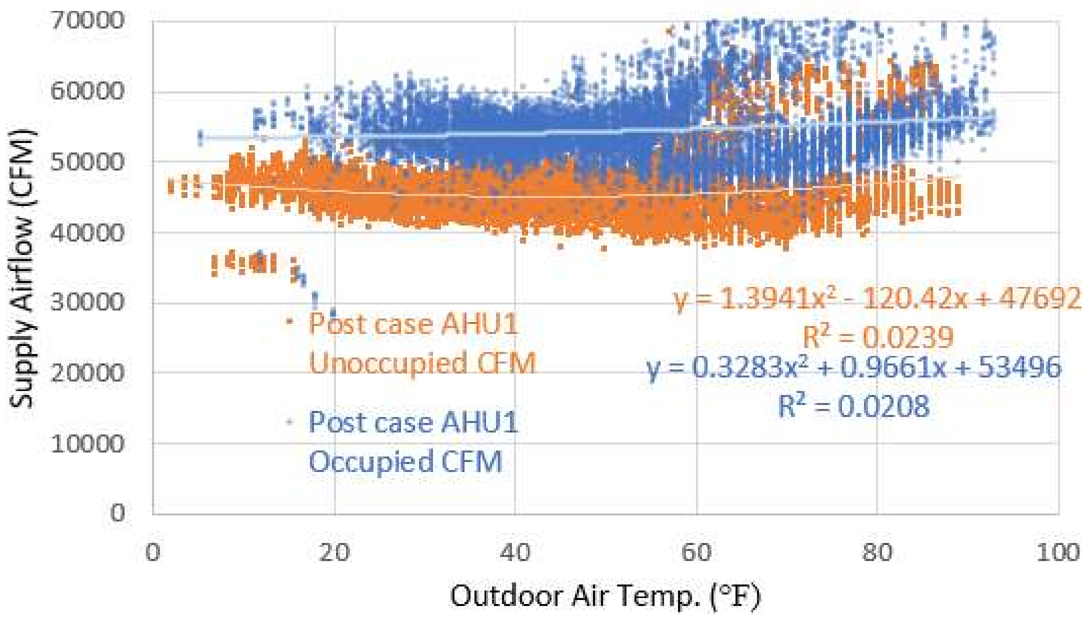


Figure 5-4 shows the post case supply fan kW plotted against the post-case supply fan CFM data, along with regression relationships between the two. This relationship was used to estimate the baseline kW, from the baseline CFM data, since baseline kW data was not available. The evaluator assumed that relationship between CFM and kW usage observed in the post case would also apply in the baseline, since the only changes to the system included adding unoccupied scheduling, which can reduce the airflow demand at the VAV boxes during unoccupied hours, and installing occupancy sensors to non-laboratory VAV boxes. The kW data was actually Amperage data from the BAS, converted to kW using 480 Volts, and a 1.0 power factor, since this equipment is on VFDs. VFDs have capacitors which make the power factor of the incoming power 1.0.

Figure 5-4. Post-case Supply Fan kW vs Post-Case Supply Fan CFM

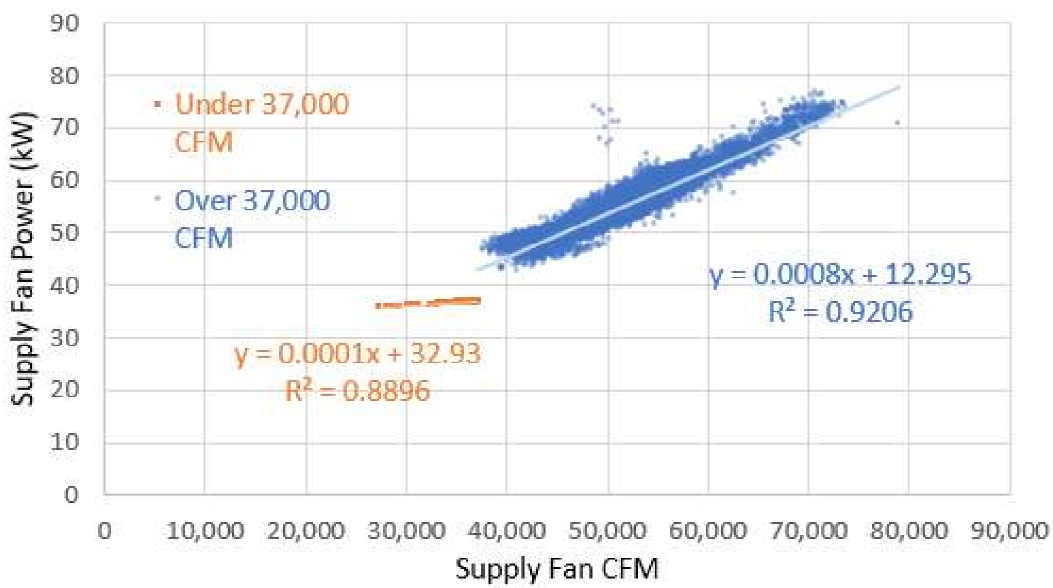


Figure 5-5 shows the post occupied and unoccupied exhaust CFM data plotted against outdoor air temperature. This data shows that in the post-case, there was not a large difference in CFM usage between unoccupied and occupied periods, like there was in the post-case supply fan CFM data (Figure 5-3). This was somewhat expected based on the tracking calculations however, since most of the fan savings as a result scheduling the VAV boxes to go into unoccupied mode during unoccupied hours from the tracking savings come from reductions to the supply fan, and not the exhaust fan.

Figure 5-5. Post Occupied and Unoccupied Exhaust CFM vs. Outdoor Air Temperature

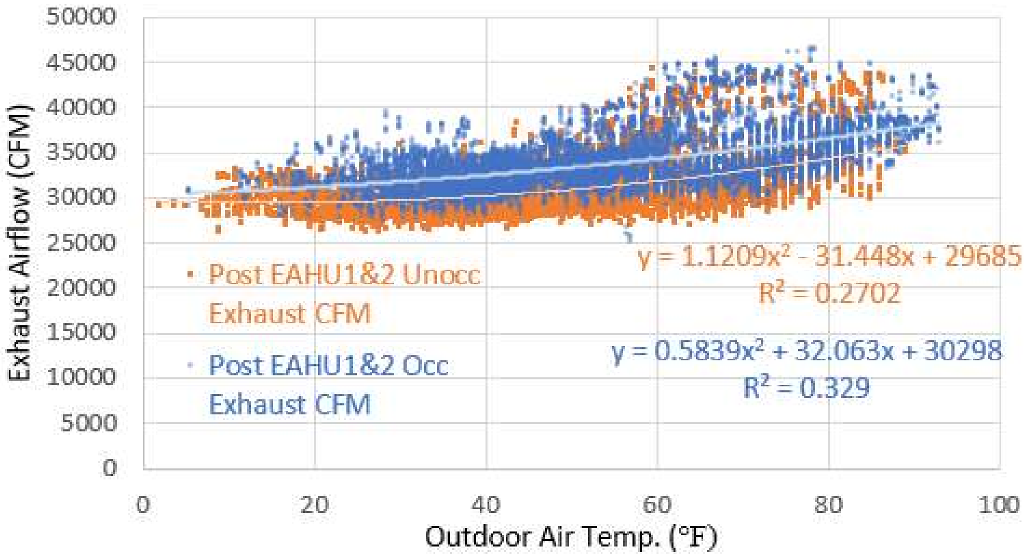


Figure 5-6 shows the post case exhaust fan CFM data plotted against the post-case supply fan CFM data. This chart was created because no baseline exhaust fan CFM data existed, only baseline supply fan data was available. Supply fan CFM and exhaust fan CFM are expected to track each other relatively closely in order to maintain necessary pressure differentials. This chart shows that supply and exhaust CFMs were tracking each other closely. With the regression below, the evaluator estimated the baseline exhaust fan CFM data from the baseline supply fan CFM data.

Figure 5-6. Post-case Exhaust Fan CFM vs Post-Case Supply Fan CFM

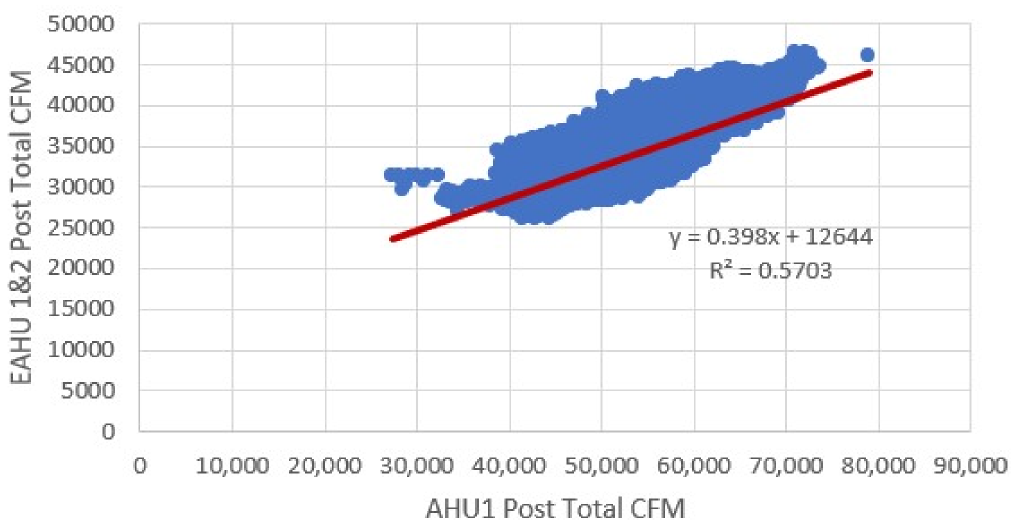
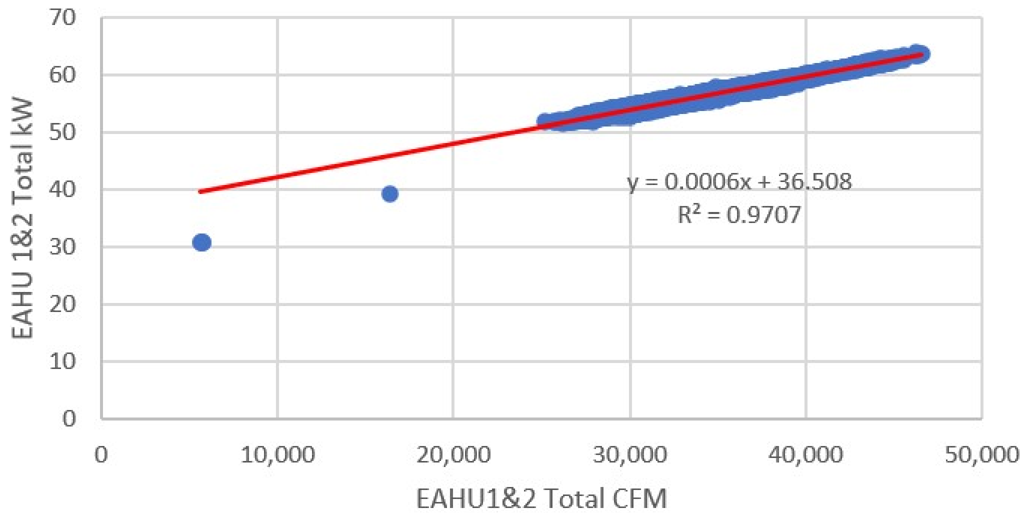


Figure 5-7 shows the post case exhaust fan kW plotted against the post-case exhaust fan CFM data, along with a regression relationship between the two. This relationship was used to estimate the baseline exhaust fan kW, from the baseline exhaust fan CFM data that was computed from the baseline supply fan CFM data and the regression relationship shown in Figure 5-6.

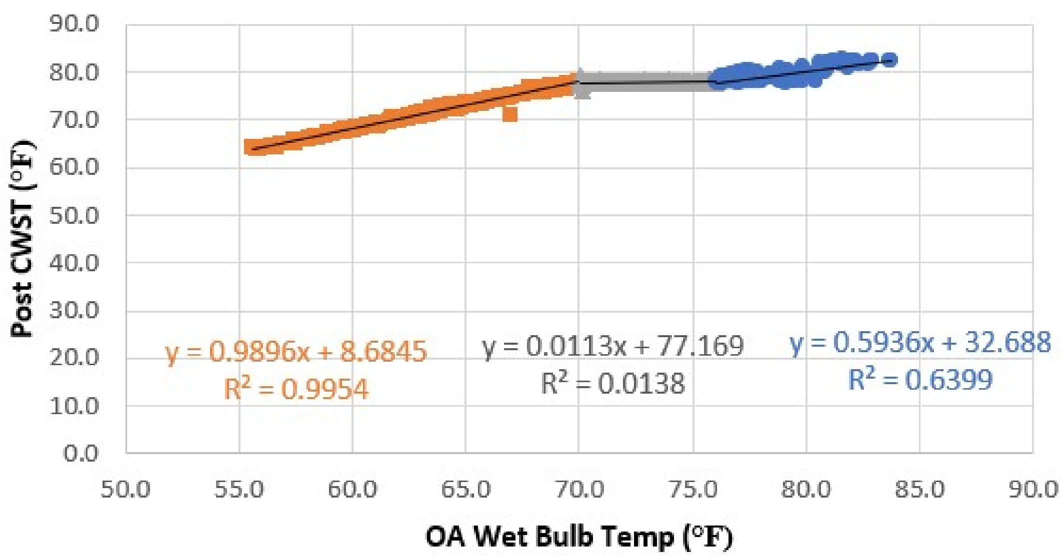
Figure 5-7. Post-case Exhaust Fan kW vs Post-Case Exhaust Fan kW



Building 2, Laboratory Building - Condenser Water Reset

Figure 5-8 shows the post-case condenser water supply temperature data from 1/24/17 to 8/31/17 plotted against the outdoor air wet bulb temperature. Figure 5-8 shows that the condenser water supply temperature is indeed resetting as a function of outdoor air wet-bulb temperature, as the measure intended.

Figure 5-8. Post-case condenser water supply temperature vs. outdoor air wet bulb temperature



The tracking documentation stated that the observed baseline condition was that the condenser water supply temperature setpoint was 75° F, even though the programming had condenser water supply temperature setpoint calculation of CWST = max(min(OA WB + 7° F, 85° F), 65° F). The documentation stated that several days were observed in the fall where the setpoint was either 65° or 85°, but for most of the time, the setpoint was fixed at 75° and was not resetting.

Building 3, Medical Education Building - Reduce Supply and Exhaust Fan Airflow During Unoccupied Hours

Figure 5-9 shows heat maps by day of week, and hour of the day, of the exhaust fan percent speed data. This data shows that the exhaust fans were indeed reduced during unoccupied hours.

Figure 5-9. Baseline, post-case, and percent reduction to exhaust fan speed

		Baseline EF Fan %Speed (9/1/16-9/31/16)							Post-case EF Fan %Speed (9/1/17-9/31/17)							EF Fan Speed Percent Savings						
		Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat
Hour	0	0.87	0.86	0.87	0.88	0.87	0.87	0.87	0.72	0.72	0.74	0.72	0.72	0.72	0.71	15%	14%	12%	15%	15%	15%	16%
	1	0.87	0.87	0.87	0.87	0.86	0.88	0.87	0.72	0.72	0.73	0.72	0.72	0.71	0.71	15%	15%	14%	15%	14%	17%	16%
	2	0.87	0.87	0.87	0.87	0.87	0.89	0.87	0.71	0.72	0.74	0.72	0.72	0.71	0.71	15%	14%	13%	14%	15%	18%	16%
	3	0.86	0.87	0.87	0.87	0.87	0.89	0.87	0.71	0.72	0.73	0.73	0.72	0.71	0.71	15%	14%	14%	14%	15%	18%	16%
	4	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.72	0.72	0.73	0.72	0.72	0.71	0.71	15%	14%	14%	14%	15%	17%	16%
	5	0.86	0.86	0.87	0.87	0.87	0.87	0.87	0.72	0.72	0.73	0.73	0.72	0.71	0.71	15%	14%	14%	14%	15%	16%	16%
	6	0.86	0.86	0.69	0.87	0.86	0.86	0.87	0.72	0.72	0.73	0.72	0.72	0.71	0.71	15%	14%	-4%	14%	14%	16%	16%
	7	0.87	0.87	0.65	0.86	0.86	0.87	0.87	0.86	0.87	0.85	0.88	0.85	0.84	0.85	1%	-1%	-20%	-2%	1%	3%	1%
	8	0.87	0.86	0.77	0.79	0.86	0.87	0.87	0.89	0.91	0.70	0.91	0.88	0.86	0.89	-2%	-5%	7%	-12%	-2%	1%	-2%
	9	0.87	0.88	0.89	0.65	0.87	0.90	0.88	0.90	0.92	0.93	0.93	0.88	0.88	0.89	-3%	-4%	-4%	-28%	-1%	2%	-1%
	10	0.88	0.88	0.89	0.65	0.89	0.89	0.90	0.91	0.92	0.92	0.92	0.90	0.89	0.90	-3%	-3%	-3%	-27%	-1%	0%	0%
	11	0.88	0.88	0.89	0.66	0.88	0.91	0.91	0.91	0.91	0.93	0.93	0.90	0.90	0.91	-3%	-3%	-4%	-27%	-2%	1%	0%
	12	0.89	0.88	0.89	0.67	0.88	0.90	0.91	0.91	0.89	0.93	0.94	0.89	0.90	0.91	-2%	-1%	-4%	-27%	-1%	-1%	0%
	13	0.89	0.88	0.89	0.75	0.88	0.90	0.89	0.89	0.88	0.90	0.91	0.88	0.91	0.88	0%	-1%	-2%	-16%	0%	-1%	1%
	14	0.89	0.87	0.88	0.92	0.88	0.89	0.87	0.87	0.88	0.91	0.90	0.87	0.89	0.86	2%	-1%	-3%	2%	1%	1%	1%
	15	0.89	0.86	0.88	0.90	0.87	0.88	0.87	0.88	0.87	0.91	0.88	0.87	0.88	0.86	1%	-1%	-3%	2%	0%	0%	0%
	16	0.88	0.86	0.87	0.88	0.87	0.87	0.87	0.88	0.87	0.91	0.88	0.87	0.89	0.86	1%	-1%	-4%	0%	0%	-1%	0%
	17	0.88	0.86	0.87	0.88	0.87	0.87	0.87	0.88	0.87	0.91	0.91	0.87	0.89	0.86	0%	0%	-4%	-3%	0%	-2%	0%
	18	0.88	0.86	0.87	0.87	0.87	0.87	0.87	0.88	0.87	0.91	0.89	0.87	0.89	0.87	-1%	0%	-4%	-2%	0%	-2%	0%
	19	0.88	0.86	0.87	0.87	0.87	0.87	0.87	0.77	0.75	0.77	0.85	0.82	0.80	0.77	11%	11%	10%	2%	4%	7%	10%
	20	0.87	0.86	0.87	0.87	0.87	0.87	0.88	0.75	0.72	0.88	0.81	0.80	0.78	0.73	11%	14%	-1%	6%	7%	9%	14%
	21	0.87	0.87	0.88	0.87	0.87	0.87	0.87	0.78	0.75	0.85	0.79	0.80	0.75	0.77	9%	12%	3%	8%	7%	13%	10%
	22	0.87	0.87	0.88	0.86	0.87	0.87	0.87	0.81	0.76	0.83	0.78	0.77	0.73	0.79	6%	11%	5%	8%	10%	14%	8%
	23	0.87	0.87	0.87	0.86	0.87	0.87	0.87	0.72	0.75	0.73	0.75	0.75	0.72	0.75	14%	11%	15%	11%	11%	15%	12%

Because this measure only is intended to save energy during unoccupied hours and should not have any impact on the occupied hours, as part of the evaluation, the evaluators created a post-normalized baseline heat map of the exhaust fan speeds and supply fan speeds. Figure 5-10 shows the same data, but with the baseline speeds adjusted in a way to be normalized to the post-case occupied data. Several outliers were also "smoothed" if they fell outside of the general pattern since these outliers would be expected to be diminished if an entire year of pre and post data were used instead of just one month. Figure 5-10 shows the adjusted savings for each hour of the day and day of the week shows that the savings for the occupied hours are now zero, whereas the unadjusted values were negative for the exhaust fans. Correspondingly, all the baseline unoccupied speed values were multiplied by 1.01 for the exhaust fans, because it appears that the post case occupied speeds (excluding outliers), were approximately 1.01 times higher than the base-case occupied periods.

Figure 5-10. Adjusted Baseline, post-case, and percent reduction to exhaust fan speed

Hour	Adjusted Baseline EF Fan %Speed (9/1/16-9/31/16)							Post-case EF Fan %Speed (9/1/17-9/31/17)							EF Fan Speed Percent Savings						
	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat
0	88%	87%	88%	89%	88%	88%	88%	72%	72%	74%	72%	72%	72%	71%	16%	15%	13%	16%	16%	16%	17%
1	88%	88%	88%	88%	87%	89%	88%	72%	72%	73%	72%	72%	71%	71%	16%	16%	15%	16%	15%	18%	17%
2	88%	88%	88%	88%	88%	90%	88%	71%	72%	74%	72%	72%	71%	71%	16%	15%	14%	15%	16%	19%	17%
3	87%	88%	88%	88%	88%	90%	88%	71%	72%	73%	73%	72%	71%	71%	16%	15%	15%	15%	16%	19%	17%
4	88%	88%	88%	88%	88%	88%	88%	72%	72%	73%	72%	72%	71%	71%	16%	15%	15%	15%	16%	18%	17%
5	87%	87%	88%	88%	88%	88%	88%	72%	72%	73%	73%	72%	71%	71%	16%	15%	15%	15%	16%	17%	17%
6	87%	87%	88%	87%	87%	87%	88%	72%	72%	73%	72%	72%	71%	71%	16%	15%	15%	15%	15%	17%	17%
7	86%	87%	85%	88%	85%	84%	85%	86%	87%	85%	88%	85%	84%	85%	0%	0%	0%	0%	0%	0%	0%
8	89%	91%	70%	91%	88%	86%	89%	89%	91%	70%	91%	88%	86%	89%	0%	0%	0%	0%	0%	0%	0%
9	90%	92%	93%	93%	88%	88%	89%	90%	92%	93%	93%	88%	88%	89%	0%	0%	0%	0%	0%	0%	0%
10	91%	92%	92%	92%	90%	89%	90%	91%	92%	92%	92%	90%	89%	90%	0%	0%	0%	0%	0%	0%	0%
11	91%	91%	93%	93%	90%	90%	91%	91%	91%	93%	93%	90%	90%	91%	0%	0%	0%	0%	0%	0%	0%
12	91%	89%	93%	94%	89%	90%	91%	91%	89%	93%	94%	89%	90%	91%	0%	0%	0%	0%	0%	0%	0%
13	89%	88%	90%	91%	88%	91%	88%	89%	88%	90%	91%	88%	91%	88%	0%	0%	0%	0%	0%	0%	0%
14	87%	88%	91%	90%	87%	89%	86%	87%	88%	91%	90%	87%	89%	86%	0%	0%	0%	0%	0%	0%	0%
15	88%	87%	91%	88%	87%	88%	86%	88%	87%	91%	88%	87%	88%	86%	0%	0%	0%	0%	0%	0%	0%
16	88%	87%	91%	88%	87%	89%	86%	88%	87%	91%	88%	87%	89%	86%	0%	0%	0%	0%	0%	0%	0%
17	88%	87%	91%	91%	87%	89%	86%	88%	87%	91%	91%	87%	89%	86%	0%	0%	0%	0%	0%	0%	0%
18	88%	87%	91%	89%	87%	89%	87%	88%	87%	91%	89%	87%	89%	87%	0%	0%	0%	0%	0%	0%	0%
19	88%	87%	88%	88%	88%	88%	88%	77%	75%	77%	85%	82%	80%	77%	12%	12%	11%	3%	5%	8%	11%
20	88%	87%	88%	88%	88%	88%	88%	75%	72%	88%	81%	80%	78%	73%	12%	15%	0%	7%	7%	10%	15%
21	88%	88%	89%	88%	88%	88%	88%	78%	75%	85%	79%	80%	75%	77%	10%	13%	4%	9%	8%	14%	11%
22	88%	88%	89%	87%	88%	88%	88%	81%	76%	83%	78%	77%	73%	79%	7%	12%	6%	9%	11%	15%	9%
23	88%	88%	88%	87%	88%	88%	88%	72%	75%	73%	75%	75%	72%	75%	15%	12%	16%	12%	12%	16%	13%

Figure 5-11 shows the raw heat maps by day of week, and hour of the day, of the supply fan percent speed data. This data shows that the supply fans were indeed reduced during unoccupied hours in the post-case, and that the supply fans did not reduce during unoccupied periods in the baseline data. Figure 5-11 shows that the overall percent speed increased during occupied hours in the post case compared to the baseline case. This could have been due to weather or other factors such as occupancy. For this reason, the evaluator created an adjused baseline where the speed during occupied periods is set equal to post-retrofit and during unoccupied periods the speed is found by multiplying the post-retrofit speed by an adjustment factor equal to the ratio of unoccupied cfm to occupied cfm. This adjustment factor varies slightly with outside air temperature but is approximately equal to 97%.

Figure 5-11. Baseline, post-case, and percent reduction to supply fan speed

	Adjusted Baseline SF Fan %Speed (9/1/16-9/31/16)							Adjusted Post-case SF Fan %Speed (9/1/17-9/31/17)							SF Fan Speed Percent Savings						
Hour	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat
0	43%	43%	43%	44%	43%	43%	43%	37%	37%	39%	37%	36%	37%	36%	6%	6%	4%	7%	7%	7%	7%
1	43%	43%	43%	43%	43%	44%	43%	37%	37%	38%	37%	36%	36%	36%	7%	6%	5%	7%	7%	7%	8%
2	43%	43%	43%	43%	43%	44%	43%	36%	37%	38%	37%	36%	36%	36%	7%	6%	5%	6%	7%	8%	8%
3	43%	43%	43%	43%	43%	44%	43%	36%	37%	38%	37%	36%	36%	36%	7%	6%	5%	6%	7%	8%	8%
4	43%	43%	43%	43%	43%	43%	43%	36%	37%	38%	37%	36%	36%	36%	7%	6%	5%	6%	7%	7%	8%
5	43%	43%	43%	43%	43%	43%	43%	36%	37%	38%	37%	36%	36%	36%	7%	6%	5%	6%	7%	7%	8%
6	43%	43%	35%	43%	43%	43%	43%	36%	37%	28%	37%	36%	35%	36%	7%	6%	6%	7%	7%	8%	8%
7	43%	45%	44%	44%	42%	42%	43%	43%	45%	44%	44%	42%	42%	43%	0%	0%	0%	0%	0%	0%	0%
8	45%	47%	35%	47%	44%	44%	45%	45%	47%	35%	47%	44%	44%	45%	0%	0%	0%	0%	0%	0%	0%
9	45%	47%	47%	48%	44%	44%	44%	45%	47%	47%	48%	44%	44%	44%	0%	0%	0%	0%	0%	0%	0%
10	46%	46%	47%	48%	45%	45%	45%	46%	46%	47%	48%	45%	45%	45%	0%	0%	0%	0%	0%	0%	0%
11	46%	45%	47%	48%	45%	45%	46%	46%	45%	47%	48%	45%	45%	46%	0%	0%	0%	0%	0%	0%	0%
12	45%	45%	47%	48%	45%	46%	45%	45%	45%	47%	48%	45%	46%	45%	0%	0%	0%	0%	0%	0%	0%
13	44%	44%	45%	46%	44%	46%	44%	44%	44%	45%	46%	44%	46%	44%	0%	0%	0%	0%	0%	0%	0%
14	44%	44%	47%	45%	44%	45%	43%	44%	44%	47%	45%	44%	45%	43%	0%	0%	0%	0%	0%	0%	0%
15	44%	44%	47%	45%	44%	45%	43%	44%	44%	47%	45%	44%	45%	43%	0%	0%	0%	0%	0%	0%	0%
16	44%	44%	47%	45%	44%	46%	43%	44%	44%	47%	45%	44%	46%	43%	0%	0%	0%	0%	0%	0%	0%
17	44%	44%	47%	46%	44%	46%	43%	44%	44%	47%	46%	44%	46%	43%	0%	0%	0%	0%	0%	0%	0%
18	45%	44%	47%	45%	43%	46%	44%	45%	44%	47%	45%	43%	46%	44%	0%	0%	0%	0%	0%	0%	0%
19	44%	44%	44%	44%	44%	44%	44%	39%	38%	40%	43%	41%	41%	39%	5%	6%	4%	1%	3%	3%	5%
20	44%	44%	44%	44%	44%	44%	44%	39%	37%	39%	41%	40%	40%	37%	5%	7%	5%	3%	4%	4%	7%
21	44%	44%	44%	44%	44%	44%	44%	40%	38%	40%	40%	40%	38%	40%	3%	5%	4%	4%	4%	5%	4%
22	43%	44%	44%	43%	44%	44%	44%	42%	39%	43%	40%	39%	38%	40%	2%	5%	1%	4%	5%	6%	4%
23	43%	43%	44%	43%	43%	44%	44%	38%	39%	37%	38%	38%	37%	38%	6%	4%	7%	5%	6%	7%	6%

Figure 5-12 shows the adjusted baseline and post-case supply fan speeds that were ultimately used in the evaluator analysis. The baseline occupied and unoccupied supply fan speeds were adjusted until the baseline occupied speeds were equal to the post case occupied CFM. Data smoothing was done in a similar manner that was done for the exhaust fan data, for data points that would be expected to level out if a full year of data were collected rather than just one month.

Figure 5-12. Adjusted baseline, adjusted post-case, and percent reduction to supply fan speed

Hour	Adjusted Baseline SF Fan %Speed (9/1/16-9/31/16)						
	Sun	Mon	Tue	Wed	Thu	Fri	Sat
0	0.43	0.43	0.43	0.44	0.43	0.43	0.43
1	0.43	0.43	0.43	0.43	0.43	0.44	0.43
2	0.43	0.43	0.43	0.43	0.43	0.44	0.43
3	0.43	0.43	0.43	0.43	0.43	0.44	0.43
4	0.43	0.43	0.43	0.43	0.43	0.43	0.43
5	0.43	0.43	0.43	0.43	0.43	0.43	0.43
6	0.43	0.43	0.35	0.43	0.43	0.43	0.43
7	0.43	0.45	0.44	0.44	0.42	0.42	0.43
8	0.45	0.47	0.35	0.47	0.44	0.44	0.45
9	0.45	0.47	0.47	0.48	0.44	0.44	0.44
10	0.46	0.46	0.47	0.48	0.45	0.45	0.45
11	0.46	0.45	0.47	0.48	0.45	0.45	0.46
12	0.45	0.45	0.47	0.48	0.45	0.46	0.45
13	0.44	0.44	0.45	0.46	0.44	0.46	0.44
14	0.44	0.44	0.47	0.45	0.44	0.45	0.43
15	0.44	0.44	0.47	0.45	0.44	0.45	0.43
16	0.44	0.44	0.47	0.45	0.44	0.46	0.43
17	0.44	0.44	0.47	0.46	0.44	0.46	0.43
18	0.45	0.44	0.47	0.45	0.43	0.46	0.44
19	0.44	0.44	0.44	0.44	0.44	0.44	0.44
20	0.44	0.44	0.44	0.44	0.44	0.44	0.44
21	0.44	0.44	0.44	0.44	0.44	0.44	0.44
22	0.43	0.44	0.44	0.43	0.44	0.44	0.44
23	0.43	0.43	0.44	0.43	0.43	0.44	0.44

Hour	Adjusted Post-case SF Fan %Speed (9/1/17-9/31/17)						
	Sun	Mon	Tue	Wed	Thu	Fri	Sat
0	0.37	0.37	0.39	0.37	0.36	0.37	0.36
1	0.37	0.37	0.38	0.37	0.36	0.36	0.36
2	0.36	0.37	0.38	0.37	0.36	0.36	0.36
3	0.36	0.37	0.38	0.37	0.36	0.36	0.36
4	0.36	0.37	0.38	0.37	0.36	0.36	0.36
5	0.36	0.37	0.38	0.37	0.36	0.36	0.36
6	0.36	0.37	0.28	0.37	0.36	0.35	0.36
7	0.43	0.45	0.44	0.44	0.42	0.42	0.43
8	0.45	0.47	0.35	0.47	0.44	0.44	0.45
9	0.45	0.47	0.47	0.48	0.44	0.44	0.44
10	0.46	0.46	0.47	0.48	0.45	0.45	0.45
11	0.46	0.45	0.47	0.48	0.45	0.45	0.46
12	0.45	0.45	0.47	0.48	0.45	0.46	0.45
13	0.44	0.44	0.45	0.46	0.44	0.46	0.44
14	0.44	0.44	0.47	0.45	0.44	0.45	0.43
15	0.44	0.44	0.47	0.45	0.44	0.45	0.43
16	0.44	0.44	0.47	0.45	0.44	0.46	0.43
17	0.44	0.44	0.47	0.46	0.44	0.46	0.43
18	0.45	0.44	0.47	0.45	0.43	0.46	0.44
19	0.39	0.38	0.40	0.43	0.41	0.41	0.39
20	0.39	0.37	0.39	0.41	0.40	0.40	0.37
21	0.40	0.38	0.40	0.40	0.40	0.38	0.40
22	0.42	0.39	0.43	0.40	0.39	0.38	0.40
23	0.38	0.39	0.37	0.38	0.38	0.37	0.38

Hour	SF Fan Speed Percent Savings						
	Sun	Mon	Tue	Wed	Thu	Fri	Sat
0	6%	6%	4%	7%	7%	7%	7%
1	7%	6%	5%	7%	7%	7%	8%
2	7%	6%	5%	6%	7%	8%	8%
3	7%	6%	5%	6%	7%	8%	8%
4	7%	6%	5%	6%	7%	7%	8%
5	7%	6%	5%	6%	7%	7%	8%
6	7%	6%	6%	7%	7%	8%	8%
7	0%	0%	0%	0%	0%	0%	0%
8	0%	0%	0%	0%	0%	0%	0%
9	0%	0%	0%	0%	0%	0%	0%
10	0%	0%	0%	0%	0%	0%	0%
11	0%	0%	0%	0%	0%	0%	0%
12	0%	0%	0%	0%	0%	0%	0%
13	0%	0%	0%	0%	0%	0%	0%
14	0%	0%	0%	0%	0%	0%	0%
15	0%	0%	0%	0%	0%	0%	0%
16	0%	0%	0%	0%	0%	0%	0%
17	0%	0%	0%	0%	0%	0%	0%
18	0%	0%	0%	0%	0%	0%	0%
19	5%	6%	4%	1%	3%	3%	5%
20	5%	7%	5%	3%	4%	4%	7%
21	3%	5%	4%	4%	4%	5%	4%
22	2%	5%	1%	4%	5%	6%	4%
23	6%	4%	7%	5%	6%	7%	6%

Building 4, Dining Hall - Add Scheduling Controls to AHU-1

Figure 5-13 shows the spot measured kW of AHU-1 collected by the evaluator on 4/8/21. AHU-1 was found to include a 3 HP supply fan motor, as indicated in the tracking calculations. We took spot measurements, and found that the average kW of the fan motor was 1.17 kW, which corresponds to 1.57 HP. This corresponds to a motor load factor on the 3 HP motor of 52%. The tracking calculations show that there is a 3HP supply fan motor, along with a 2 HP return fan motor. We did not notice a 2 HP return fan motor during the site visit. We did however measure kW that fed the entire unit, when the DX compressors were off, so if there were a return fan, it would have been included in the 1.17 measured kW.

Figure 5-13. AHU-1 spot measured kW

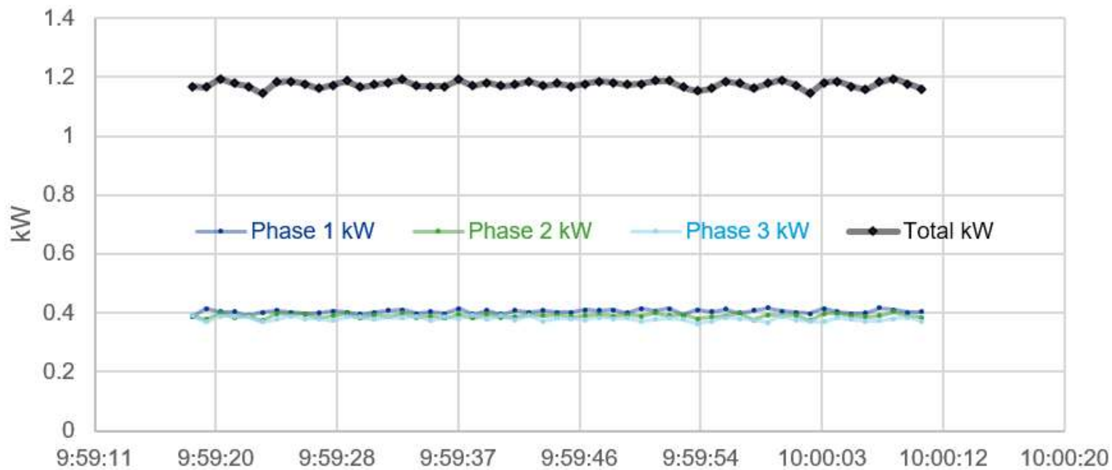


Figure 5-14. shows a heat map of the baseline and post-case supply fan status data by hour of the day, and day of the week. The baseline value of 99.4% that is shown in Figure 5-14. was the average for the entire baseline data period. Figure 5-14. shows that the unit was indeed shut off during the unoccupied hours as intended by the measure.

Figure 5-14. AHU-1 Supply fan status heat map by day of week and hour of day

	Adjusted Baseline SF Status Data (4/5/17 - 5/31/17)							Post SF Status Data (8/1/17 - 9/30/17)						
Hour	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
5	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
6	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
7	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
8	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
9	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
10	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
11	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
12	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
13	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
14	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
15	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
16	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
17	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
18	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
19	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
20	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
21	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
22	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Building 5, Office Building - Integrate VRF with BAS for Scheduling Control

Figure 5-15 shows the post-case amperage data by hour of day and day of week in a heatmap format for VRF 1 and VRF 2. This measure was intended to put the units into unoccupied mode during unoccupied hours, resulting in less cooling energy. The data shows that during unoccupied periods, the unit used more energy (1.63 Amps and 2.07 Amps) than during occupied periods (1.40 Amps and 1.78 Amps). This may be because these VRF units provide both heating and cooling, and that during unoccupied periods, the units may have been in heating mode, and during the mild spring days when there is not much heating or cooling load during the day, but there is more of a heating load at night. The data in Figure 5-14 is therefore not absolutely conclusive that this measure results in no savings over the entire year, but is suggestive. A follow up question to the site contact resulted in the following response: "There are schedules in the system, but they appear to be occupied 24/7". Based on this response, along with the suggestive data shown in Figure 5-14, the evaluator is assigning 0 savings to this measure. The tracking savings assumed a savings factor from the RI TRM to the square footage of the space. Using this data, and responses from the customer, the evaluators believe that there are no savings for this measure.

Figure 5-15. AHU-1 VRF 1 and 2 post-case average amperage heat map by day of week and hour of day

		VRF 1 Post Amps (4/8/21-5/13/21)						
		Sun	Mon	Tue	Wed	Thu	Fri	Sat
Hour	0	1.62	1.60	1.39	1.16	1.31	1.93	1.58
	1	1.48	1.40	1.39	1.16	1.16	1.78	1.51
	2	1.39	1.40	1.39	1.16	1.26	1.77	1.37
	3	1.64	1.51	1.39	1.16	1.35	1.99	1.47
	4	1.59	1.52	1.39	1.16	1.26	1.66	1.42
	5	1.39	1.53	1.39	1.16	1.54	1.68	1.32
	6	1.79	1.50	1.38	1.16	1.47	1.82	1.54
	7	1.38	1.47	1.38	1.15	1.25	1.52	1.83
	8	1.39	1.38	1.36	1.15	1.16	1.78	1.74
	9	1.39	*1.39*	*1.15*	*1.06*	*1.16*	*1.59*	1.75
	10	1.39	*1.39*	*1.15*	*0.93*	*1.16*	*1.59*	1.64
	11	1.39	*1.39*	*1.16*	*1.02*	*1.16*	*1.62*	1.95
	12	1.39	*1.39*	*1.15*	*1.16*	*1.16*	*1.55*	1.98
	13	1.39	*1.39*	*1.15*	*1.16*	*1.55*	*1.62*	2.03
	14	1.39	*1.39*	*1.15*	*1.16*	*1.16*	*1.58*	1.87
	15	1.39	*1.39*	*1.15*	*1.16*	*1.16*	*1.57*	1.88
	16	1.39	*1.39*	*1.16*	*1.16*	*1.16*	*1.65*	2.05
	17	1.39	*1.39*	*1.16*	*1.16*	*1.16*	*1.62*	1.77
	18	1.39	1.39	1.16	1.16	1.16	1.46	1.74
	19	1.39	1.38	1.16	1.16	1.16	1.55	1.80
	20	1.39	1.38	1.16	1.16	1.16	1.48	1.76
	21	1.39	1.38	1.15	1.15	1.16	1.49	1.74
	22	1.39	1.39	1.16	1.16	1.16	1.48	1.78
	23	1.40	1.39	1.16	1.16	1.16	1.38	1.83
Occ (MF 9AM-5PM) Amps							*1.40*	
Unocc Amps							1.63	

		VRF 2 Post Amps (4/8/21-5/13/21)						
		Sun	Mon	Tue	Wed	Thu	Fri	Sat
Hour	0	2.44	2.24	1.86	1.76	1.75	3.20	2.66
	1	2.09	1.70	2.40	1.45	1.44	3.21	2.20
	2	2.19	1.71	2.34	1.44	2.11	2.90	2.75
	3	2.23	2.02	2.65	1.44	2.37	3.05	2.47
	4	2.50	2.11	2.31	1.44	2.24	3.52	2.76
	5	2.52	2.23	2.78	1.44	2.56	3.23	3.11
	6	2.26	2.20	2.61	1.70	2.81	3.47	2.70
	7	2.10	2.64	2.41	1.43	2.77	3.00	3.23
	8	2.08	1.52	2.19	1.43	2.38	2.62	2.22
	9	1.68	*1.80*	*2.10*	*1.43*	*1.70*	*2.23*	2.37
	10	1.44	*1.78*	*1.60*	*1.43*	*2.40*	*2.43*	2.02
	11	1.43	*1.44*	*1.71*	*1.44*	*1.91*	*2.70*	1.88
	12	1.43	*1.44*	*1.44*	*1.43*	*2.15*	*2.44*	2.10
	13	1.43	*1.73*	*1.44*	*1.44*	*1.56*	*2.61*	1.84
	14	1.43	*1.44*	*1.44*	*1.43*	*1.94*	*2.52*	1.44
	15	1.43	*1.60*	*1.44*	*1.44*	*1.63*	*2.45*	1.65
	16	1.43	*1.47*	*1.44*	*1.44*	*1.73*	*2.63*	1.76
	17	1.43	*1.90*	*1.44*	*1.44*	*1.44*	*2.15*	1.79
	18	1.43	1.44	1.44	1.44	2.17	2.62	1.48
	19	1.43	2.04	1.43	1.44	2.33	2.45	1.87
	20	1.43	1.64	1.43	1.44	2.75	2.19	1.68
	21	1.44	1.99	1.43	1.44	2.70	2.55	1.79
	22	1.78	1.86	1.44	1.44	2.94	2.43	1.93
	23	1.72	2.11	1.44	1.44	2.72	2.57	1.92
Occ (MF 9AM-5PM) Amps							*1.78*	
Unocc Amps							2.07	

Evaluation Methods and Findings

Evaluation Description of Baseline

The evaluator reviewed the project files and interviewed the site contact to gather information on the baseline. DNV determined the all the measures are retrofit and using existing conditions as the baseline is appropriate.

Evaluation Calculation Method

This section describes the calculation methods used by the evaluators.

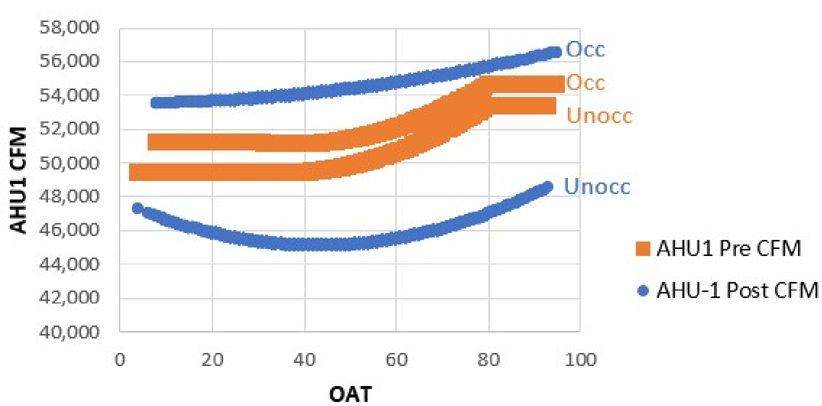
Building 1, Laboratory Building - New Occ Sensors and Scheduling Controls

The evaluator followed the following procedure to calculate savings for this measure:

1. Convert Amperage for post data to kW assuming a 1.0 PF (these are on VFDs which have capacitors which make incoming displacement power factor close to 1.0[20]), and 480 Volts.
2. Develop regression equation between post CFM to post kW for supply and exhaust fans (see Figure 5-4 and Figure 5-7)
3. Develop regression equation between post outdoor air temperature and post supply and exhaust CFM, for both occ and unocc times (see Figure 5-3 and Figure 5-5).
4. Develop baseline OA temp vs. baseline AHU1 CFM regression equation for occupied and unoccupied times (see Figure 5-2).
5. Develop regression equation between post AHU-1 CFM and post EAHU-1&2 CFM, since we do not have any baseline EAHU1&2 data, but supply CFM is strongly correlated to exhaust CFM (see Figure 5-6).
6. Apply OA temp vs Post CFM Regressions to TMY3 weather file, to estimate post-case CFM profiles for AHU1 and EAHU1
7. Apply OA temp vs. baseline AHU1 CFM Regression to TMY3 weather file, to estimate baseline CFM profile for AHU1
8. Apply regression equation between post AHU-1 CFM and post EAHU-1&2 CFM to TMY3 normalized baseline AHU1 CFM profile, to estimate TMY3 normalized baseline EAHU1&2 CFM profile

Figure 5-16 shows the regression equations for the baseline and post-case occupied and unoccupied supply fan CFM applied to a local TMY3 file. Figure 5-16 illustrates how in the post-case, the CFM reduced much more significantly during unoccupied times than during the baseline period. It is important to note that the baseline data is from 2012, and the post data is from 2017, and in that time period, a lot may have changed either to the spaces, operation, or the meters used to measure and record the CFM data. A later step adjusts for these types of operational differences that are not due to the implementation of the measure, but due to extraneous factors, like changes in operation, or drift in calibration of the CFM measuring devices.

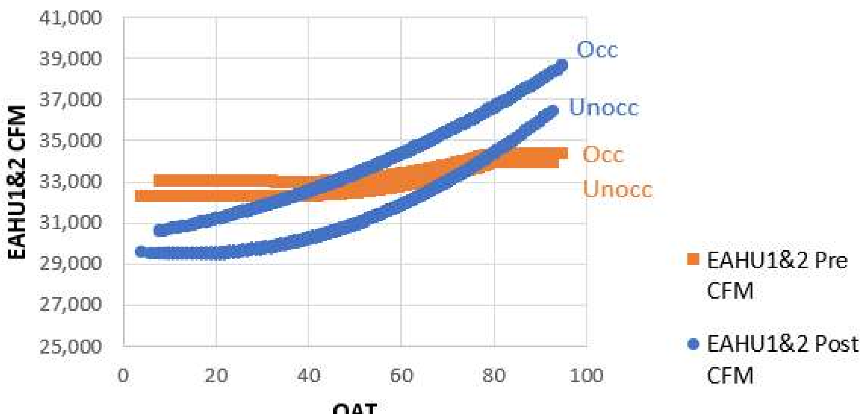
Figure 5-16. TMY3 normalized baseline and post case occupied and unoccupied supply CFM



[20] While the displacement power factor is typically 1.0, the true, or apparent power factor may not be close to 1.0 unless the VFDs components that also reduce THD, like diode based rectifier VFDs that use line reactors or DC link chokes, or VFDs that use an active front end drive (AFE). https://www.motioncontroltips.com/the-truth-about-vfds-and-power-factor/ Therefore, this assumption of a 1.0 power factor may overestimate savings if the apparent factor is actually lower than 1.0.

Figure 5-17 shows the regression equations for the baseline and post-case occupied and unoccupied exhaust fan applied to a local TMY3 file. Like Figure 5-16, Figure 5-17 also shows that in the post-case, the CFM reduced much more significantly during unoccupied times than during the baseline period. Also like Figure 5-16, Figure 5-17 illustrates how simply comparing the baseline curves to the post case curves would not result in an apples to apples comparison, because had nothing changed with respect to the operation, or calibration of the CFM measuring devices, the baseline and post-case occupied curves would be expected to be much more closely in alignment. Because they are not in alignment, an adjustment is needed to ensure that the comparison between the baseline and post-case period properly accounts for any non-measure related changes to the CFM usage profile.

Figure 5-17. TMY3 normalized baseline and post case occupied and unoccupied exhaust CFM



This measure is mainly expected to save energy during unoccupied periods, but the measure also involved installing occupancy sensors on some of the terminal boxes serving the non-laboratory spaces. Details on how many terminal boxes occupancy sensors, and the rated CFM of those terminal boxes could not be provided by the site contact.
There was a list of terminal boxes in the building, along with the names of the rooms and/or spaces that each terminal box served. Based on the name of the room/space, the evaluator assigned whether that space was a laboratory space, a non-laboratory space, or unknown. Twenty percent of the total rated terminal box CFM was categorized in this manner as laboratory space, 33% was categorized as non-laboratory space, and 47% as unknown. The evaluator then applied the known non-laboratory to laboratory CFM ratio to the unknown, to estimate that 62% of the rated terminal box supply CFM was dedicated to non-laboratory space, and 38% to laboratory space.
So, it is likely that some savings are likely to occur on the non-laboratory spaces where occupancy sensors were installed during the occupied period when the occupancy sensors indicate that these non-laboratory spaces are not occupied. The tracking calculations indicated that for 1,095 hours per year, the entire ~75 kW of supply and exhaust fan kW could be reduced to zero. After adjusting base-case occupied and unoccupied CFM upwards so that the baseline occupied CFM matched the post-case occupied CFM the evaluator then applied a 5% savings factor (from the occupancy sensors) to the 62% of the CFM that the evaluator estimated is serving non-laboratory space in the building.

Figure 5-18 and

Figure 5-19 are updated versions of Figure 5-16 and Figure 5-17 after adjustments had been made to the baseline CFM to ensure that the baseline CFM was being compared in an apples to apples manner with the post case CFM. Figure 5-18 refers to the supply airflow and

Figure 5-19 is for the exhaust airflow.

Figure 5-18. TMY3 normalized baseline and post case occupied and unoccupied supply CFM where baseline CFM is adjusted upwards for an apples to apples comparison with the post-case CFM

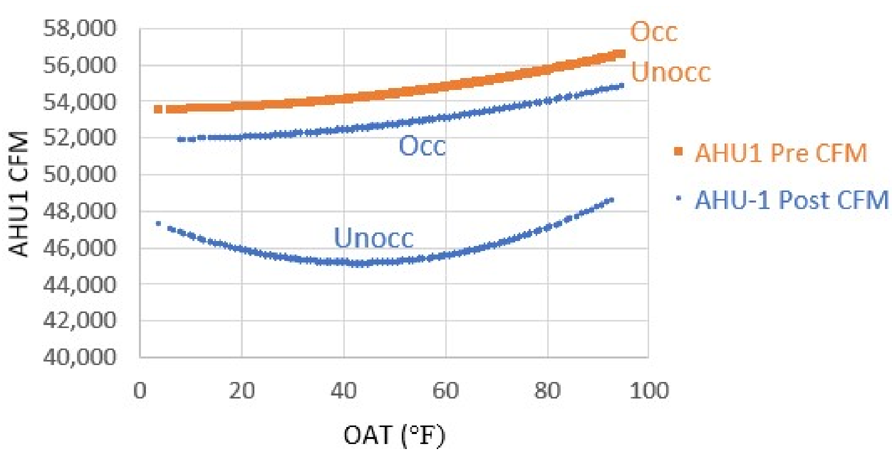
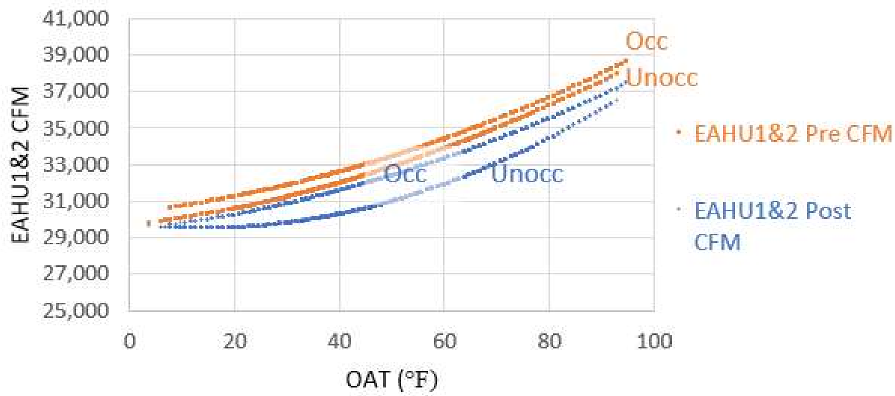


Figure 5-19. TMY3 normalized baseline and post case occupied and unoccupied exhaust CFM where baseline CFM is adjusted upwards for an apples to apples comparison with the post-case CFM

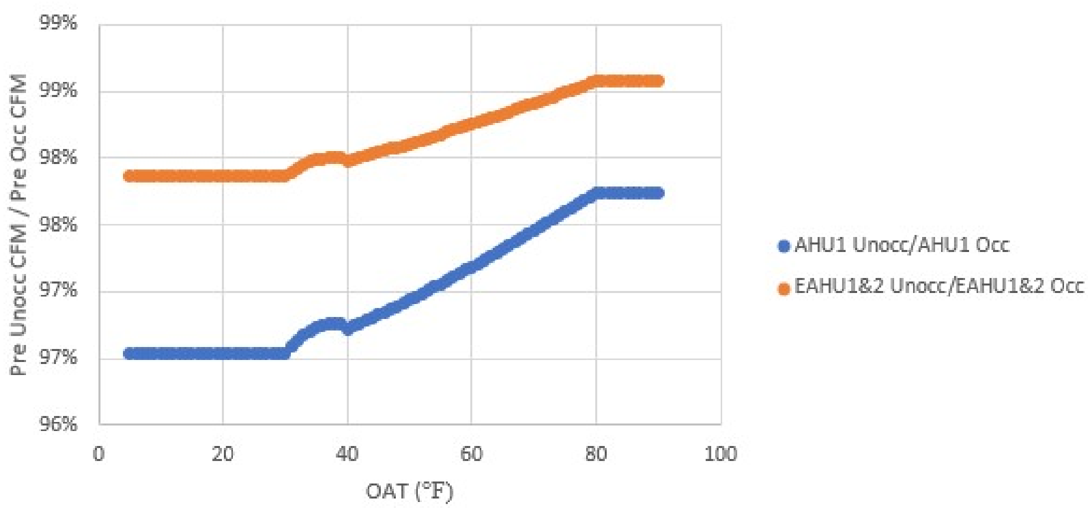


The adjustment that was made to convert the baseline CFM data so that it would be more of an apples to apples comparison with the post-case CFM data consisted of the following steps:

The first step was to revisit the relationships between outdoor air temperature, and the baseline occupied and unoccupied CFM values for AHU1 (supply), and EAHU1&2 (exhaust), which are show in Figure 5-16 and Figure 5-17.

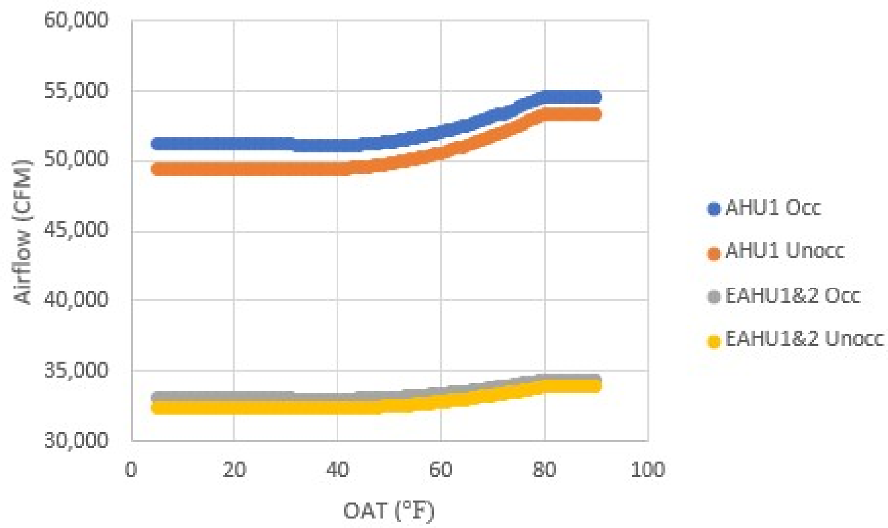
The second step was to develop ratios between AHU1Unocc CFM:AHU1 Occ CFM and EAHU1&2 Unocc CFM: EAHU1& Occ CFM, as a function of outdoor air temperature, as shown in Figure 5-20. The next step was to set all the baseline occupied CFM equal to the post-case occupied CFM. The following step was to apply the relationships shown in Figure 5-20 to estimate the corresponding post-normalized unoccupied CFM for a given outdoor air temperature.

Figure 5-20. TMY3 normalized ratios of AHU1Unocc CFM:AHU1 Occ CFM and EAHU1&2 Unocc CFM: EAHU1& Occ CFM vs. outdoor air temperature



The next step was to adjust the post-case CFM downwards by 5% x 62% of the total CFM, to account for possible savings during occupied times as a result of the occupancy sensors. Figure 5-21 shows the resulting adjustments made to the baseline data shown in Figure 5-16 and Figure 5-17 so that it more closely reflects post-case operation during occupied hours, while also accounting for a reduction in 5% to the CFM associated with non-laboratory VAV boxes during occupied periods.

Figure 5-21. TMY3 normalized baseline occupied and unoccupied supply and exhaust CFM



9. Apply the post-case kW vs. CFM regression equation to the normalized AHU1 CFM profiles in the TMY3 analysis.
10. Apply the regression equation between Post EAHU1 CFM, and post EAHU-1 kW to the exhaust CFM profiles in the TMY3 analysis.
11. The tracking savings calculate the cooling savings to be 5.71% of the total savings for this measure. Because the cooling savings should track the cfm savings and to reduce the work effort for this evaluation, the evaluators use this same 5.71% ratio, to estimate the ex-post cooling savings from the evaluator estimated fan savings.
12. Sum the total normalized baseline and post kW values in the TMY3 8,760 spreadsheet and compute fab savings.

Building 2, Laboratory Building - Condenser Water Reset

The evaluator followed the following procedure to calculate savings for this measure:

1. Using the nearest TMY 3 file with dry bulb temperature, and relative humidity, develop a column of outdoor air wet bulb temperatures using a psychrometric formula.
2. Set the baseline CWST for chillers 1 and 2 (centrifugal chillers) to 75° in the TMY3 file, and the baseline CWST for chiller 3 to 80° F. The tracking documentation state that the observed baseline condenser water temperature was 75°, which was used in the calculations for chiller 1 and 2, but the tracking calculations used 85° for chiller 3. Took the average of 75° and 85°, which is 80, and used that in the evaluator calculations for chiller 3.
3. Referred to table used in tracking calculations which referred to trend data from 2015, and that showed the percentage of hours that chiller 1, chiller 2, and chiller 3 were on for each 5° weather bin. Applied those values to the TMY3 file using a lookup formula.
4. Added in post-case condenser water supply temperatures using data collected from between 1/23/17 and 8/31/17. See Figure 5-8.
5. Use the same regression equations that were used in the tracking calculate the baseline chiller kW values for chiller 1 and 2 based on outdoor air temperature. See a screenshot of those regression equations in Figure 5-22.

Figure 5-22. Screenshot of Regression equations used to estimate chiller 1 and chiller 2 kW based on outdoor air temperature in tracking and evaluator calculations

Chiller 1 kW vs OAT OAT >30 F		
Regression curves to get kW based on OAT:	OAT > 45 F	Chlr 1 kW = .6243* OAT^2-5.6243*OAT+254.64
From trend data - Aug 1 thru Sep 30 2015		See Chlr 1 kW vs OAT in Chw Trend tab this workbook
see "70Ship St CHWTrends Apr-May2014.xlsx"	OAT < 45 F	Chlr 1 kW = 150 kW
		See Chlr 1 kW vs OAT in Chw Trend tab this workbook
Chiller 2 kW vs OAT OAT >30 F		
Regression curves to get kW based on OAT:	OAT > 45 F	Chlr 2 kW = .0147*OAT^2+1.1237*OAT+13.268
From trend data - Aug 1 thru Sep 30 2015		See Chlr 2 kW vs OAT in Chw Trend tab this workbook
see "70Ship St CHWTrends Apr-May2014.xlsx"	OAT < 45 F	Chlr 2 kW = 150 kW
		See Chlr 2 kW vs OAT in Chw Trend tab this workbook

6. Use the same regression equations that were used in the tracking calculate the total chiller plant (ch1, ch2, ch3) tonnage in the TMY3 file. See a screenshot of those regression equations in Figure 5-23.

Figure 5-23. Screenshot of Regression equations used to estimate chiller plant tonnage based on outdoor air temperature in tracking and evaluator calculations

Chiller Load Profile (tons vs weather bins)								
Total Plant For OAT > 45 F:	based on Trends Aug-Sep 2015							
Refer to Chw Trend tab this workbook:					Check	OAT	tons	OK=X
Regression curves to get tons based on OAT:		Tons = 14.913 * OAT - 405.3				95	1,011.4	X
From trend data - Aug 1 through Sept 30, 2015		See Chiller trend Tons vs OAT Aug-Sep 2015\ in Chw Trends tab this workbook				80	787.7	X
		See EXCEL workbook " "70 Ship Street Chiler Plant Trends Aug-Sep&Nov-Dec 2015.xlms"				65	564.0	X
						50	340.4	X
Total Plant For OAT < 45 F:	based on Trends December 2016							
						OAT	tons	OK=X
Refer to Chw Load Dec 2016 tab this workbook:		OAT	tons			45	40	
Regression curves to get tons based on OAT:		30	29			40	36	X
From trend data - Dec 2016		45	40			35	33	X
		Less than 30 F OAT =		29 tons		30	29	X
						25	29	X
		See CHW Load Dec 2016 tab this workbook				0	29	

7. Estimate the chiller 1 and chiller 2 tonnage in the TMY3 file from the chiller 1 and chiller 2 kW data, and an average kW/ton value of 0.5075, which is from the specification sheets.
8. Estimate chiller 3 tonnage by subtracting out the chiller 1 and chiller 2 tonnage from the total tonnage.
9. Develop a regression relating the chiller 3 kW/ton as a function of chiller 3 tons and entering condenser water temperature using manufacturer performance data. Apply that regression equation to the TMY3 data and estimate the baseline chiller 3 kW values from the chiller 3 tonnage data, and the baseline chiller 3 condenser water temperature.
10. Estimate the % savings for chiller 1&2, and chiller 3 for each hour in the TMY3 file, by assuming that for each °F reduction in CWST for chillers 1 and 2 (centrifugal chillers), results in a 1.3% reduction in kW, and that for each °F reduction in CWST for chiller 3 (reciprocal chiller), results in a 1.7% reduction in kW. This is based on a reference to a whitepaper from Trane, a chiller manufacturer.
11. Apply the % savings values to estimate the post case chiller kW data.
12. Use the regression equation that was used in the tracking calculations to estimate the baseline cooling tower kW. See Figure 5-24.

Figure 5-24. Screenshot of regression equations used to estimate baseline cooling tower kW as a function of outdoor air temperature

	See Chw Trends Tab this workbook : regression curves							
Summer (OAT>55F)								
	CT-1,2&3	kW =	(0.0220)	* OAT^2	3.8120	* OAT +	-144.84	Aug-Sep 2015 trends
Winter OAT< 55F								
	Trends show at OAT > 85, all 3 fans operating at				20	kW		
Winter OAT< 55F								
	Trends show all three fans kW=			0.71 kW				
	some show at zero but this is due CT fan commmand speed between							
	greeater than zero but less than 20% (actual fan speed still 20 HZ (33%)							
	Trends show Chillers 1 &2 off when OAT < 30 F							
	and	CT-1 kW=	0.71	kW				
		CT-2&3 kV	0	kW				

13. Estimate the post-case cooling tower kW by making the simplifying assumption that the post case cooling tower kW increases from the baseline by the same percentage amount that the total chiller kW decreases.
14. Estimate kW savings between the baseline and post kW data for the chillers and cooling towers, and compute annual savings.

Building 3, Medical Education Building - Reduce Supply and Exhaust Fan Airflow During Unoccupied Hours

The evaluator followed the following procedure to calculate savings for this measure:

1. Because this measure only is intended to save energy during unoccupied hours and should not have any impact on the occupied hours, as part of the evaluation the evaluators created a post-normalized baseline heat map of the exhaust fan speeds. All the baseline unoccupied speed values were multiplied by the ratio of the average post case occupied speed values to the average baseline occupied speed values (1.01) , because the post case occupied speeds (excluding outliers), were approximately 1.01 times higher than the base-case occupied periods. Using a TMY3 file, apply the adjusted baseline and post-case exhaust fan % speed values from Figure 5-10.

2. Estimate the baseline and post case exhaust fan kW from the baseline and post case % speed data, and the rated BHP of EAHU1&2, using the formula below based on the fan affinity laws.

$$Exhaust\ Fan\ kW = \frac{Rated\ BHP \times 0.746\frac{kW}{HP}}{92\%\ Motor\ Efficiency} \times (\%Speed)^{2.7}$$

3. Follow the same steps described above for the exhaust fans but applied to the supply fans.

4. Compute the fan savings by taking the difference in sums of the baseline and post-case hourly supply and exhaust fan kW data.

5. Estimate the cooling savings using the following formulas:

$$Cooling\ Energy\ Savings = Baseline\ Cooling\ Energy - Post\ Cooling\ Energy$$

$$Baseline\ Cooling\ Energy = \frac{Total\ CFM\ \times 0.075 \frac{lb}{ft^3} \times 60 \frac{min}{hr} \times 0.80 \frac{kW}{ton}}{12{,}000 \frac{Btu}{ton \cdot hr}} \times \sum_{hour=}^{8{,}760} Outdoor\ Air\ \%\ \times (Outdoor\ Air\ Enthalpy - Supply\ Air\ Enthalpy)\ Btu/lb$$

$$Post\ Cooling\ Energy = \frac{Total\ CFM\ \times 0.075 \frac{lb}{ft^3} \times 60 \frac{min}{hr} \times 0.80 \frac{kW}{ton}}{12{,}000 \frac{Btu}{ton \cdot hr}} \times \sum_{hour=}^{8{,}760} Outdoor\ Air\ \%\ \times (Outdoor\ Air\ Enthalpy - Supply\ Air\ Enthalpy)\ Btu/lb$$

The above equations are used only when the outdoor air temperature is above 55°F.

6. Estimate the total evaluator savings by summing the total evaluator fan saving with the total evaluator cooling savings.

Building 4, Dining Hall - Add Scheduling Controls to AHU-1

The evaluator used the following algorithms to calculate savings for this measure:

$$Total\ Savings = Fan\ Savings + Cooling\ Savings$$

$$Fan\ Savings = Baseline\ Fan\ Energy - Post\ Fan\ Energy$$

$$Baseline\ Fan\ Energy = Measured\ Fan\ kW\ \times Baseline\ Annual\ Operating\ Hours$$

$$Post\ Fan\ Energy = Measured\ Fan\ kW \times Post\ Annual\ Operating\ Hours$$

The evaluator measurements of the entire power serving this AHU indicated that the measured motor load factor was 47% on a 3 HP motor rather than a 100% motor load factor on a 3 HP supply fan and 2 HP return fan.

The cooling savings were estimated using the equations below. Outdoor air percent data in the equations below comes from a different building, because there was no % outdoor air data for this building. The other building was a gymnasium, while this building is a cafeteria, which are both buildings where there are large numbers of people which requires a lot of outdoor air.

$$Cooling\ Savings = Baseline\ Cooling\ Energy - Post\ Cooling\ Energy$$

$$Baseline\ Cooling\ Energy = \frac{Total\ CFM\ \times 0.075 \frac{lb}{ft^3} \times 60 \frac{min}{hr} \times 1.2 \frac{kW}{ton}}{12{,}000 \frac{Btu}{ton \cdot hr}} \times \sum_{hour=1}^{8{,}760} Outdoor\ Air\ \%\ \times (Outdoor\ Air\ Enthalpy - Supply\ Air\ Enthalpy)\ Btu/lb$$

$$Post\ Cooling\ Energy = \frac{Total\ CFM\ \times 0.075 \frac{lb}{ft^3} \times 60 \frac{min}{hr} \times 1.2 \frac{kW}{ton}}{12{,}000 \frac{Btu}{ton \cdot hr}} \times \sum_{hour=}^{8{,}760} Outdoor\ Air\ \%\ \times (Outdoor\ Air\ Enthalpy - Supply\ Air\ Enthalpy)\ Btu/lb$$

The outdoor air percent was during the cooling season was estimated using trend data from the BAS for another building on campus which showed that when OAT>55F, OA% varied slightly, decreasing with increasing OAT, following the formula:

$$Fraction\ OA = -0.00218 \text{ x } OAT + 0.3722$$

The supply air enthalpy was assumed to be 22.87 Btu/lb, corresponding with 55° F, and 97% RH, corresponding to saturated air leaving the cooling coil. Cooling was assumed to occur for any temperature above 55°.

Building 5, Office Building - Integrate VRF with BAS for Scheduling Control

The evaluator concluded that this measure is resulting in 0 savings based on the following pieces of information:

1. The unoccupied measured kW usage for the two VRF units is higher during unoccupied hours than during occupied hours. See Figure 5-14.
2. A follow up question to the site contact about the data in Figure 5-14 resulted in the following response: "There are schedules in the system, but they appear to be occupied 24/7".

Based on this response, along with the suggestive data shown in Figure 5-14, the evaluator is assigning 0 savings to this measure.

Final Results

Explanation of Differences

This section describes the differences in the key variables between the tracking and evaluator savings values.

Building 1, Laboratory Building - New Occ Sensors and Scheduling Controls

Table 5-37 shows the baseline and post key parameters for this measure. Table 5-37 shows that the tracking calculations for 1,095 "standby" hours, erroneously omitted the entire 75.6 kW associated with AHU-1. This represents 82,731 kWh, which makes up 44% of the 189,275 kWh of the tracking savings. The evaluator found that the AHU-1 does not go to 0 kW based on reviewing the BAS trend data. The other major difference between the tracking and evaluator key parameters is the difference in occupied and unoccupied post-case kW values. The tracking calculations show that the kW associated with AHU-1 could decrease from 75.6 kW to 47.0 kW in the post-case, resulting in a difference of 28.5 kW between those periods. The post data reviewed by the evaluator showed that the difference between occupied and unoccupied kW for AHU-1 was only 6.1 kW. These are the main factors which resulted in the lower realization rate for this measure.

Table 5-37. Tracking and evaluator baseline and post key parameters for measure 1

	Tracking		Evaluator	
Parameter Name	**Baseline**	**Proposed**	**Baseline**	**Proposed**
AHU-1, EAHU1&2, EF 1-4 Fan Occupied Hours	5,475	4,380	3,654	3,654
AHU-1, EAHU1&2, EF 1-4 Fan Unoccupied Hours	3,285	3,285	5,106	5,106
AHU-1, EAHU1&2, EF 1-4 Fan Standby Hours	0	1,095	0	0
AHU-1 Fan Occupied Weighted Average kW	75.6	75.6	57.6	56.2
AHU-1 Fan Unoccupied Weighted Average kW	56.5	47.0	57.4	50.1
AHU-1 Fan Standby Weighted Average kW	0	0	0	0
EAHU1&2 Fan Occupied Weighted Average kW	58.9	58.9	56.3	55.7
EAHU1&2 Fan Unoccupied Weighted Average kW	59.1	59.1	55.7	54.7
EAHU1&2 Fan Standby Weighted Average kW	0	0	0	0

AHU-1 Fan Occupied Weighted Average kWh	413,656	330,925	210,355	205,192
AHU-1 Fan Unoccupied Weighted Average kWh	185,678	154,428	293,017	255,652
AHU-1 Fan Standby Weighted Average kWh	0	0	0	0
EAHU1&2 Fan Occupied Weighted Average kWh	322,404	257,923	205,721	203,464
EAHU1&2 Fan Unoccupied Weighted Average kWh	194,288	194,288	284,260	279,206
EAHU1&2 Fan Standby Weighted Average kWh	0	0	0	0
Total Fan kWh	1,116,026	937,564	993,353	943,513
Total Cooling kWh	445,081	434,268	396,158	393,139
Total kWh	1,561,107	1,371,832	1,389,512	1,336,652
Total Fan Savings		178,462		49,840
Total Cooling Savings		10,813		3,020
Total Savings		189,275		52,860

Building 2, Laboratory Building - Condenser Water Reset

Table 5-38 shows the tracking and evaluator baseline and post-case key parameters for the condenser water reset measure. The savings percent is higher in the evaluator calculations compared to the tracking savings because the evaluator used a savings of 1.3% and 1.7% per °F that the condenser water temperature can be reduced (for centrifugal and reciprocating chillers respectively), based on the Trane manual, whereas the tracking calculations used 1% per °F for both the centrifugal and reciprocating chillers.

Table 5-38. Tracking and evaluator baseline and post key parameters for measure 2

	Tracking			Evaluator		
Variable	**Baseline**	**Post**	**Savings %**	**Baseline**	**Post**	**Savings %**
Chiller 1 average power consumption (kW)	166	157	5.0%	161	150	7.0%
Chiller 2 average power consumption (kW)	156	148	5.2%	152	141	6.8%
Chiller 3 average power consumption (kW)	51	46	9.5%	104	96	8.2%
Cooling tower average power consumption (kW)				16	17	-5.1%
Chiller 1 annual runtime (hours)	4,381	4,381	0.0%	4,051	4,051	0.0%
Chiller 2 annual runtime (hours)	4,556	4,556	0.0%	4,206	4,206	0.0%
Chiller 3 annual runtime (hours)	2,054	2,054	0.0%	2,241	2,241	0.0%
Cooling tower annual runtime (hours)				8,760	8,760	0.0%
Chiller 1 annual energy use (kWh)	725,741	689,428	5.0%	652,018	606,642	7.0%
Chiller 2 annual energy use (kWh)	711,981	674,647	5.2%	638,264	594,937	6.8%
Chiller 3 annual energy use (kWh)	104,484	94,591	9.5%	234,086	214,988	8.2%
Cooling tower annual energy use (kWh)				139,566	146,729	-5.1%
Total annual energy use (kWh)	1,542,205	1,458,665	5.4%	1,663,934	1,563,295	6.0%
Total annual energy savings (kWh)		83,540	5.4%		100,639	

Building 3, Medical Education Building - Reduce Supply and Exhaust Fan Airflow During Unoccupied Hours

Table 5-39 shows the tracking and evaluator baseline and post-case key parameters for the reduce supply and exhaust fan airflow measure. The total savings are very similar between the tracking and evaluator savings. The evaluator found that there were more unoccupied hours that the fans were observed operate at reduced speed compared to the tracking calculations, but the evaluator found that the reduction between occupied and unoccupied kW for the supply and exhaust fans were lower than what was estimated in the tracking calculations.

Table 5-39. Tracking and evaluator baseline and post key parameters for measure 3

	Tracking		Evaluation	
Variable	**Base value**	**Post value**	**Base value**	**Post value**
Supply fan quantity	4	4	4	4
Exhaust fan quantity	2	2	2	2
Supply fan nameplate airflow per fan (CFM)	8,000	8,000	8,000	8,000
Exhaust fan nameplate airflow per fan (CFM)	32,000	32,000	32,000	32,000
Supply fan nameplate horsepower per fan (hp)	20	20	20	20
Exhaust fan nameplate horsepower per fan (hp)	50	50	50	50
Supply fan occupied input power per fan (kW)	9.85	9.85	4.95	4.95
Supply fan unoccupied input power per fan (kW)	9.85	6.04	4.49	3.07
Exhaust fan occupied input power per fan (kW)	30.74	30.74	24.32	24.32
Exhaust fan unoccupied input power per fan (kW)	30.74	18.88	23.55	15.14
Fan occupied annual runtime (hours)	8760	5840	4380	4380
Fan unoccupied annual runtime (hours)	0	2920	4380	4380
Supply fan annual energy use (kWh)	115,054	70,601	41,330	35,136
Exhaust fan annual energy use (kWh)	89,765	55,130	209,632	172,820
Cooling energy use (kWh)	45,406	38,595	55,636	51,280
Total energy use (kWh)	250,226	164,326	306,598	259,236
Total energy savings (kWh)		85,900		47,362

Building 4, Dining Hall - Add Scheduling Controls to AHU-1

Table 5-40 shows the tracking and evaluator baseline and post-case key parameters for the add scheduling controls to AHU-1 measure. The main driver for the reduced savings for this measure is due to the finding that the fan power draw when this constant volume unit is on is only 1.17 kW, rather than 3.41 kW that was used in the tracking calculations. The tracking calculations assumed a 100% load factor on 5 HP of fan motors. AHU-1 was found to include a 3 HP supply fan motor. We took spot measurements, and found that the average kW of the fan motor was 1.17 kW, which corresponds to 1.57 HP. This corresponds to a motor load factor on the 3 HP motor of 52%. The tracking calculations show that there is a 3HP supply fan motor, along with a 2 HP return fan motor. We did not notice a 2 HP return fan motor during the site visit. We did however measure kW that fed the entire unit, when the DX compressors were off, so if there were a return fan, it would have been included in the 1.17 measured kW.

Table 5-40. Tracking and evaluator baseline and post key parameters for measure 4

	Tracking		Evaluation	
Variable	**Baseline**	**Post**	**Baseline**	**Post**
Supply and Return Fan HP	5	5	3	3
Occupied Fan kW	3.41	3.41	1.17	1.17
Unoccupied Fan kW	3.41	1.02	0	0
Occupied Fan Annual Hours	8760	5,904	8,760	6,570
Unoccupied Fan Annual Hours	0	2,856	0	2,190
Fan Occupied Energy Use (kWh)	29,874	20,134	10,292	7,719
Fan Unoccupied Energy Use (kWh)	0	2922	0	0
Fan Total Energy Use (kWh)	29,874	23,056	10,292	7,719
Fan Energy Savings (kWh)		6,818		2,573
Cooling System Energy Use (kWh)	1,807	1,550	1,090	860
Cooling System Savings (kWh)		257		231
Fan and Cooling Energy Use (kWh)	31,681	24,606	11,382	8,579
Fan and Cooling Energy Savings (kWh)		7,075		2,803

Building 5, Office Building - Integrate VRF with BAS for Scheduling Control

The tracking energy savings were calculated by referencing the RI TRM for a savings factor per square feet for programmable thermostats.

Tracking Savings = 5,030 ft^2 x 0.539 kWh/ft^2

The evaluator concluded that this measure is resulting in 0 savings based on the following pieces of information:

1. The unoccupied measured kW usage for the two VRF units is higher during unoccupied hours than during occupied hours. See Figure 5-14.
2. A follow up question to the site contact about the data in Figure 5-14 resulted in the following response: “There are schedules in the system, but they appear to be occupied 24/7”.

Based on this response, along with the suggestive data shown in Figure 5-14, the evaluator is assigning 0 savings to this measure.

Table 5-41 summarizes the adjustments that were made to the savings estimates for each measure, broken down by administrative adjustments (differences between tracking database values, and tracking calculator values), methodology differences, and operational differences. Resultes for sampled and non-sampled results are presented. Operational differences are defined as differences driven by changes to variables within algorithms, based on observed data, whereas methodology adjustments are defined as differences driven by changes to the underlying algorithms themselves. There were no baseline adjustments, but an example of that would be changing from an in-situ baseline to a market, industry standard practice (ISP), or code baseline.

Table 5-41. Summary of Adjustment Factors by Measure

Measure #	Tracking Savings	Adjustment Factor				Evaluated Savings	Realization Rate	Comments
		Admin/ Tracking	**Baseline**	**Methodology**	**Operational**			
1 (large stratum, sampled)	189,275	0.0%	0	0	-72.1%	52,860	27.9%	Tracking savings excluded 76.1 kW of supply fan kW for 1,095 hours, year. This was due to an inadvertent omission in the calculations. Tracking savings showed a difference between unoccupied and occupied hours of 28.3 kW, whereas evaluato found a difference of 7.1 kW. Tracking assumed unoccupied h of 4,380, evaluator found 5,106 unoccupied hours.
2 (large stratum, sampled)	57,560	45.1%			20.5%	100,639	174.8%	Tracking claimed 1% chiller savings per °F in CWST reduction whereas evaluator claimed 1.3% and 1.7% for the centrifugal, reciprocating chillers, respectively.
3 (large stratum, sampled)	89,500	-4.0%			-44.9%	47,362	52.9%	Evaluator found more unoccupied hours that the fans ran at reduced speed compared to the tracking, but less reduction between occupied and unoccupied kW
4 (small stratum, sampled)	11,089	-36.2%			-60.4%	2,803	25.3%	Tracking calculations assumed 100% load factor on 5 HP of fa evaluator found 52% load factor on 3 HP fan.
5 (small stratum, sampled)	5,766	-53.0%			-100.0%	0	0.0%	Evaluator found no evidence of setbacks occurring, and site-contact stated that schedule was set to operate as occupied 2
2,4,5 (large stratum, non-sampled)	240,123	22.2%			-44.0%	164,361	68.4%	
6-24, 26-35, 37-46 (small stratum, non-sampled)	596,308	-5.5%			-71.4%	161,435	27.1%	
Total	**1,189,622**	**3.0%**	**0.0%**	**0.0%**	**-56.8%**	**529,460**	**44.5%**	

Ancillary impacts

No ancillary impacts were calculated for the projects analysed in this report.

RICE18C050

Program Administrator	National Grid	
Application ID(s)	6588264, 7682615, 7721844, 7959790, 7970786, 8003259	
Project Type	New construction lighting, existing building retrofit	
Program Year	2018	
Evaluation Firm	DNV	
Evaluation Engineer	Ryan Brown	
Senior Engineer	Stephen Carlson	

Evaluated site summary and results

The evaluated project was installed at a university campus and consisted of installing multiple measures across multiple buildings on campus. The projects involved the following measures categorized by application number:

6588264: High performance lighting design as part of a major renovation. Project savings are based on the comparison between the lighting proposal and building code for the identified space (1.20 W/sf for a university building, IECC 2012). The applicant proposal identified lighting fixtures but does not mention if controls are included.

7682615: Efficient transformers. A total of twenty-nine (29) existing dry transformers ranging from 15 to 225 kVA were replaced with high efficiency transformers of equivalent size. Project savings are based on the increase in efficiency between baseline and installed transformers.

7721844 & 8003259: Both measures represent duct sealant for building AHUs. Duct sealant reduces the air leakage rate to an assumed 5%. Application 7721844 represents 3 AHUs for one building and application 8003259 represents 1 AHU for a separate building.

7959790: Plug load controls for window AC units that implement a programmed schedule for units. Project savings are based on the reduction in operating hours as the controls reduced occupied peak and off-peak hours by 80%.

7970786: Kitchen exhaust controls. Project savings are based on the reduction in cfm due to demand control ventilation controls for kitchen exhaust.

The evaluation for this site was limited to a base scope with non-operational adjustments. Due to the COVID-19 pandemic, University occupancy has been severely cut as they took an online approach for classes. Due to this, the operational hours for all measures would be severely reduced compared to a typical year. Based on this information, the evaluation will only consider non-operational impacts such as quantity and technology changes.

The evaluators modelled energy savings based on the given inputs in the proposal, which were vetted on-site during the in-person audit. The site tracking estimated energy savings of 459,816 kWh, 47.2 on peak summer kW and 35.5 on peak winter kW. The evaluated savings are estimated to be 482,552 kWh. The evaluation results are presented in Table 5-42.

Table 5-42. 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)
6588264	**New construction lighting**	**Tracked**	14,941	88%	4.60	4.60
		Evaluated	7,000	69%	1.94	0.00
		Realization rate	47%	78%	42%	0%
Lighting Total	**Total**	**Tracked**	**14,941**	**88%**	**4.60**	**4.60**
		Evaluated	**7,000**	**69%**	**1.94**	**0.00**
		Realization rate	**47%**	**78%**	**42%**	**0%**
7682615	Highly efficient transformers	Tracked	130,912	46%	14.4	15.5
		Evaluated	133,642	37%	15.3	15.3
		Realization rate	102%	80%	106%	99%
7721844	Duct sealant	Tracked	129,483	46%	14.8	14.8
		Evaluated	169,141	46%	19.3	19.3
		Realization rate	131%	100%	130%	130%
8003259	Duct sealant	Tracked	93,778	46%	10.7	10.7
		Evaluated	93,778	46%	10.7	10.7
		Realization rate	100%	100%	100%	100%
7959790	AC plug load controls	Tracked	29,971	3%	6.98	0.00
		Evaluated	22,951	2%	0.00	0.00
		Realization rate	77%	67%	N/A	N/A
7970786	Kitchen exhaust controls	Tracked	60,731	46%	10.1	5.37
		Evaluated	56,040	100%	11.1	11.1
		Realization rate	92%	217%	110%	207%
Non Lighting Total	**Total**	Tracked	**444,875**	**43%**	**57.0**	**46.4**
		Evaluated	**475,552**	**48%**	**56.4**	**56.4**
		Realization rate	**107%**	**112%**	**99%**	**122%**
Site Total	**Total**	**Tracked**	**459,816**	**46%**	**61.6**	**51.0**
		Evaluated	**482,552**	**50%**	**58.3**	**56.4**
		Realization rate	**105%**	**109%**	**95%**	**111%**

N/A = Not applicable

Explanation of deviations from tracking

The evaluated savings are greater than the applicant reported savings, primarily due to a change in supply and outdoor air cfm for the duct sealant measure. Further details regarding deviations from the tracked savings are presented in Section 3-1.

Recommendations for program designers and implementers

Rather than applying a general operating schedule to the whole building, it is recommended to apply operating schedules to fixtures that coincide with the area type and control scheme installed. For this site, some areas such as classrooms and office spaces were found to be installed with occupancy control. Although IECC 2012 requires occupancy control to be installed to areas such as these, the annual operating schedule for these areas are expected to be reduced compared to the general schedule applied to the whole building. It is also recommended to clearly document referenced information when using Excel. There were several instances where cells used hard values that could not be tracked.

Customer alert

There are no customer alerts for this project.

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 information available. The project consisted of multiple measures including performance interior lighting as part of a major renovation to a building on campus, installing high efficient transformers, installing duct sealant for building AHUs, installing plug load controls for window AC units, and installing controls for kitchen exhaust fans.

Application information and applicant savings methodology

This section describes the application information, savings methodology provided by the applicant, and the evaluation assessment of the savings calculation algorithm used by the applicant. Both applicant and evaluated approaches calculated energy savings based on site findings and assumptions. Project savings were primarily based on the reduction in lighting power density (LPD) compared to code for the university building, reduction in use of equipment installed with controls, increase in efficiency for installed transformers, and decrease in air leakage due to installed duct sealant.

Applicant description of baseline

The applicant classified most measures as a retrofit with a single baseline with the pre-existing conditions assumed as the baseline throughout the measure life. Application 6588264 is the only measure processed as new construction where baseline is equivalent to code compliance for the identified building type. The baseline code used was 1.20 W/sf LPD for the university building, based on IECC 2012. Measures are broken down below:

6588264: High performance lighting design as part of a major renovation. The baseline code is based on IECC 2012 for the specified space (university building) – 1.2 W/sf.

7682615: Efficient transformers. A total of twenty-nine (29) existing transformers ranging from 15 to 225 kVA with “occupied” load efficiencies ranging between 87.8% and 94.3% and “unoccupied” load efficiencies ranging between 83.2% and 92%.

7721844 & 8003259: Both measures represent duct sealing for building AHUs. Baseline cfm leak rates are as follows: 7221844: AHU A – 23.7%, AHU B – 24.3%, AHU C – 26.5%. 8003259: 20.8%. Baseline cfm leaks are calculated based on measured duck leakage divided by the minimal design airflow for the system.

7959790: Plug load controls for window AC units. Baseline hours are 3,166 and equipment EER is assumed to be 10 for the pre-existing window ACs without controls.

7970786: Kitchen exhaust controls. Baseline hours are 8,760 and fans would run full load.

Applicant description of installed equipment and operation

The proposed conditions for each measure are outlined as follows:

6588264: High performance lighting design as part of a major renovation. The proposal consisted of installing 1,621 LEDs throughout the building. Fixtures ranged between 2 and 144 W and were proposed to operate for 5,680 annual hours. The proposal calculates to a LPD of 0.7 W/sqft. Control measure beyond what is required by code were not mentioned as part of the proposal.

7682615: Efficient transformers. A total of twenty-nine (29) transformers 1 for 1 transformer retrofits ranging from 15 to 225 kVA with "occupied" load efficiencies ranging between 97.1% and 98.8% and "unoccupied" load efficiencies ranging between 96.0% and 98.4%.

7721844 & 8003259: Both measures represent duct sealing for building AHUs. Proposed cfm leak rates are assumed to be 5% for all four AHUs between both applications.

7959790: Plug load controls for window AC units. Proposed hours range between 1,312 and 2,636.

7970786: Kitchen exhaust controls. Baseline hours are 4,693 as fans no longer run during the unoccupied period and fans would run controlled by variable speed drives.

Applicant energy savings algorithm

The applicant calculated savings using custom analysis spreadsheets for all measures. Methodology is broken down for each measure:

6588264: New construction lighting. The applicant savings calculations were based on the reduction in lighting power density (LPD) between code compliancy and installed equipment. Savings estimates are as follows:

$$Annual\ kWh = \frac{\Delta LPD * Area}{1{,}000} * Hours * Diversity\ Factor$$

$$LPD\ Proposed = \frac{\Sigma(Qty * W)}{Area}$$

Where,

$LPD\ baseline$	= 1.2 W/sqft
$LPD\ proposed$	= 0.7 W/sqft
$Area$	= 9,727 sqft
$Diversity\ Factor$	= 95%
$Hours$	= 3,255

Where the 95% diversity factor represents the fluctuation in annual operating hours for the space as a single operating schedule was applied to the whole building rather than using a space by space or usage group approach.

The equipment information can be noted in the Table 5-43. Lighting equipment proposed.

Table 5-43. Lighting equipment proposed

Lamp Type	Watts	Quantity
LED	39	43
LED	36	48
LED	47	11
Incandescent	180	9
LED	11	10
LED	20	7
LED	64.8	1
LED	97.2	2
LED	55	9
LED	55.2	2
LED	92	2
Total	697.2	144

7682615: Efficient transformers. Savings for the transformer measure were calculated as follows:

$$kWh_{savings} = A\ \Sigma\Delta Peak\ kWh + \Sigma\Delta Offpeak\ kWh$$

$Peak\ kWh = \Delta\ (Peak\ Occ\ hours * Occ\ kW\ Losses + Peak\ Unocc\ hours * Unocc\ kW\ Losses)$
$OffPeak\ kWh = \ \Delta(OffPeak\ Occ\ hours * Occ\ kW\ Losses + Offpeak\ Unocc\ hours * Unocc\ kW\ Losses)$

Occ kW losses and unocc kW losses for both existing and proposed cases are equal to the following:

Table 5-44. Transformer losses

Transformer size (kVA)	Existing kW loss during occupied periods	Existing kW loss during unoccupied periods	Proposed kW loss during occupied periods	Proposed kW loss during unoccupied periods
15	0.297	0.287	0.052	0.045
30	0.441	0.429	0.084	0.069
45	0.615	0.597	0.115	0.095
75	0.787	0.756	0.168	0.138
112.5	0.965	0.926	0.224	0.191
225	2.053	1.981	0.404	0.352

The occupied and unoccupied existing and proposed kW losses were calculated using the following formula:

$$kW_{loss,occ} = \frac{kVA_{rated} \times \%load_{occ}}{eff_{occ}} - \ kVA_{rated} \times \ \%load_{occ} \times Load\ Factor$$

$$kW_{loss,unocc} = \frac{kVA_{rated} \times \%load_{unocc}}{eff_{unocc}} - \ kVA_{rated} \times \ \%load_{unocc} \times Load\ Factor$$

Where the load factor is equal to 95%. The variables of the above formulas are defined as follows:

Table 5-45. Transformer algorithm variables

Transformer size (kVA) (kVA_{rated})	Load% during occupied periods ($\%load_{occ}$)	Load% during unoccupied periods ($\%load_{unocc}$)	Existing efficiency during occupied periods (eff_{occ})	Existing efficiency during unoccupied periods (eff_{unocc})	Proposed efficiency during occupied periods (eff_{occ})	Proposed efficiency during unoccupied periods (eff_{unocc})
15	15%	10%	88%	83%	98%	97%
30	15%	10%	91%	87%	98%	98%
45	15%	10%	91%	88%	98%	98%
75	15%	10%	93%	90%	98%	98%
112.5	15%	10%	94%	92%	99%	98%
225	15%	10%	94%	92%	99%	98%

7721844 & 8003259: Duct sealant. Both measures represent duct sealant for AHUs in separate buildings. Application ID 7721844 is for a classroom building with three AHUs while ID 8003259 is for a separate art building with 1 AHU. The savings methodology is based on the reduction in air leakage from the pre-existing measures air leak rate to an assumed rate of 5%. Savings do not include the reduction in cooling load, only the reduction in fan use. Savings algorithms are as follows:

$$Annual\ kWh = \Delta Fan\ kW * Hours$$
$$Pre\ Fan\ kW = (A * \%kW\ red + (1 - A) * \%kW\ red^3) * kW\ design$$
$$kW\ design = bhp * .746\ kw/bhp * .9$$
$$\%kW\ red = \%Post\ cfm\ red * (1 + (\Delta\%Leak))$$
$$\%Post\ cfm\ red = \frac{CFM\ supply}{CFM\ design}$$
$$Post\ Fan\ kW = (A * \%Post\ cfm\ red + (1 - A) * \%Post\ cfm\ red^3) * kW\ design$$

Where A refers to 30%. The kW calculations are split between static and dynamic pressures where 30% of the time is static and the remaining 70% is dynamic. The dynamic portion of the algorithm is the fan affinity law.

The variables for the above formulas are defined below:

Table 5-46. Duct sealant variables

Application	Unit	Pre cfm leak rate	Post cfm leak rate	bhp	kW reduction	Supply cfm	Design cfm
7721844	AHU A	23.70%	5%	33.8	77%	12,924	19,885
	AHU B	24.30%	5%	33.5	92%	14,602	18,980
	AHU D	26.50%	5%	37.8	80%	15,040	22,995
8003259	AHU 1	20.85%	5%	51.75	99%	44,141	50,000

7959790: AC plug load controls. This measure encompasses 11 buildings with similar equipment. Installed controls reduced unoccupied operating hours by 80%. Savings algorithms are as follows:

$$Annual\ kWh\ Savings = \frac{Cooling\ Load\ (MBH)}{EER} * \Delta(occ\ hours + unocc\ hours)$$
$$unocc\ hours\ post = unocc\ hours\ pre * 0.2$$

Hours are divided into temperature bins. Cooling load is calculated based on equipment for the 95 – 100 bin. Cooling load is assumed to be 100% of this value in the 95 – 100 bin, and there is assumed to be no cooling load below 60°F. Cooling load is linearly interpolated for the 8 temperature bins between these two points. Other bins reference the 95 – 100 bin cooling load cell and other cells to determine load for that bin, as shown in the cooling load equations.

$$Cooling\ Load\ (MBH)\ 95 - 100 = \frac{AC\ Load * Quantity}{1{,}000}$$

$$Cooling\ Load\ (MBH) < 95 - 100 = cooling\ load\ (bin\ above) - \frac{Cooling\ Load\ (MBH)\ 95 - 100}{8}$$

Where,

$AC\ Load$ = Rated Btu/hr from equipment nameplate

$Quantity$ = Number AC units left on overnight (unocc period), 106

EER = 10.5

7970786: Kitchen exhaust controls. Savings were calculated based on fan reductions for the dining and servings spaces as well as cooling load reductions for the servings space. Savings algorithms are as follows:

$$Savings = fan\ kWh + \frac{Cooling\ MBTU * 1000}{3{,}413}$$
$$fan\ kWh = (occ\ pre\ fan + unocc\ pre\ fan) - (occ\ post\ fan + unocc\ post\ fan)$$
$$occ\ pre\ fan = (Kitchen\ hood\ exhaust\ hp + Kitchen\ MAU\ hp) * .746 * \frac{0.7}{0.9} * (occ\ on\ peak\ hours + occ\ off\ peak\ hours)$$
$$unocc\ pre\ fan = (Kitchen\ hood\ exhaust\ hp) * .746 * \frac{0.7}{0.9} * (unocc\ on\ peak\ hours + unocc\ off\ peak\ hours * \%unocc\ off\ peak\ hours)$$
$$occ\ post\ fan = (Kitchen\ hood\ exhaust\ hp + Kitchen\ MAU\ hp) * .746 * \frac{0.7}{0.9} * (occ\ on\ peak\ hours + occ\ off\ peak\ hours) * (1 - cfm\ reduction)^{2.2/.98}$$
$$unocc\ post\ fan = 0$$
$$Cooling\ MBTU = (occ\ pre + unocc\ pre) - (occ\ post + unocc\ post)$$
$$occ\ pre\ cool\ consumption = Occ\ pre\ cool\ load * \frac{(occ\ on\ peak\ hours + occ\ off\ peak\ hours)}{COP}$$
$$unocc\ pre\ cool\ consumption = unocc\ pre\ cool\ load * \frac{(unocc\ on\ peak + unocc\ off\ peak\ hours)}{COP}$$
$$occ\ post\ cool\ consumption = Occ\ post\ cool\ load * \frac{(occ\ on\ peak + occ\ off\ peak\ hours)}{COP}$$
$$unocc\ post\ cool\ consumption = unocc\ post\ cool\ load * \frac{(unocc\ on\ peak + unocc\ off\ peak\ hours)}{COP}$$
$$Unocc\ cool\ load\ (pre\ and\ post) = 0$$
$$occ\ cool\ load\ pre = 4.5 * cfm * (OA\ enthalpy - RA\ enthalpy)/1000$$
$$occ\ cool\ load\ post = 4.5 * cfm * (1 - cfm\ reduction) * (OA\ enthalpy - RA\ enthalpy)/1000$$

Where 0.7/0.9 is assumed to refer to (motor load factor)/(motor efficiency).

$Kitchen\ hood\ exhaust\ hp$ = 6.5 for the kitchen, 12.5 for the servery
$Kitchen\ MAU\ hp$ = 20 for the kitchen
$\%\ Unocc\ Off\ peak\ hours$ = 64%, represents percent of time exhaust fans were running overnight based on data logging
$Cfm\ reduction$ = 26.2%
COP = 3.37
$OA\ Enthalpy$ = TMY data
$RA\ Enthalpy$ = 27.7 Btu/lb
Cfm = 24,100 for the kitchen, 900 for the servery

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

Evaluation assessment of applicant methodology

The applicant reported savings are derived from custom spreadsheets for each measure, and the evaluator determined the application calculation methodology reasonable as the proposed inputs were used correctly in the algorithms presented above.

Regarding the lighting measure, IECC 2012 code compliancy was an appropriate baseline in this case as the project design plans are dated in 2015 when IECC 2012 was still adapted. However, findings from the Rhode Island Commercial and Industrial Impact Evaluation of 2013-2015 Custom CDA Installations[21] study found that the energy code requirements for interior lighting power density is not reflective of current standard practices. The DNV GL team's analysis of interior LPD results, factoring in PA program participation, suggests that standard lighting practices exceed

[21] http://rieermc.ri.gov/wp-content/uploads/2019/05/ri_cda_programreport_final.pdf

the code requirements, which is mostly due to the increased penetration of LEDs. The findings from this study state that on average, the installed lighting LPDs were 0.78 times the code requirements for buildings permitted under IECC 2009. Though this result is for an older adoption of code, the recommendation to come out of the CDA study was to use this factor until a final LPD factor for IECC 2012 was determined under subsequent studies. Therefore, the evaluator deemed it reasonable to apply the 0.78 factor to the baseline code LPD for the evaluation analysis to adjust for the study findings.

Regarding the duct sealant measure, savings were mentioned to be based on collected trend data for the site RTUs which included cfm, temperature, and VFD flow. Savings were stated to reference average values from these trends, but the hard values in the Excel application files did not equate to the average. These references were updated in the evaluation.

Regarding the window AC measure, savings were determined based on calculated cooling load for the 95-100 °F temperature bin, which is assumed to be the design load. All other weather bins reference this cooling load to prorate remaining cooling load values up or down based on the temperature bins. Calculating cooling load using this method creates a linear trend between the minimum and maximum cooling loads and leads to a wide disparity between both values which may not be accurate. The applicant methodology may be overestimating savings using this proration method, but without measured values such as return air enthalpy, the evaluator cannot calculate total cooling load based on outdoor air temperature in a more appropriate way.

On-site inspection

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

Summary of on-site findings

The evaluators conducted a site visit on May 6, 2021. During the site visit, the evaluators interviewed the Associate Director of Facilities and Operation for the university and verified the installed measures. The site visit was spent interviewing the site contact, gathering building electrical plans to verify lighting, and auditing the installed lighting fixtures, transformers, and controls measures.

The evaluator used the lighting plans to easily break down the provided lighting proposal and determine a sample of fixtures on-site to visually verify, and to ensure the count on the plans is accurate. For the sample verified, the evaluator found the lighting plans to be precise in terms of quantity and fixture, so after the site visit the plans were used more thoroughly to ensure the rest of the fixtures were installed as specified. While on-site the evaluator found a handful of rooms such as offices and suites that were equipped with occupancy sensors. Though areas such as these are required per IECC 2012 to have occupancy controls, annual operating hours for these areas are expected to be reduced compared to the general schedule the applicant applied to the whole building.

The transformer measure was verified through a visual audit where the evaluator sampled a handful of buildings and verified the installation of the equipment. At least one transformer of every size was verified. All transformers installed were found to match the application for both size and quantity. During the analysis phase, the evaluator found that one transformer was included for a building in the applicant analysis file, but the savings for that building were not included in the total measure level savings. The savings algorithm for that building in the Excel file for the final tracking savings was not pulled into the associated column for the building. The evaluator confirmed that this transformer was installed on site. This change led to an increase in evaluated savings and is attributed to an administration error.

The duct sealing measures were verified by means of a visual audit. Rooftop duct work was identified with the Aeroseal sealant, and the site contact confirms further interior work within the return ducts were also sealed. Photos of the AHUs and nameplate information was also noted for both measures. For application 7721844, the applicant savings analysis was based off trend data for each of the three AHUs, which included supply cfm, outdoor air (OA) cfm, VFD speed, and wet and dry bulb temperatures. For the application, these trend points were used to inform the average trended supply and OA cfm, and to show the variation between temperature bins (though this information was used only for a visual aid). However, the evaluator noted the values used in the Excel algorithms were hard values that could not be easily traced. The Excel notes that the cells should refer to the average trended values for each variable, but they are noticeably off. The evaluator updated the methodology by referring to the trend data and used the average values for both supply and OA cfm over the trended period. The differences can be seen in Table 5-47. Duct sealing cfm differences below. Application 883259 did not have this trended information for the AHU, so the evaluation methodology was unchanged.

Table 5-47. Duct sealing cfm differences

Unit	Applicant Supply cfm	Evaluation Supply cfm	Tracking OA cfm	Evaluation OA cfm
AHU A	12,924	15,744	5,394	8,876
AHU B	14,602	15,744	6,095	8,876
AHU D	15,040	15,744	6,277	8,876

The window AC plug load control measures were verified by means of a visual audit, where all accessible buildings were verified for both quantity and technology. There were a handful of buildings that could not be accessed as they were being occupied by students in class or within dorms. Of the (11) buildings noted in the application to be installed with AC controls, the evaluator was able to audit (4) buildings. There were some buildings shown in the application that the site contact mentioned controls were not installed and should not have been listed. One of these buildings was even torn down years prior to when the application took place. This was further backed up by control operating schedules forwarded by the site contact where those three buildings mentioned were not listed. Of the buildings visited, the evaluator found a significant decrease in installed controls compared to the application. Most of the audited buildings did not have window ACs. There were a handful of buildings that had installed plug load controls, but the installed controller was installed separately and prior to the application and bought from Home Depot. These controllers were not the same as those installed through the application but operated in a similar fashion. As for the controls themselves, the plug load controllers were initially programmed individually through a smartphone. The site has intention to tie the controllers into their Siemens BAS system so they could be controlled more fluidly, but they haven't been able to do that yet. As of now, the operating schedules controlled have not been changed. Window ACs are of different sizes between buildings. For buildings such as dorms and the pre-school, the window ACs are the primary source of cooling so they will generally be larger compared to office spaces. Photos of accessible nameplate information for the windows ACs were noted when able. Regarding the analysis, the evaluator updated the quantity for the buildings observed. The site contact mentioned he would do an additional walkthrough for the remaining buildings once students vacated the campus, but the timing of the semester did not coincide with the timing of this site analysis so that information was not provided. The evaluator also updated the average EER for the units based on the observed nameplate information.

The kitchen exhaust controls were verified by means of a visual inspection. The evaluator verified the installed controller for the window hoods, the tie into the exhaust fans and MAU, and the installed temperature and opacity sensors. Photos and nameplate information were noted for the rooftop exhaust fans. It was confirmed that the temperature sensors monitor the exhaust temperature, which adjusts the fan stage. Opacity sensors help to determine when to increase/decrease fan speed based on contamination. For the analysis the evaluator updated the supply and exhaust cfm as well as motor HP for all MAU and exhaust fans based on nameplate data. The differences can be seen below in Table 5-48. Kitchen MAU cfm differences.

Table 5-48. Kitchen MAU cfm differences

Unit	Applicant cfm	Evaluation cfm	Applicant HP	Evaluation HP
EF1	5,800	4,771	1.5	1.5
EF2	5,800	5,015	1.5	1.5
EF3	4,700	5,571	1.5	1.5
EF4	3,900	1,330	1	1
EF5	3,900	1,232	1	1
Kitchen MAU	24,100	29,007	20	20
EF6	-	4,495	1.5	1.5
EF7	-	4,316	1	1
EF8	N.R.	1,486	N.R.	1
Servery MAU	900	2,188	5	5

Evaluation methods and findings

This section describes the evaluator methods and findings.

Evaluation description of baseline

The evaluator reviewed the project files and interviewed the site contact to gather information on the baseline. The evaluator determined that the transformer measure is a retrofit single baseline. All other measures besides the lighting measure are add on retrofit, as the underlying equipment is expected to outlive the useful life of the installed controls. The baseline for these measures is equivalent to the applicant reported baselines as presented in section 2.2. As for the lighting measure. the evaluator determined the measure is a new construction single baseline measure where the baseline is code compliancy for the area type established. In this case, code is 1.2 W/sf LPD for the university building based on IECC 2012. A factor will be applied to baseline LPD based on the findings of the Rhode Island Commercial and Industrial Impact Evaluation of 2013-2015 Custom CDA Installations study which suggest that standard lighting practices exceed code requirements. A 0.78 factor will be applied bringing the baseline LPD to 0.936 W/sf.

Evaluation calculation method

The evaluator calculated the savings using the same approach as the applicant but used verified parameters. Considering metering data could not be collected for this site due to changes in operation from COVID, operational impacts are not considered for this application. The savings equations used are presented below:

6588264: New construction lighting:

$$Annual\ kWh = \frac{\Delta LPD * Area}{1{,}000} * Hours * Diversity\ Factor$$

$$LPD\ Proposed = \frac{\Sigma(Qty * W)}{Area}$$

Where,

$LPD\ baseline$	= 1.2 *0.78 = 0.936 W/sqft
$LPD\ proposed$	= 0.70 W/sqft
$Area$	= 9,727 sqft
$Diversity\ Factor$	= 95%
$Hours$	= 3,255

Where the 95% diversity factor represents the fluctuation in annual operating hours for the space as a single operating schedule was applied to the whole building rather than using a space by space or usage group approach.

7682615: Efficient transformers. Savings for the transformer measure were calculated as follows:

$$kWh_{savings} = Annual\ kWh = \Sigma\Delta Peak\ kWh + \Sigma\Delta Offpeak\ kWh$$

$$Peak\ kWh = \Delta\ (Peak\ Occ\ hours * Occ\ kW\ Losses + Peak\ Unocc\ hours * Unocc\ kW\ Losses)$$

$$OffPeak\ kWh = \Delta(OffPeak\ Occ\ hours * Occ\ kW\ Losses + Offpeak\ Unocc\ hours * Unocc\ kW\ Losses)$$

$$kW_{loss,occ} = \frac{kVA_{rated} \times \%load_{occ}}{eff_{occ}} - kVA_{rated} \times \%load_{occ} \times Load\ Factor$$

$$kW_{loss,unocc} = \frac{kVA_{rated} \times \%load_{unocc}}{eff_{unocc}} - kVA_{rated} \times \%load_{unocc} \times Load\ Factor$$

Where the load factor is equal to 95%. Values for transformer losses and other variables are shown in Table 5-44. Transformer losses and

Table 5-45. Transformer algorithm variables. The only difference between the applicant and evaluation is the quantity.

7721844 & 8003259: Duct sealant. Savings algorithms are as follows:

$$Annual\ kWh = \Delta Fan\ kW * Hours$$
$$Pre\ Fan\ kW = (A * \%kW\ red + (1 - A) * \%kW\ red^3) * kW\ desig$$
$$kW\ design = bhp * .746 * .9$$
$$\%kW\ red = \%Post\ cfm\ red * (1 + (\Delta\%Leak))$$
$$\%Post\ cfm\ red = \frac{CFM\ supply}{CFM\ design}$$
$$Post\ Fan\ kW = (A * \%Post\ cfm\ red + (1 - A) * \%Post\ cfm\ red^3) * kW\ design$$

Where A refers to 30%. The kW calculations are split between static and dynamic pressures where 30% of the time is static and the remaining 70% is dynamic. The dynamic portion of the algorithm is the fan affinity law. Variables for the above equations are presented in the following table.

Table 5-49. Duct sealant variables

Application	Unit	Pre cfm leak rate	Post cfm leak rate	bhp	kW reduction	Supply cfm	OA cfm	Design cfm
7721844	AHU A	23.70%	5%	33.8	93%	15,744	8,876	19,885
	AHU B	24.30%	5%	33.5	99%	15,744	8,876	18,980
	AHU D	26.50%	5%	37.8	83%	15,744	8,876	22,995
8003259	AHU 1	20.85%	5%	51.75	99%	44,141	24,884	50,000

7959790: AC plug load controls. Savings algorithms are as follows:

$$Annual\ kWh\ Savings = \frac{Cooling\ Load\ (MBH)}{EER} * \Delta(occ\ hours + unocc\ hours)$$
$$unocc\ hours\ post = unocc\ hours\ pre * .2$$
$$Cooling\ Load\ (MBH)\ 95 - 100 = \frac{AC\ Load * Quantity}{1{,}000}$$
$$Cooling\ Load\ (MBH) < 95 - 100 = cooling\ load\ (bin\ above) - \frac{Cooling\ Load\ (MBH)\ 95 - 100}{8}$$

Hours are divided into temperature bins. Cooling load is calculated based on equipment for the 95 – 100 bin. Other bins reference this cell and other cells to determine load for that bin, as shown in the cooling load equations.

Where,

$AC\ Load$	= Rated Btu/hr from equipment nameplate
$Quantity$	= Number AC units left on overnight (unocc period), 90
EER	= 10.5

7970786: Kitchen exhaust controls. Savings algorithms are as follows:

$$Savings = fan\ kWh + \frac{Cooling\ MBTU * 1000}{3{,}413}$$
$$fan\ kWh = (occ\ pre\ fan + unocc\ pre\ fan) - (occ\ post\ fan + unocc\ post\ fan)$$
$$occ\ pre\ fan = (Kitchen\ hood\ exhaust\ hp + Kitchen\ MAU\ hp) * .746 * \frac{.7}{.9} * (occ\ on\ peak + occ\ off\ peak\ hours)$$
$$unocc\ pre\ fan = (Kitchen\ hood\ exhaust\ hp) * .746 * \frac{.7}{.9} * (unocc\ on\ peak + unocc\ off\ peak\ hours * \%unocc\ off\ peak\ hours)$$
$$occ\ post\ fan = (Kitchen\ hood\ exhaust\ hp + Kitchen\ MAU\ hp) * .746 * \frac{.7}{.9} * (occ\ on\ peak + occ\ off\ peak\ hours) * (1 - cfm\ reduction)^{2.2/.98}$$
$$unocc\ post\ fan = 0$$
$$Cooling\ MBTU = (occ\ pre + unocc\ pre) - (occ\ post + unocc\ post)$$
$$occ\ pre\ cool\ consumption = Occ\ pre\ cool\ load * \frac{(occ\ on\ peak\ hours + occ\ off\ peak\ hours)}{COP}$$

$$unocc\ pre\ cool\ consumption = unocc\ pre\ cool\ load * \frac{(unocc\ on\ peak + unocc\ off\ peak\ hours)}{COP}$$

$$occ\ post\ cool\ consumption = Occ\ post\ cool\ load * \frac{(occ\ on\ peak + occ\ off\ peak\ hours)}{COP}$$

$$unocc\ post\ cool\ consumption = unocc\ post\ cool\ load * \frac{(unocc\ on\ peak + unocc\ off\ peak\ hours)}{COP}$$

$$Unocc\ cool\ load\ (pre\ and\ post) = 0$$

$$occ\ cool\ load\ pre = 4.5 * cfm * (OA\ enthalpy - RA\ enthalpy)/1000$$

$$occ\ cool\ load\ post = 4.5 * cfm * (1 - cfm\ reduction) * (OA\ enthalpy - RA\ enthalpy)/1000$$

Where .7/.9 is assumed to refer to (motor load factor)/(motor efficiency).

$Kitchen\ hood\ exhaust\ hp$ = 6.5 for the kitchen, 3.5 for the servery
$Kitchen\ MAU\ hp$ = 20 for the kitchen, 5 for the servery
$\%\ Unocc\ Off\ peak\ hours$ = 64%, represents percent of time exhaust fans were running overnight due to data logging
$Cfm\ reduction$ = 26.2%
COP = 3.37
$OA\ Enthalpy$ = TMY data
$RA\ Enthalpy$ = 27.7 Btu/lb
Cfm = 29,007 for the kitchen, 2,188 for the servery

Final Results

The evaluated savings for the project were greater than the applicant reported savings mostly due to a change in cfm for the duct sealant measure, as the evaluator updated applicant fixed cfm numbers in the applicant spreadsheet to use the applicant reported trend data for the AHUs instead. Main factors impacting savings are shown below for each measure.

Table 5-50. Main factors impacting savings

Measure	Factor	Applicant	Evaluation
Lighting	Baseline LPD (W/sf)	1.20	0.936
Lighting	Proposed LPD (W/sf)	.703	.703
Lighting	Quantity	144	144
Lighting	Proposed kW	6.84	6.84
Lighting	Hours	3,255	3,255
Lighting	Building area (sf)	9,727	9,272
Transformers	Quantity	28	29
Duct sealant	AHU A supply cfm	12,924	15,744
Duct sealant	AHU B supply cfm	14,602	15,744
Duct sealant	AHU D supply cfm	15,040	15,744
Duct sealant	AHU 1 supply cfm	44,141	44,141
Duct sealant	AHU A OA cfm	5,394	8,876
Duct sealant	AHU B OA cfm	6,095	8,876
Duct sealant	AHU D OA cfm	6,277	8,876
Duct sealant	AHU 1 OA cfm	24,884	24,884
AC Plug load	Quantity	106	90
AC Plug load	EER	10	10.5
Kitchen controls	EF1 cfm	5,800	4,771
Kitchen controls	EF2 cfm	5,800	5,015
Kitchen controls	EF3 cfm	4,700	5,571
Kitchen controls	EF4 cfm	3,900	1,330
Kitchen controls	EF5 cfm	3,900	1,232
Kitchen controls	Kitchen MAU cfm	24,100	29,007
Kitchen controls	EF6 cfm	-	4,495
Kitchen controls	EF7 cfm	-	4,316

Measure	Factor	Applicant	Evaluation
Kitchen controls	EF8 cfm	N.R.	1,486
Kitchen controls	Servery MAU cfm	900	2,188
Kitchen controls	EF1 hp	1.5	1.5
Kitchen controls	EF2 hp	1.5	1.5
Kitchen controls	EF3 hp	1.5	1.5
Kitchen controls	EF4 hp	1	1
Kitchen controls	EF5 hp	1	1
Kitchen controls	Kitchen MAU hp	20	20
Kitchen controls	EF6 hp	1.5	1.5
Kitchen controls	EF7 hp	1	1
Kitchen controls	EF8 hp	N.R.	1
Kitchen controls	Servery MAU hp	5	5

Explanation of differences

The evaluated overall site level savings are greater than the tracked savings. Table 5-51 and Table 5-52. Summary of deviations Non-Lighting provides a summary of the differences between tracking and evaluated values for both lighting and non-lighting measure groups.

Table 5-51. Summary of deviations Lighting

End-use	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
Lighting	Baseline	LPD	-53%	Decrease in savings due to the change in baseline LPD. The evaluator applied a .78 factor to code LPD, which is based on the findings from the Rhode Island Commercial and Industrial Impact Evaluation of 2013-2015 Custom CDA Installations report that suggests standard practices outpace code LPD.

Table 5-52. Summary of deviations Non-Lighting

End-use	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
Transformers	Administrative	Quantity	+<1%	Increase in savings due to an admin error where the quantity of transformers for one building was incorrectly referenced in the summary table for measure savings.
Duct sealant	Methodology	cfm	+9%	Increase in savings due to a change in methodology where the evaluator referenced the AHU trended data for both supply and OA cfm.
AC Plug load controls	Quantity	Quantity	-1%	Decrease in savings due to a change in installed quantity.
AC Plug load controls	Technology	EER	-<1%	Decrease in savings due to a change in equipment EER.
Kitchen controls	Technology	HP & cfm	-1%	Decrease in savings due to a change in equipment cfm and HP.

Ancillary impacts

There are no ancillary impacts associated with this measure.

RICE18C094

Program Administrator	National Grid
Application ID(s)	7574458
Project Type	Existing building retrofit
Program Year	2018
Evaluation Firm	DNV GL
Evaluation Analysis Type	Non-Ops only
Evaluation Engineer	Ryan Brown
Senior Engineer	Srikar Kaligotla

1 Evaluated Site Summary and Results

The facility is part of a chain of coffee and donut shops, generally known as quick-serve restaurants. The facility operated 24 hours pre-pandemic, but the site has had to adapt by reducing hours by over half. Currently, the facility allows people to come into the building to order food, but they aren't allowed to stay to sit down and eat within the restaurant. The project consisted of installing three measures: (1) RTU setback controls & kitchen appliance controls, (2) refrigeration controls, and (3) retrofit lighting and occupancy controls. Considering the impact on facility operation and building load due to the COVID-19 pandemic, this site evaluation will only consider non-operational impacts as part of the discrepancy analysis.

The kitchen appliance and RTU controls represent an add on control system designed to schedule certain pieces of equipment from manual operation (on, idle, off) to a specific schedule when the equipment is needed for use (on, idle) and off when the site is closed or during periods of low traffic. The application also included an RTU portion where savings were calculated due to temperature setbacks. The project was developed based on a joint 2016 pilot study conducted by Eversource and National Grid ("PA Pilot"), which was performed at a sample of six locations to establish a general savings value for the measure. A separate pilot study was performed at a different quick-serve restaurant chain to establish general RTU savings. Savings were averaged between the site participants and rolled into a general savings package based on the control strategies and RTUs incorporated. This study concluded that the appliance portion of the measure generated 18,700 kWh in annual savings with 500 kWh/year for each controlled RTU. The control system features local overrides switches for the kitchen appliances. This enables the site staff to manually override the control settings for approximately 30 minutes for each instance. For the RTUs, the measure also involves setpoint changes in the heating season. However, no natural gas savings were included in the tracking savings – and subsequently not included in the evaluator's analysis for this electric-only site. This measure is the same that was also considered during previous evaluation efforts (MA19C03-E-SBIMPCT and MA19C07-E-CUSTELEC).

Refrigeration improvements included two walk-ins (one cooler and one freezer) that received several energy efficiency retrofits, including EC motor replacements, evaporator fan controls, anti-condensate door heater controls, demand-based defrost, and direct digital temperature controls for setback and shut down controls. Details on measure impacts are discussed further in the applicant savings section.

The final measure is a retrofit lighting measure where pre-existing lamps and fixtures were replaced with LEDs for interior and exterior spaces. Occupancy-based sensors were also installed in two areas (restroom and office spaces). kWh savings are attributed to the reduction in wattage from the fixture and bulb replacement and the reduction in operating hours due to controls.

The site tracking estimated energy savings of 42,781 kWh, 4.49 on peak summer kW, and 5.64 on peak winter kW. The evaluation kWh savings estimate is 28,083 kWh, yielding a 66% realization rate. Site results are compared to the tracking system estimates in

Table 5-53. Evaluation Results Summary below.

Table 5-53. 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)
7574458	**RTU setback & kitchen equipment controls**	**Tracked**	19,200	46%	3.33	1.68
		Evaluated	2,870	91%	1.59	1.78
		Realization Rate	15%	198%	48%	106%
7574458	Refrigeration controls	**Tracked**	9,301	46%	0.96	0.96
		Evaluated	10,076	46%	0.70	0.70
		Realization Rate	108%	100%	73%	73%
7574458	Lighting Retrofit	Tracked	14,129	27%	0.20	3.00
		Evaluated	14,887	36%	0.23	3.00
		Realization Rate	105%	115%	113%	100%
7574458	Lighting Controls	Tracked	151	N.R.	N.R.	N.R.
		Evaluated	250	25%	0.00	0.00
		Realization Rate	164%	N/A	N/A	N/A
Totals		**Tracked**	**42,781**	**40%**	**4.49**	**5.64**
		Evaluated	**28,083**	**50%**	**2.52**	**5.48**
		Realization Rate	**66%**	**125%**	**56%**	**97%**

NR = Not reported by program

1.1 Explanation of Deviations from Tracking

The evaluated savings are 34% less than the applicant-reported savings primarily due to the change in methodology for the kitchen appliance control measure as the evaluator used appliance profiles specific to the site from the PA pilot[22] data rather than general averages. Further details regarding deviations from the tracked savings are presented in Section 3-4.

1.2 Recommendations for Program Designers & Implementers

In previous MA evaluation efforts (MA19C03-E-SBIMPCT and MA19C07-E-CUSTELEC), the tracking savings associated with the kitchen appliance measure for coffee and donut shops have been found to be significantly overestimated. In response to the evaluated sample, DNV conducted an ad hoc study to determine a more appropriate deemed savings estimate for this measure moving forward. For future projects where this measure is proposed, it is recommended to use the deemed savings value of 5,344 kWh for kitchen appliance controls as stated in the MA20C07-E-DUN study.

1.3 Customer Alert

There are no customer alerts.

2 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.

[22] https://ma-eeac.org/wp-content/uploads/MA20C07-E-DUN-Final-Report.pdf

The project consisted of installing several retrofit control measures, including RTU temperature setback, kitchen appliance scheduling, refrigeration controls, and retrofitting pre-existing interior and exterior lighting.

2.1 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: both applicant and evaluated approaches calculated energy savings based on on-site findings and assumptions.

Appliance Control:

The application folder did not include site-specific savings methodology. Instead, the tracking savings were established from the PA Pilot study[22] completed in MA. This pilot consisted of installing the measure in six locations, three from each PA. Before the controls were activated, baseline energy consumption was collected, on average, for 14 days. Similarly, post-implementation energy consumption was collected for a similar period. The results were extrapolated to a full calendar year with the annual electrical savings for each site calculated from:

- $\text{Savings}|_{\text{Site 1-6}} = \text{Baseline}|_{\text{Site 1-6}} – \text{Post-Implementation}|_{\text{Site 1-6}}$

The appliance tracking savings were calculated from the average savings from the six sites. The PA Pilot noted that one site was excluded from the average, but we found the averaging formula to include all six sites and resulted in:

- Base Plus Savings (the top 8-10 Loads) = **18,700 kWh/Year**

RTU Setback Control:

The RTU savings were derived from a pilot study of RTUs in a different store brand. This study and the adjustments to align more closely with the perceived RTUs in this franchise resulted in annual savings of 500 kWh per RTU controlled. The evaluator was not involved with the PA Pilot study. However, we understand the adjustment based on capacity or size differences between the RTUs in the two chains. The PA Pilot produced the following tracking savings, which was applied to all incentive applications for this measure, as follows:

- RTU Savings = **500 kWh/Year** per RTU being controlled

For example, a site that includes the control of three RTUs, the overall tracking savings supplied by the PA are 20,200 kWh/year (See Table-1-1 for site-specific information)

Refrigeration Improvements:

The evaluator had access to the applicant's savings calculation model and confirmed that the parameters used for run-time and kW ratings were consistent with the Massachusetts Technical Reference Manual (MA TRM) for the 2016-2018 program period. The evaluator used the applicant calculation model as the basis for the evaluation – and used the pre-data in this model as the evaluated baselines.

2.2 Applicant Description of Baseline

The RTU setback and kitchen appliance measure were submitted as an add-on retrofit measure with a measure life of 5 years. The refrigeration controls were submitted as a retrofit measure with a measure life of 13 years. The applicant defined the baseline for appliance control as the average pre-existing conditions of the six sites included in the PA Pilot. The baselines for the RTUs were derived from the pilot study for a different chain and applied to this customer's chain, scaled down to reflect size variations. The baselines for the refrigeration controls were based on site-specific pre-existing conditions.

Table 5-54. Applicant baseline key parameters

		BASELINE		
Measure	Parameter	Value(s)	Source of Parameter Value	Note

Appliance Controls	Pre-existing conditions	Equipment is turned on/off manually	PA Pilot	Same Chain
RTUs	Setpoints	72F Cooling/68 Heating	PA Pilot	Different Chain
Refrigeration improvements	Evaporator fan annual run time	8,760 hours	Applicant	MA TRM
	Compressor fan load and annual run time (compressor motor + condenser fans)	3.22 kW & 4,072 hours (Summer) and 1.86 kW & 2,195 hours (Winter) = 25,191 kWh/yr	Applicant	MA TRM
	Evaporator fan motor load	0.436 kW (0.133 kW for cooler and 0.304 kW for freezer)	Applicant	MA TRM
	Cooler/freezer door heater load and operating profile	0.46 kW operating continuously 8,760 hours per year	Applicant	MA TRM
	Freezer defrost optimization	974 hours per year @ 2 kW	Applicant	MA TRM
	Motor load	4,730 hours per year @ 0.436 kW	Applicant	MA TRM

The applicant measure type for the lighting application is Retrofit. The retrofit installation was performed throughout the tenant space. The baseline condition for the 52 fixtures was a mix of T8 and T12 fluorescents and some LED fixtures. Assumed annual operating hours were either 4,380 or 8,760 for exterior and interior fixtures, respectively. Applicant documentation does not state if lighting controls were present as a baseline condition.

2.2.1 Applicant Description of Installed Equipment and Operation

This section will describe the proposed condition assumed in the application analysis. It will only discuss the assumptions made in the original analysis, not any information gained through this evaluation. Included will be information on the source of all key model inputs used if known.

Table 5-55. Applicant proposed key parameters

Measure	Parameter	Value(s)	Source of Parameter Value	Note
Appliance Controls	EMS Controls	Equipment is controlled on equipment-specific schedule	PA Pilot	Same Chain
RTUs	Setpoints	500 kWh savings per RTU	PA Pilot	Different Chain
Refrigeration improvements	Evaporator fan annual run time[23]	4,036 hours per year (Freezer and Cooler)	Applicant	MA TRM
	Compressor fan load reduction (compressor motor + condenser fans)	5% annual load reduction: 1,260 kWh/yr	Applicant	MA TRM
	Evaporator fan motor load	0.17 kW (65% load reduction)	Applicant	MA TRM
	Cooler/freezer door heater load and off hours per year	Freezer: 4,066 hours @ 0.230 kW; Cooler: 6,504 hours @ 0.230 kW	Applicant	MA TRM
	Freezer defrost optimization	hours defrost can be turned off: 341 hours/year (35%)	Applicant	MA TRM
	Motor load	4,730 hours per year @ 0.283 kW (65%)	Applicant	MA TRM

[23] The hours given for this parameter are attributed to the cycling evaporator fan control measure. There is another measure (ECM for evaporator fans) that utilizes evaporator fan run time. That measure assumes the run time is 4,730 hours for both cooler and freezer

The proposed condition for the lighting retrofit consisted of replacing all baseline fixtures with LEDs. Hours of operation were stated to be either 4,380 or 8,760, equivalent to the baseline condition. Occupancy controls were proposed to be installed in the restroom and office spaces, where a 24% reduction was applied to the operating hours.

2.2.2 Applicant Energy Savings Algorithm

The project documents include spreadsheet calculation files for all measures.

RTU & Kitchen Equipment Controls:

The tracking savings were derived from an average of the total savings from the six sites that participated in the PA pilot. These savings were derived for pre and post-energy logging (derived from current measurements applied to an average voltage reading and an assumed power factor) for a period of 14 days. The annual pre and post energy consumption was calculated from prorating the pilot period energy consumption into a full calendar year as follows:

$$\text{Annual Savings} = \frac{(\text{kWh Savings})_{\text{14-day pilot}} \times 360 \text{ days/year*}}{14 \text{ days}}$$

*The pilot assumed that each store was closed a total of five days per year

The RTU savings were derived from a pilot study of RTUs in a different store brand. This study, along with adjustments to align more closely with the perceived RTUs in this franchise, resulted in a savings of 500 kWh/year per controlled RTU. NOTE: RTU tracking savings represent less than 3% of the total tracking savings reported for this measure.

Refrigeration Controls:

- EC motor retrofit savings assume a **65%** reduction in input power for replacing pre-retrofit SP/PSC motors.
- Cycling evaporator fan control savings are based on a reduction in operating hours of **54%.**
- Anti-condensate heater control savings are based on a reduction in the run-time of **65%** for the freezer and **60%** for the cooler
- Electric defrost demand-based control savings are based on a reduction in operating of **35**%
- Direct digital temperature control savings are estimated assuming a **5**% reduction in compressor energy use. This is the result of reduced cooling loads from space temperature setbacks. Additional energy savings due to reduced evaporator loads are estimated to be **5**% for evaporator fan annual operating hours.

The applicant calculated the lighting retrofit savings using a custom lighting analysis spreadsheet provided by the Program Administrators using the findings from the lighting audit as inputs. The tool determines energy savings by using the following formulas.

Baseline Fixture kWh = $\frac{Quantity_B * Wattage_{\boldsymbol{B}}}{1000} * Operating\ Hours\ without\ controls$

Proposed Fixture kWh = $\frac{Quantity_P * Wattage_{\boldsymbol{P}}}{1000} * Operating\ Hours\ without\ controls$

Fixture kWh Savings = $Baseline\ Fixture\ kWh\ - Proposed\ Fixture\ kWh$

Control kWh Savings = $Proposed\ Fixture\ kW\ * (\ Operating\ Hours\ without\ controls * \%\ Estimated\ Reduction)$

Estimated Hour Reduction %: Occupancy Sensor – 24%

Total kWh Savings = $Fixture\ kWh\ Savings + Control\ kWh\ Savings$

Additional details on the applicant algorithm could be found in the project files. **Table 5-56. Tracking System Fixture Inputs and kWh Savings** below shows the tracking system inputs and savings calculations for the lighting retrofit.

Table 5-56. Tracking System Fixture Inputs and kWh Savings

	A	B	C	D	E	G=A*B*E/1000	H=C*D*E/1000	I=((C*D)-(C*D*76%))*E/1000	J=H-G+I
Space Type	Baseline Quantity	Baseline Watts per Fixture	Installed Quantity	Installed Watts per Fixture	Annual Hours	Baseline kWh	Installed kWh	Control kWh Savings	Total Fixture Savings
OFFICE*	1	36	1	36	8,760	315	315	76	0
RESTROOM*	1	36	1	36	8,760	315	315	76	0
MENU LIGHTS	4	60	4	22	8,760	2,102	771	0	1,331
SLOP SINK	1	60	1	24	8,760	526	210	0	315
SOFFIT 3'	3	66	3	36	4,380	867	473	0	394
SOFFIT 6'	12	125	12	50	4,380	6,570	2,628	0	3,942
SOFFIT 8'	4	113	4	36	4,380	1,980	631	0	1,349
DRIVE THRU MENU	6	90	2	44	4,380	2,365	385	0	1,980
BUILDING	10	90	2	300	4,380	3,942	2,628	0	1,314
STREET PYLON SIGN	10	90	2	50	4,380	3,942	438	0	3,504
Total	**52**		**32**			**22,924**	**8,795**	**151**	**14,129**

*Area proposed with controls.

2.2.3 Evaluation Assessment of Applicant Methodology

Appliance and RTU Controls:

The savings methodology used by the applicant (PA Pilot) did not consider the appliance and RTU mix involved in the control scheme when establishing baselines. Instead, the baselines were established by averaging site-level savings – without considering the variations in equipment types and operating hours from site to site.

The evaluation also used the PA Pilot as a source for both baselines and post-implementation data. However, the evaluator considered the unique equipment mix of the evaluated site and extracted baselines and post-implementation profiles from the same equipment types in the PA Pilot data set.

Refrigeration Improvements:

The refrigeration measures follow the MA TRM, based on the applicant's controls platform and experience with the control and ECM motor replacement measures covered in this application. The evaluator was able to validate the applicant's assumptions about the freezer and cooler nameplate data. The evaluator could not validate the applicant's baseline assumptions, including whether it is reasonable for the compressors, condenser fans, and evaporator fans to have pre-run-times of 8,760 hours per year.

It is important to mention that the freezer and cooler boxes are connected, with freezer access through the cooler only. Both refrigerated boxes are located inside conditioned space, and the condensing units (compressor and condenser) for both the freezer and cooler are located on top of the boxes - rejecting heat into the ceiling plenum. This heat is channeled to the outside via passive ductwork. This is an important consideration since the normally strong correlation between refrigeration energy and outdoor ambient conditions does not apply in this case. For example, the evaluator found the cooler energy consumption to be more a function of door openings than the outdoor dry bulb temperature.

Lighting Retrofit:

The applicant correctly used the eTRM algorithms and the custom lighting tool, and the evaluator determined the application calculation methodology to be reasonable.

2.3 On-Site Inspection and Metering

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

2.3.1 Summary of On-site Findings

The evaluators conducted an in person site visit on February 22, 2020. During the site visit, the evaluator interviewed the store energy manager and verified the applicant's inputs by performing a site audit.

Appliance and RTU Controls:

Regarding the appliance controls measure, the evaluator confirmed the appliance types controlled. Each EMS panel labeled the auxiliary panels and circuits/appliances controlled. The evaluator cross-referenced this label with each of the (3) electrical panels to verify the circuits and appliances of the (3) panels, (2) matched with the EMS panel. Panel A may have been labeled incorrectly as the circuits identified in the panel label did not match the intended appliances from the EMS panel. For example, where the EMS identified a turbo chef, panel A lists a drive-through refrigerator. Considering the evaluator did not have an electrician accompanying him, the dead front cover was not removed to see the EMS CTs. To be conservative, the evaluator will use the EMS labeled appliances to develop savings profiles. The evaluator also confirmed the site has (2) RTUs, each installed with the setpoint controls identified in the application. This is different from the application where savings are associated with only (1) RTU.

Refrigeration Improvements:

The refrigeration measures were confirmed by performing a visual audit while also taking photos of nameplates and motor information. The evaluator confirmed the site has (3) motors, (1) in the cooler and (2) freezer for each evaporator fan. Motors were confirmed to be 1/20 hp. The evaluator assessed the baseline information with the site contact, who confirmed the present information in the application and the run-time hours for the proposed condition. The evaluator found that there was a discrepancy in the analysis where a quantity of (2) motors were shown to be replaced with EC motors as opposed to the reported (3) that was observed on-site for each evaporator fan. This was corrected for in the evaluation analysis. Nameplate information was also used to update the characteristics of the cooler and freezer evaporator fans such as amperage.

Lighting Retrofit:

The evaluator performed a visual audit to confirm the lighting installation. All applicant LED counts were found to match the proposed quantity. There was one space, however (restroom), where a proposed occupancy sensor was not installed. However, one of the back areas did install an occupancy sensor which increased control savings. This sensor was confirmed to have been installed with the lighting project. So overall, (5) fixtures were found to be controlled via occupancy sensors compared with the (2) fixtures proposed to be controlled in the application. To consider HVAC interaction, the evaluator confirmed the site used (2) DX rooftop units that use electricity for cooling and natural gas for heating.

2.4 Evaluation Methods and Findings

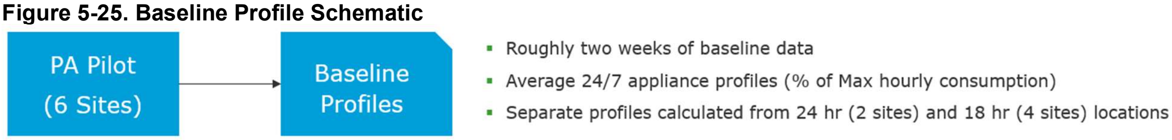
This section describes the evaluator methods and findings.

2.4.1 Evaluation Description of Baseline

Appliance Control:

The baselines for the kitchen appliances were derived from the PA Pilot. The baselines from this pilot date back to February/March 2016, assuming that the general consumption patterns for appliances are not subject to seasonal variations. That may be true relative to weather-related dependencies, but we suspect that some appliances, such as coffee makers, may exhibit seasonal variations with more ice coffee consumed during the summer months and more hot coffee in the colder months of the year. We contacted the seller and distributor/installer of the EMS, and they confirmed that their go-to-market model generally precludes collecting appliance pre-data. We developed a baseline profile for each applicable equipment type from EMS data supplied as part of the PA Pilot. This data was then used to develop utilization profiles for each appliance type by taking the average hourly kW divided by the maximum hourly kW value into the PA Pilot data set. We calculated an average utilization profile for each group of similar appliance types, as illustrated in Figure 1 below.

Figure 5-25. Baseline Profile Schematic



The resulting library of profiles is listed in Table 6, with examples shown in Figure 2. Note a key attribute of these profiles is the number of hours a location is open each day (i.e., 18 hours, 24 hours).

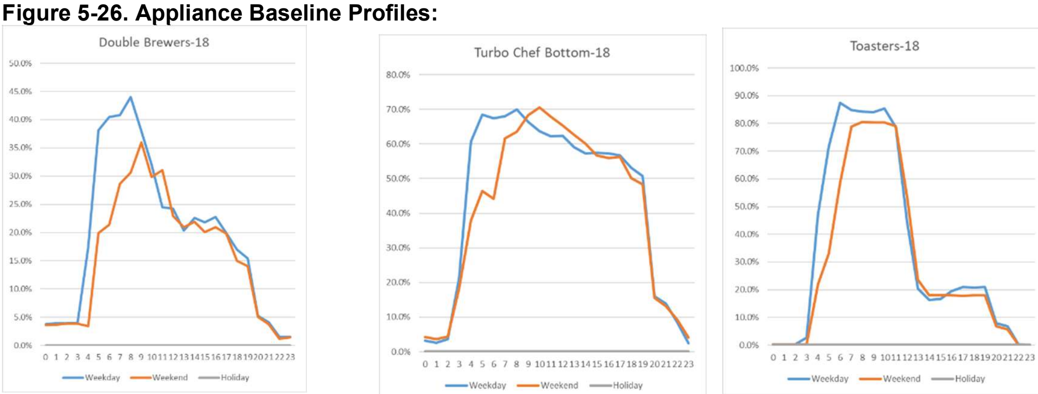
Table 5-57. Baseline and post profile library

Profile No.	Profile	Period	Source
1	Toasters	Baseline	All PA Pilot Sites
2	Turbo Chef Bottom	Baseline	All PA Pilot Sites
3	Turbo Chef Top	Baseline	All PA Pilot Sites
4	Double Brewers	Baseline	All PA Pilot Sites
5	Single Brewer	Baseline	All PA Pilot Sites
6	Ice Coffee Maker	Baseline	All PA Pilot Sites
7	Ice Machines	Baseline	All PA Pilot Sites
8	Hot Chocolate	Baseline	All PA Pilot Sites
9	Outdoor Lights	Baseline	All PA Pilot Sites
10	Turbo Chef DT	Baseline	All PA Pilot Sites - Drive Through
11	Toaster DT	Baseline	All PA Pilot Sites - Drive Through
12	Double Brewer DT	Baseline	All PA Pilot Sites - Drive Through

Profile No.	Profile	Period	Source
13	Toaster Post	Post	All PA Pilot Sites
14	Toasters-18	Baseline	18-hour PA Pilot Sites
15	Toasters-24	Baseline	24-hour PA Pilot Sites
16	Turbo Chef Bottom-18	Baseline	18-hour PA Pilot Sites
17	Turbo Chef Bottom-24	Baseline	24-hour PA Pilot Sites
18	Turbo Chef Top-18	Baseline	18-hour PA Pilot Sites
19	Turbo Chef Top-24	Baseline	24-hour PA Pilot Sites
20	Ice Machines-18	Baseline	18-hour PA Pilot Sites
21	Ice Machines-24	Baseline	24-hour PA Pilot Sites
22	Double Brewers-18	Baseline	18-hour PA Pilot Sites
23	Double Brewers-24	Baseline	24-hour PA Pilot Sites
24	Ice MachinesPost-18	Baseline	18-hour PA Pilot Sites
25	Avg. Brewers-18	Baseline	18-hour PA Pilot Sites
26	Avg. Turbo Chef-18	Baseline	18-hour PA Pilot Sites

The following are samples of profiles used to characterize the baseline operating profiles of the kitchen appliances:

Figure 5-26. Appliance Baseline Profiles:



For this site, the evaluator did not follow the PA methodology of averaging the entire site profile regardless of the blend of equipment. Instead, the evaluator used the PA pilot data to choose the specific equipment mix associated with this site. The equipment controlled at this site includes a toaster, turbo chef top, turbo chef bottom, (2) ice coffee brewers, (4) double coffee brewers.

Refrigeration improvements:

The evaluator used the MA TRM as the basis for the baselines for all sub-measures associated with the refrigeration improvements. This was reflected in the refrigeration vendor's calculation workbook. The evaluator updated the baseline count of ECMs to match the installed value and updated the evaporate fan amperage based on nameplate data.

Lighting Retrofit:

The evaluator reviewed the project files and interviewed the site contact to gather information on the baseline. The evaluator determined the lighting measure is a retrofit with a single baseline measure, where the baseline would be the pre-existing fixtures identified in the lighting audit.

2.4.2 Evaluation Calculation Method

Appliance and RTU Controls:

Similar to the applicant, the evaluator used the PA pilot data to create baseline and post-implementation appliance profiles. Unlike the applicant who averaged all sites to determine deemed savings regardless of the equipment variation, the evaluator only considered the appliance profiles that matched this specific store. Post-implementation profiles were developed in the same way as the baseline profiles mentioned in the section above. The max kW observed in the PA pilot data for each appliance used to create the operating profiles can be seen in the following table.

Table 5-58. PA Pilot Max Appliance kW

Appliance Type	Max kW
Toasters	4.276
Ice Coffee	3.361
Turbo Chef Top	2.923
Turbo Chef Bottom	2.796
Double Brewer	3.337

With appliance-specific baseline and post-implementation profiles generated from the PA pilot data, pre and post energy consumption were calculated from the following relationship:

Figure 5-27. Savings Relationship

An 8,760 spreadsheet-based calculation model was built to calculate pre and post-consumption for each hour of the year. The analysis produced the following results:

Table 5-59. Appliance Savings Summary

Profile	Appliance	Baseline	Post	Savings
1	Toasters	16,080	14,420	1,660
2	Turbo Chef Top	13,101	13,226	-125
3	Turbo Chef Bottom	11,262	9,896	1,366
4	Ice Coffee (2)*	3,386	3,593	-414
6	Double Brewer (4)*	8,504	8,658	-616
	Totals	**81,230**	**79,360**	**1,870**

*There were two ice coffee machines and four double brewers connected to the EMS, so savings are multiplied out accordingly.

As for the RTU controls to measure, the evaluator found (2) RTUs installed with controls via the EMS instead of the assumed (1) in the application. Evaluated savings were adjusted based on this change in quantity.

Refrigeration Controls:

The evaluator's approach was based on the applicant's calculation methodology. We used the calculation workbook supplied by the applicant and updated key drivers for savings. Considering the impacts of the pandemic, the evaluator did not adjust the workbook variables for anything that could be considered an operational impact. The only parameters that were corrected were the quantity of ECMs installed as the applicant incorrectly missed one ECM in the application, and evaporator motor amperage for the cooler and freezer based on nameplate data for the cooler and freezer.

Lighting Retrofit:

The evaluator calculated the savings using a similar approach to the applicant, though updated the spreadsheet to reflect site observations. The custom savings equations are presented below.

$$\text{Baseline Fixture kWh} = \frac{Quantity_B * Wattage_B}{1000} * Tracking\ \ Operating\ Hours\ without\ controls$$

$$\text{Proposed Fixture kWh} = \frac{Quantity_P * Wattage_P}{1000} * Tracking\ Operating\ Hours\ without\ controls$$

$$\text{Fixture kWh Savings} = Baseline\ Fixture\ kWh\ - Proposed\ Fixture\ kWh$$

$$\text{Control kWh Savings} = Proposed\ Fixture\ kW\ * (Tracking\ Operating\ Hours\ without\ controls - Tracking\ \ EFL\ Operating\ Hours\ with\ controls)$$

$$\text{HVAC Interactive Fixture Savings} = (pre\ conn\ kW - post\ conn\ kW) * Coincident\ Occupied\ Cooling\ Hours * \frac{0.8}{Cooling\ COP}$$

HVAC Interactive Controls Savings = *(post conn kW * (pre coincident occupied cooling hours-post coincident cooling hours) *0.8)/(Cooling COP)*

$$\text{Total kWh Savings} = Fixture\ kWh\ Savings + Occupancy\ Control\ kWh\ Savings + HVAC\ Interactive\ Fixture + HVAC\ Interactive\ Control\ Saving$$

All spreadsheets used to estimate evaluation savings will be made available to the PAs for review at their request. For site cooling hours, the evaluator assumed cooling would only occur between April and October. For each hourly interval within that range of months in the 8760 model, if dry bulb temperature taken from local TMY3 data was greater than or equal to the setpoint of 55°F, then that hour was determined to be a cooling hour. Cooling hours that coincided with the lighting hours were used to determine total annual cooling interactive savings. The cooling COP is assumed to be 3.5, which is the average value for the packaged DX units that served the space.

3 Final Results

This section will summarize the evaluation results determined in the analysis above.

Table 5-60. Summary of Key Parameters Non-Lighting measures

	BASELINE		PROPOSED / INSTALLED	
Parameter	Tracking Value(s)	Evaluation Value(s)	Tracking Value(s)	Evaluation Value(s)
Appliance Operating Profiles	Average of PA Pilot sites	Site-specific appliance data from PA pilot	Average of PA Pilot sites	Site-specific appliance data from PA pilot
Appliance kW Ratings	From PA Pilot EMS monitoring data	From PA Pilot EMS monitoring data	From PA Pilot EMS monitoring data	From PA Pilot EMS monitoring data
Quantity RTU(s) controlled	1	2	1	2
Refrigeration Operating Hours	TRM parameters	Same as tracking values	TRM Parameters	Same as tracking values
Refrigeration kW Ratings	Nameplate ratings	Same as tracking values	TRM parameters	Nameplate ratings
Refrigeration ECM installed	0	0	2	3
Evaporator amperage	Cooler: 2.1 Freezer: 1.2	Cooler: 1.8 Freezer: 1.1	Cooler: 2.1 Freezer: 1.2	Cooler: 1.8 Freezer: 1.1

The evaluated savings for the lighting project were higher than the applicant-reported savings primarily due to the addition of interactive effects with on-site HVAC as well as an increase in quantity of controlled fixtures. Detailed values are shown in Table 5-61Table 5-196. Summary of Key Parameters and Table 5-62. Evaluation Inputs and kWh Savings Lighting Controls comparing changes in the baseline and proposed conditions for both the application and evaluation hours of use for each area.

Table 5-61. Evaluation Inputs and kWh Savings Lighting Fixtures

	A	B	C	D	E	F	G=A*B*E /1000	H=C*D*E/1000	I=G-H	J	K	L	M=F*J*K*0.8/L	N=U+M
Space Type	Baseline Quantity	Baseline Watts per Fixture	Installed Quantity	Installed Watts per Fixture	Annual Hours	Connected kW Savings	Baseline kWh	Installed kWh	kWh Fixture Savings	Percent of Space Cooled	Annual Cooling Hours	Cooling COP	Interactive Cooling Savings	Total kWh Fixture Savings
OFFICE	1	36	1	36	8,760	0.000	315	315	0	100%	3,246	2.9	0	0
RESTROOM	1	36	1	36	8,760	0.000	315	315	0	100%	3,246	2.9	0	0
MENU LIGHTS	4	60	4	22	8,760	0.152	2,102	771	1,331	100%	3,246	2.9	146	1,477
SLOP SINK	1	60	1	24	8,760	0.036	526	210	315	100%	3,246	2.9	34	350
SOFFIT 3'	3	66	3	36	4,380	0.090	867	473	394	100%	1,467	2.9	40	434
SOFFIT 6'	12	125	12	50	4,380	0.900	6,570	2,628	3,942	100%	1,467	2.9	401	4,343
SOFFIT 8'	4	113	4	36	4,380	0.308	1,980	631	1,349	100%	1,467	2.9	137	1,486
DRIVE THRU MENU	6	90	2	44	4,380	0.452	2,365	385	1,980	0%	1,467	2.9	0	1,980
BUILDING	10	90	2	300	4,380	0.300	3,942	2,628	1,314	0%	1,467	2.9	0	1,314
STREET PYLON SIGN	10	90	2	50	4,380	0.800	3,942	438	3,504	0%	1,467	2.9	0	3,504
Total	**52**		**32**			**3.038**	**22,924**	**8,795**	**14,129**				**758**	**14,887**

Table 5-62. Evaluation Inputs and kWh Savings Lighting Controls

	A	B	C	D=A*B/1000	E=C*D	F	G	H	I=D*F*G*0.8/H	J=E+X
Space Type	Installed Quantity	Installed Watts per Fixture	Annual Hours Reduction	Connected kW	kWh Controls Savings	Percent of Space Cooled	Annual Cooling Hours Reduction	Cooling COP	Interactive Cooling Savings	Total kWh Controls Savings
OFFICE	1	36	2,102	0.04	76	100%	784	2.9	8	84
SOFFIT 8'	4	36	1,051	0.14	151	100%	329	2.9	15	166
Total	**26**			**1.04**	**227**				**21**	**250**

3.1 Explanation of Differences

The evaluation is 34% less than the applicant reported savings, as shown in Table 1-1. Table 5-63. Summary of Deviations provides a summary of the primary differences between tracking and evaluated values.

Table 5-63. Summary of Deviations

End-use	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
Kitchen appliance control	Methodology	Savings methodology	-39.3%	**Decreased savings** – due to the change in methodology, the evaluator used the actual equipment mix of appliances while the applicant used the site-level savings derived from the 2016 PA Pilot.
Refrigeration Controls – EC motors	Administrative	Installed Quantity	+2.9%	**Increased savings** – due to an error in the application where one fan was missed in the EC motor calculations.
Lighting & lighting controls	Interactive	HVAC Interactivity	+1.8%	**Increased savings** – due to the addition of HVAC interactive effects from lighting wattage reduction.
RTU Controls	Quantity	Installed Quantity	+1.2%	**Increased savings** – due to the additional quantity of RTUs installed with controls.
Refrigeration Controls	Technology	Nameplate information (cooler & freezer Amps and Volts)	-1.1%	**Decreased savings** – due to the change in equipment specs based on nameplate information, specifically amps and volts for the evap fans.
Lighting Controls	Quantity	Installed Quantity	+0.2%	**Increased savings –** due to the addition of occupancy sensor control.

3.1.1 Ancillary impacts

For this measure, electric HVAC interaction savings occur in retrofitting the fluorescent fixtures to LED. The tracking estimate did not include HVAC interactive effects. The areas where all fixture retrofits took place are served by a packaged DX (cooling COP: 3.5). Adding this effect accounts for a 2% increase in savings compared to the tracking system application

RICE18L009 (fixtures) & RICE19L019 (controls)

Report Date: July 22, 2021

Program Administrator	National Grid	
Application ID(s)	7404765, 8425087	
Project Type	Exterior lighting retrofit	
Program Year	2018	
Evaluation Firm	DNV	
Evaluation Engineer	Jeff Zynda	
Senior Engineer	Srikar Kaligotla	

5.1 Evaluated site summary and results

The evaluated project is for a large city where pre-existing high-pressure sodium streetlighting fixtures were replaced with LED fixtures in program year (PY) 2018 under application 7404765 and dimming controls in PY2019 under application 8425087. Per the application documentation, the project upgraded all streetlights throughout the city to LED lighting. The kWh reduction for this site is attributed to the fixture wattage reduction when retrofitting to LED. Further savings are achieved from reducing wattage due to scheduled dimming controls for 575 of the installed fixtures which is programmed and managed through an EMS platform.

The evaluation for this site is a full scope measurement, and verification site as the COVID-19 pandemic did not impact the streetlights. Lights still operated under normal parameters and dimmed schedules. The evaluator used the extensive EMS platform to capture trend data for a sample of fixtures used to make operational adjustments in the evaluation analysis.

The evaluators modeled energy savings based on on-site parameters, and EMS reported dimming levels, which were vetted on-site during the in-person audit. The site tracking estimated energy savings of 180,793 kWh, 0.00 on peak summer kW and 43.5 on peak winter kW. The evaluated savings are estimated to be 229,430 kWh. The evaluation results are presented in Table 5-42.

Table 5-64. 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)
7404765 (PY2018)	**Lighting retrofit**	**Tracked**	155,676	22%	0.00	37.3
		Evaluated	154,242	24%	0.00	1.8
		Realization rate	99.1%	110.2%	N/A	4.7%
8425087 (PY2019)	Lighting controls	Tracked	25,117	25%	0.00	6.2
		Evaluated	75,188	23%	0.00	0.0
		Realization rate	299.4%	92.8%	N/A	0.0%
Total	**Combined**	**Tracked**	**180,793**	**22%**	**0.00**	**43.5**
		Evaluated	**229,430**	**24%**	**0.00**	**1.8**
		Realization rate	**126.9%**	**107.2%**	**N/A**	**4.1%**

N/A = Not applicable

5.1.1 Explanation of deviations from tracking

The evaluated savings are higher than the applicant reported savings, primarily due to an increase in the quantity of installed fixtures with dimming controls that were operational at the time of the installation. The evaluated winter peak kW savings are also lower than the applicant reported winter peak savings due to the low winter diversity factors calculated from the EMS-derived lighting schedules. Further details regarding deviations from the tracked savings are presented in Section 3-1.

5.1.2 Recommendations for program designers and implementers

There are no recommendations currently.

5.1.3 Customer alert

There are no customer alerts for this project.

5.2 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 an exterior street lighting retrofit throughout a large city.

5.2.1 Application information and applicant savings methodology

This section describes the application information, savings methodology provided by the applicant, and the evaluation assessment of the savings calculation algorithms used by the applicant. Both applicant and evaluated approaches calculated energy savings based on applicant supplied information and on-site findings. Project savings were primarily based on reducing wattage when retrofitting 1,123 pre-existing high-pressure sodium fixtures with 1,123 LEDs and installing dimming controls on 575 of these installed fixtures.

5.2.2 Applicant description of baseline

The applicant classified the measure as a retrofit with a single baseline, where the baseline includes the pre-existing lighting fixtures operating without controls. The pre-existing fixtures include 1,123 high-pressure sodium fixtures operating with wattages ranging from 65 watts to 460 watts and an assumed operating schedule of 4,175 annual hours.

5.2.2.1 Applicant description of installed equipment and operation

The proposed condition for the lighting measure consisted of a one-for-one retrofit where all 1,123 fixtures were replaced with LEDs throughout the city. The new fixture wattages ranged from 39 watts to 88 watts and were proposed to operate for 4,175 annual hours, equivalent to the baseline. More than half (575 or 51.2%) of the installed fixtures were programmed into a city-wide EMS platform where 39-watt fixtures were assumed to dim to approximately 73% of the proposed fixture wattage of each fixture and 88-watt fixtures were assumed to dim to approximately 76% of the proposed fixture wattage of each fixture. The proposed control savings include a 1 kWh per fixture quantity reduction, which is attributed to the power draw due to the controls.

5.2.2.2 Applicant energy savings algorithm

The applicant calculated savings using a custom analysis spreadsheet. The lighting energy savings are calculated using the following formula:

$$\text{Baseline Fixture kWh} = \frac{Quantity_B * Wattage_B}{1000} * Applicant\ Operating\ Hours$$

$$\text{Proposed Fixture kWh} = \frac{Quantity_P * Wattage_P}{1000} * Applicant\ Operating\ Hours$$

$$\text{Fixture kWh Savings} = Baseline\ Fixture\ kWh\ - Proposed\ Fixture\ kWh$$

$$\text{Control kWh Savings} = (Proposed\ Fixture\ kW * (1 - \%\ Operating\ Level_{Control}) - (Quantity * 1kWh)$$

In the tracking savings estimate there were two fixture groups with two dimming schedules on each. Table 5-65. Control operating levels below shows the average percent reduction value for each fixture group.

Table 5-65. Control operating levels

Baseline wattage	Average %Operating level	Average operating Wattage
39 W	73.3%	29 W
88 W	76.4%	67 W

Table 5-66. Tracking System Lighting Inputs and kWh Savings below shows the tracking system inputs and savings calculations for the lighting retrofit. Additional details on the applicant algorithm could be found in the project files.

Table 5-66. Tracking System Lighting Inputs and kWh Savings

	A	B	C	D	E	F=A*B*E /1000	G=C*D*E/1000	H[24]	I=F-G	J=H+I
Space Type	**Baseline Quantity**	**Baseline Watts per Fixture**	**Installed Quantity**	**Installed Watts per Fixture**	**Annual Hours**	**Baseline kWh**	**Installed kWh**	**Control kWh Savings**	**kWh Fixture Savings**	**kWh Total Savings**
Streetlighting	1,042	65	1,042	39	4,175	282,778	169,667	23,831	113,111	136,942
Streetlighting	13	295	13	88	4,175	16,011	4,776	1,114	11,235	12,349
Streetlighting	5	460	5	88	4,175	9,603	1,837	86	7,766	7,851
Streetlighting	1	90	1	39	4,175	376	163	0	213	213
Streetlighting	61	130	61	39	4,175	33,108	9,933	0	23,176	23,176
Streetlighting	1	130	1	88	4,175	543	367	86	175	261
Total	**1,123**		**1,123**			**342,419**	**186,743**	**25,117**	**155,676**	**180,793**

[24] These values include a 1 kWh reduction per controlled fixture to account for the power draw for each fixture due to controls.

5.2.2.3 Evaluation assessment of applicant methodology

The applicant correctly used the custom analysis tool for the lighting measure, and the evaluator determined the application calculation methodology reasonable as the proposed inputs were used correctly in the algorithms presented above based on on-site assumptions.

5.2.3 On-site inspection

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

5.2.3.1 Summary of on-site findings

The evaluators conducted a site visit on May 11, 2021. During the site visit, the evaluators worked with an electrician and the lighting contractor to verify the street lighting fixtures and their associated step dimming levels from the EMS. A summary of the on-site verification is provided in DNV interviewed the facility staff and verified the equipment installed onsite. DNV completed an initial site visit on 4/8/21 to visually verify and collect data on select measures.

Table 5-34 shows the verification method and result for each of the ten measures evaluated within this report.

Table 5-34.

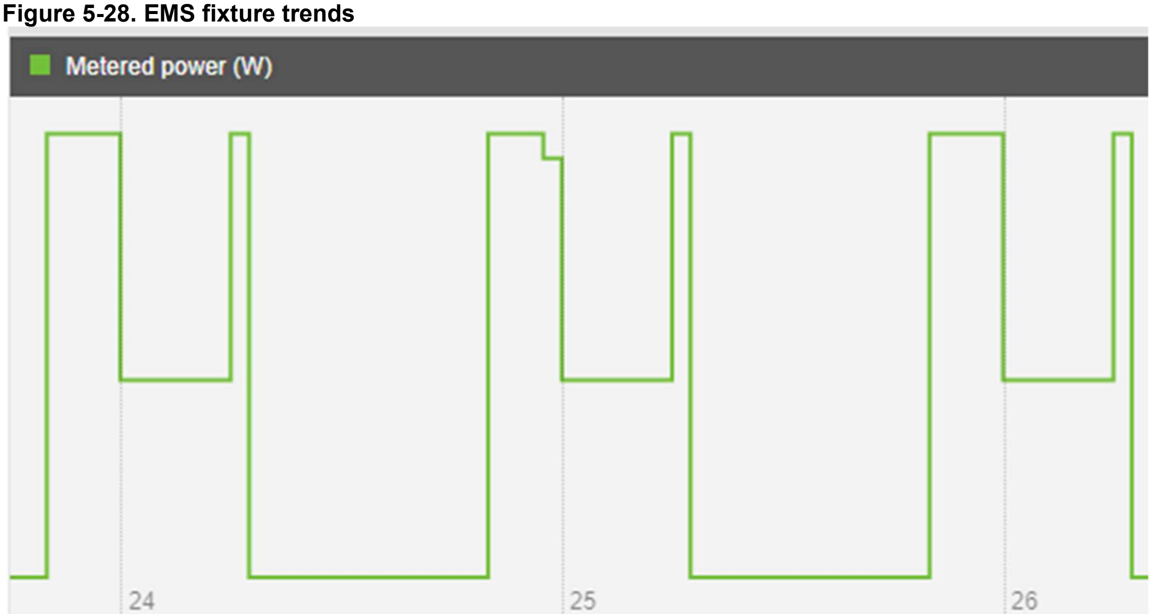
Table 5-67. Measure verification

Measure Name	Verification Method	Verification Result
Streetlighting fixtures	Visual audit	Confirmed the installed lighting measure by counting a sample of 303 fixtures (~27%) across 11 different streets and verifying the fixture's Wattage as posted underneath the fixture heads on six different fixtures.
Streetlighting dimming controls via the EMS	Visual audit and spot measurements using a multimeter	Confirmed the operation of the step dimming schedules by taking spot measurements at a sample of streetlighting poles while throttling the dimmed levels of each fixture. The EMS data that was provided showed when and to what Wattage the fixtures were dimmed. Also, the evaluator confirmed that all 1,123 fixtures have controls installed and are operating as intended.

Prior to the site visit, the evaluator worked extensively with the main lighting contractor, who also manages the EMS platform for several cities in the state and the PA review team to ensure all parameters were captured for the site visit. Given the wide breadth of data provided by the EMS platform, the team decided to primarily use EMS trend data for the evaluation analysis but to spend the site visit confirming operational levels of the step dimming procedure. While on-site, the evaluator had the lighting contractor on call to capture the volts (V), Amps (A), and power factor (PF) for each scheduled dimmed level via spot measurements at the fixture using a multimeter. The lighting contractor also vocalized the associated Wattage (W) present on the EMS readings, which matched the W calculated using the equation W=V*A*PF. The sample of 6 fixtures was developed to ensure all control schedules were captured, which were found to be based on Wattage. For this specific site, two fixture groups were developed based on wattage, where controls schedules were the same within each fixture group but varied between others based on differing dimmed levels and hours at each dimmed level. In addition, the application file included information on which streets the fixtures are installed, which proved useful when planning the sampling strategy for the on-site visit.

While on-site, at least three lamps from each of the fixture groups were verified. Trend data, including wattage and dimmed step levels for each matching fixture, were downloaded to be used in the analysis. The following screenshot is an example of the EMS platform for one of the 43 W fixtures mentioned in the above table. Reports could be run to observe wattage fluctuations throughout the day, and a csv file can be pulled to show the periods of change. The screenshot shows three days of fixture use. Three months of data were downloaded.

Figure 5-28. EMS fixture trends



Trend data, including wattage and dimmed step levels for each matching fixture, were downloaded to be used in the analysis. These trend data were then validated using the spot measurements taken on-site using the multimeter, as explained below. Spot measurements were conducted at a sample of 6 streetlights (anonymized for reporting purposes) as shown in

Table 5-68 below using a multimeter as mentioned above. Most of the measured readings were deemed reasonably close to the EMS readings. For example, in the table below, the EMS reading for the fixture on Street 1 at 90% load was found to be 87 Watts, while the spot reading was calculated to be 84.8 Watts. However, some readings are not as close (compare Street 2 fixture's EMS and Spot readings for Command 1). This could be due to the display limitation on the multimeter's Amperage reading to only one decimal point (for example, on the Street 3 fixture, if we use 0.44 Amp instead of 0.4 Amp, the calculated spot measurement would be 53.3 Watt instead of 48.5 Watt). Therefore, the evaluator assumed the EMS readings for the sampled streetlights to be true or reasonably close to the actual power draw.

Table 5-68: Spot Measurements and EMS readings

Street #	Rated Watt	EMS Reading 1		Spot Reading 1			EMS Reading 2		Spot Reading 2		
		Watt	Command	Voltage	Amp	Watt[25]	Command 2	Watt	Voltage	Amp	Watt
Street 1	101	87	90%	120	0.7	84.8	30%	47	120	0.4	48.5
Street 1	101	87	90%	120	0.8	96.9	30%	47	120	0.4	48.5
Street 2	101	88	90%	120	0.8	96.9	38%	48	120	0.4	48.5
Street 3	54	41	90%	120	0.4	48.5	23%	19	120	0.2	24.2
Street 4	54	39	48%	117	0.3	35.4	23%	22	117	0.2	23.6
Street 5	54	39	48%	117	0.3	35.4	23%	20	117	0.2	23.6

The remainder of the site visit was spent auditing a quantified sample of the streetlighting population. The evaluator audited a total of 27% of the population to develop a ratio of audited lights over the applicant population for the audited street, which

[25] Watt = (Voltage*Amp*0.98 + Voltage*Amp*0.98*.03); where 0.98 is the power factor and 3% was assumed to the %power drawn from the control system.

was applied to the remainder of the evaluation proposed quantity. The auditor found a small discrepancy in counts at street level, but the total counts matched overall. Therefore no changes have been made to the quantities in the evaluation.

The evaluator used the EMS trend data to calculate an operating profile to show when and at what dimming level the fixtures were used. Hourly trend data was expanded to fit a weekly profile. The logged operating profile in Figure 5-29. Logged operating data – 39 W fixture depicts the average percent of full load for each hour. This value was determined by taking the wattage trended at the hour and dividing it by the maximum wattage provided in the EMS data for each hourly interval. Figure 5-30 shows the average percent of full load for each hour in the baseline condition. Since the baseline fixtures did not have dimming controls, this figure also represents the average %ON for each hour.

Figure 5-29. Logged operating data – 39 W fixture

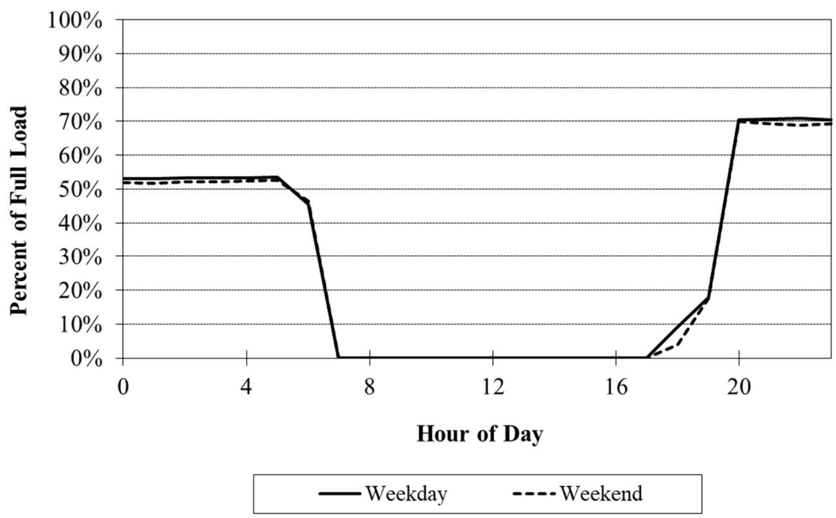
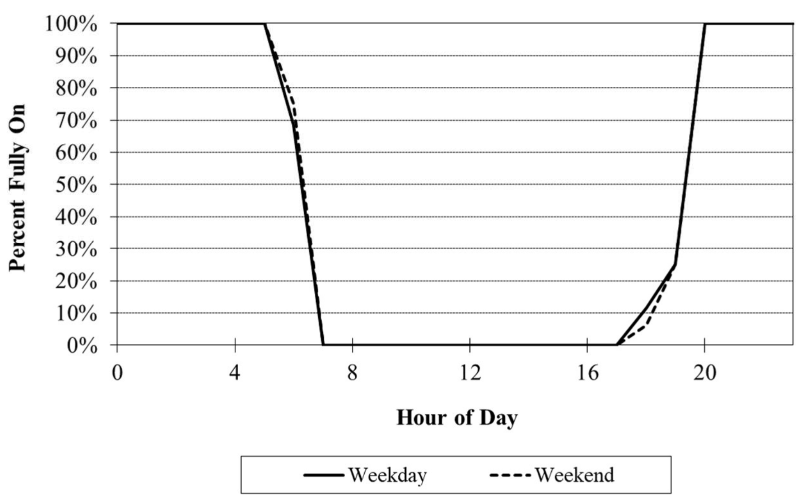


Figure 5-30. Baseline operating data – 39 W fixture



For the analysis, the evaluator expanded the trend data set to an 8,760-operating profile.

Table 5-69. Trend data schedules lists the expanded operating profiles for each of the trended fixtures downloaded from the EMS and the baseline and averaged schedules developed from the trend data.

Table 5-69. Trend data schedules

Schedule ID	Description	(Fixture Wattage) Streetlight	Max Watts from EMS data	EFLH	On-Peak Hours
1	EMS hours	(39) Birch 0002	44	3,573	749
2	EMS hours	(88) Fish 0060	88	2,985	822
3	EMS hours	(88) Main 0028	90	2,983	822
4	EMS hours	(39) Mathew 0002	43	2,729	743
5	EMS hours	(39) Borden 1160	43	963	308
6	EMS hours	(88) Fish 0063	89	2,991	823
1B	EMS baseline hours	(39) Birch 0002 Baseline	44	4,010	935
2B	EMS baseline hours	(88) Fish 0060 Baseline	88	4,263	1,032
3B	EMS baseline hours	(88) Main 0028 Baseline	90	4,263	1,032
4B	EMS baseline hours	(39) Mathew 0002 Baseline	43	4,226	1,030
5B	EMS baseline hours	(39) Borden 1160 Baseline	43	4,120	1,032
6B	EMS baseline hours	(88) Fish 0063 Baseline	89	4,270	1,032
8	Average	39 Watt Schedule	43 (Average)	2,422	600
8B	Average Baseline	39 Watt Baseline Schedule	43 (Average)	4,119	999
9	Average	88 Watt Schedule	89 (Average)	2,987	822
9B	Average Baseline	88 Watt Baseline Schedule	89 (Average)	4,265	1,032

5.2.4 Evaluation methods and findings

This section describes the evaluator methods and findings.

5.2.4.1 Evaluation description of baseline

The evaluator reviewed the project files and interviewed the lighting contractor to gather information on the baseline. As a result, the evaluator determined the lighting measure is a retrofit with a single baseline, where the baseline would be the pre-existing fixtures identified in the site documentation without controls.

Baseline schedules for controlled fixtures were developed assuming that for every hour the fixtures were operating based on the EMS trend data, regardless of dimming level, they would've been operating at 100% output for that hour in the baseline condition. Evaluation calculation method

The evaluator calculated the savings using a similar approach to the approach used by the applicant. EMS trend data was used to determine the operation schedules and effective full load (EFL) hours for all sampled streetlights. Data were drawn from the EMS and expanded to fit an 8,760-model based on trends in the data. The custom savings equations are presented below:

$$\text{Baseline Fixture kWh} = \frac{Quantity_B * Wattage_B}{1000} * Evaluated\ Operating\ Hours\ without\ controls$$

$$\text{Proposed Fixture kWh} = \frac{Quantity_P * Wattage_P}{1000} * Evaluated\ Operating\ Hours\ without\ controls$$

$$\text{Fixture kWh Savings} = Baseline\ Fixture\ kWh\ - Proposed\ Fixture\ kWh$$

$$\text{Control kWh Savings} = Proposed\ Fixture\ kW\ * (Evaluated\ Operating\ Hours\ without\ controls - Evaluated\ EFL\ Operating\ Hours\ with\ controls)$$

$$\text{Total kWh Savings} = Fixture\ kWh\ Savings + Control\ kWh\ Savings$$

All spreadsheets used in the estimation of evaluation savings will be made to the PAs for review at their request.

5.3 Final Results

The evaluated savings for the lighting project were greater than the applicant reported savings primarily due to an increase in the quantity of installed fixtures with dimming controls. Baseline hours of use were slightly lower than assumed in the application estimate, while the quantity and wattage evaluation were consistent with the application. The main factors impacting savings are shown in Table 5-70.

Table 5-70. Summary of key parameters

	Applicant		Evaluation	
Fixture group	Baseline Hours	Proposed Hours	Baseline Hours	Proposed Hours
39 Watt	4,175	3,614	4,119	2,422
88 Watt	4,175	3,614	4,265	2,987

Table 5-71. Evaluation fixture inputs and kWh savings and Table 5-72. Evaluation controls inputs and kWh savings below show the evaluation inputs and savings calculations for the lighting fixtures and controls, respectively.

Table 5-71. Evaluation fixture inputs and kWh savings

	A	B	C	D	E	F	G=A*B*E/1000	H=C*D*E/1000	I=G-H
Space Type	Baseline Quantity	Baseline Watts per Fixture	Installed Quantity	Installed Watts per Fixture	Annual Hours	Connected kW Savings	Baseline kWh	Installed kWh	kWh Fixture Savings
Streetlighting	1,042	65	1,042	39	4,119	27.092	278,950	167,370	111,580
Streetlighting	1	90	1	39	4,119	0.051	371	161	210
Streetlighting	61	130	61	39	4,119	5.551	32,660	9,798	22,862
Streetlighting	13	295	13	88	4,265	2.691	16,357	4,879	11,477
Streetlighting	5	460	5	88	4,265	1.860	9,810	1,877	7,933
Streetlighting	1	130	1	88	4,265	0.042	554	375	179
Total	**1,123**		**1,123**			**37.287**	**338,702**	**184,460**	**154,242**

Table 5-72. Evaluation controls inputs and kWh savings

	A	B	C	D=A*B/1000	E=C*D
Space Type	Installed Quantity	Installed Watts per Fixture	Annual EFL Hours Reduction	Connected kW	kWh Controls Savings
Streetlighting	1,042	39	1,697	40.64	68,948
Streetlighting	1	39	1,697	0.04	66
Streetlighting	61	39	1,697	2.38	4,036
Streetlighting	13	88	1,278	1.14	1,463
Streetlighting	5	88	1,278	0.44	563
Streetlighting	1	88	1,278	0.09	113
Total	**1,123**			**44.73**	**75,188**

5.3.1 Explanation of differences

The evaluated savings are greater than the tracked savings primarily due to an increase in the quantity of installed fixtures with dimming controls. In the tracking system and site documentation, savings were claimed for controls installed on 575 fixtures or 51.2% of all fixtures that controls were installed on. The controls for the remaining 548 fixtures (or 48.8%) were not claimed but were essentially installed at the same time as the controls for which savings were claimed. They were not claimed or paid for because when this project was commissioned not all the controls were operating at that time. Since the original lights installed include the controls but they were not commissioned at the time of initial incentive payment but later found to be operational, the savings were claimed as the capabilities were part of the original installation,

Table 5-51 provides a summary of the differences between tracking and evaluated values.

Table 5-73. Summary of deviations

End-use	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
Lighting controls	Quantity	Quantity of fixture with controls	+20.2%	Increase in savings due to an increase in the quantity of fixtures controlled using the EMS system.
Lighting controls	Operation	Annual hours	+7.5%	Increase in savings due to a greater impact on operational schedule due to dimming controls.
Lighting fixtures	Operation	Annual hours	-0.8%	Decrease in savings due to the reduction in baseline fixture operational hours.

5.3.1.1 Ancillary impacts

There are no ancillary impacts associated with this measure as the street lighting fixtures are exterior.

RICE18L025

Program Administrator	National Grid
Application ID(s)	6911935, 7804134
Project Type	New Construction Performance Lighting
Program Year	2018
Evaluation Firm	DNV
Evaluation Type	Full M&V
Evaluation Engineer	Shaobo Feng
Senior Engineer	Srikar Kaligotla

5.4 Evaluated site summary and results

The evaluated performance lighting project was installed at a large, big-box retailer distribution warehouse. This is a parent-child lighting project completed in 2018, and there is no non-lighting measure associated with this application. Project savings were calculated based on the Building Code baseline for the identified building type, i.e., 0.6 W/sf for a warehouse building, per IECC 2012. All fixtures installed interior only. The application also included including occupancy sensors and dimming controls, but the facility was not operational at the time of their installation, so control savings were not included in the tracking project savings.

As a distribution warehouse, this facility had a minor impact from the COVID-19 pandemic, so the scope of evaluation includes installing metering to capture the control impact and apply operational adjustments.

The evaluators re-calculated the energy savings based on the metered data collected from loggers and an in-person on-site audit. The tracking analysis estimated energy savings of 2,083,156 kWh, 256 on peak summer kW and 256 on peak winter kW. The evaluated savings are estimated to be 2,113,416kWh, 228.6 on summer peak kW and 237.17 on winter peak kW. The increase in savings is due to a change in the evaluated installed annual operating hours reduction due to controls which was more significant than a reduction in savings due to a revised baseline. The evaluation results are presented in Table 5-42.

Table 5-74. 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)
6911935, 7804134	**New Construction Lighting & Controls**	**Tracked**	2,083,156	49%	256.0	256.0
		Evaluated	2,113,416	44%	228.6	237.17
		Realization rate	**101%**	**91%**	**88%**	**88%**

5.4.1 Explanation of deviations from tracking

The evaluated savings are higher than the applicant reported savings, primarily from the reduced full load hours of operation due to newly installed controls on the fixtures. The lighting controls (occupancy sensor and dimming), which is not a mandatory energy code requiremt for the warehouse, but was part of the installed fixture capability, provided additional savings over what was claimed. The project did not claim controls savings due to the control system not being functional during the post inspection. There was also a reduction in code LPD which is based on the Rhode Island Commercial and Industrial Impact Evaluation of 2013-2015 Custom CDA Installations[26] findings that standard practice is outpacing code which reduced savings significantly. Further details regarding deviations from the tracked savings are presented in Section 3-1.

5.4.2 Recommendations for program designers and implementers

Rather than applying a general operating schedule to the whole building, it is recommended to apply operating schedules to fixtures that coincide with the area type and control scheme installed.In addition, the evaluator recommends a follow-up inspection if any proposed system was not operational during the post inspection but the commissioning had been planned.

5.4.3 Customer alert

There are no customer alerts for this project.

5.5 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 performance interior lighting with controls on the distribution warehouse.

[26] http://rieermc.ri.gov/wp-content/uploads/2019/05/ri_cda_programreport_final.pdf

5.5.1 Application information and applicant savings methodology

This section describes the application information, savings methodology provided by the applicant, and the evaluation assessment of the savings calculation algorithm used by the applicant. Project savings were primarily based on reducing lighting power density (LPD) compared to code for a warehouse.

5.5.2 Applicant description of baseline

The applicant classified the measure as a new construction lighting measure with a single baseline, equivalent to code standard for the identified building type. The baseline code used was 0.60 W/sf LPD for the Warehouse, based on IECC 2012.

5.5.2.1 Applicant description of installed equipment and operation

The proposed condition for the lighting measure consisted of installing 681 LEDs throughout the building. Fixtures ranged between 32 and 190 W and were proposed to operate for 8,136 annual hours (24 hours Mon – Fri and Sun, 12 hours on Sat). The proposal calculates to an LPD of 0.14. Control measures included occupancy sensors with dimming control through the facility. However, the facility was not operational during the installation, and the controls system was not operational during the post-inspection, so control savings were not included in the applicant tracking project savings.

5.5.2.2 Applicant energy savings algorithm

The applicant calculated savings using a custom analysis spreadsheet, which compares the lighting proposal to code standard. The lighting energy savings are calculated using the following formula:

$$Annual\ energy\ savings\ kWh = \frac{\Delta LPD * Area}{1{,}000} * Hours * Diversity\ Factor = (0.6 - 0.14) * 592{,}196 * 95\% \frac{8136}{1000}$$

= 2,083,156 kWh

Where,

$LPD\ Proposed = \frac{\Sigma(Qty*W)}{Area}$ =85.8*1000/592,196=0.14 kW

$LPD\ baseline$	= 0.6 W/sqft (IECC 2012 code baseline for Warehouse)
$Area$	= 592,196 sqft
$Diversity\ Factor$	= 95%
$Hours$	= 8,136

The diversity factor represents the percent of the time that the equipment operates at maximum load or demand. For example, the 95% factor used assumes that the device operates at a maximum load of approximately 95% when the lights are turned on.

Table 5-75. Applicant Lighting Proposed Details

Fixture Type	Manufacturer	Model Number	Wattage	Description	Quantity	Type of Control
A1	Lithonia	2BLT4 40LHE ADPT MVOLT EZ1 LP840	32	LED recessed 2x4	69	Occupancy
A2	Lithonia	2BLT2 33LHE ADPT MVOLT EZ1 LP840	28	LED recessed 2x2	11	Occupancy
C2	Lithonia	ZL1N L48 5000LM FST MVOLT 35K 80CRI WH	42	linear ambient	24	Occupancy
B1	Digital Lumens	CLE-F1-ST-D-850	151	LED high bay	140	Occupancy+Dimming
B2	Digital Lumens	CLE-F1-ST-D-850	151	LED high bay	103	
B3	Digital Lumens	CLE-F1-ST-D-850	151	LED high bay	86	
B4	Digital Lumens	CLE-F1-ST-D-850	151	LED high bay	172	
B5	Digital Lumens	HLE-3-18-W	190	LED high bay	20	
B6	Digital Lumens	LLE-6-ST-D-850	52	LED stairwell	56	
Total					**681**	

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

5.5.2.3 Evaluation assessment of applicant methodology

The applicant correctly used the custom analysis tool for the lighting measure, and the evaluator determined the application calculation methodology to be reasonable as the proposed inputs and comparison to code (IECC 2012) were used correctly in the algorithms presented above. However, the Massachusetts Commercial Energy Code Compliance and Baseline for IECC 2012 study. found that the energy code requirements for interior lighting power density are not reflective of current standard practices. The findings from this study state that, on average, the installed lighting LPDs were 0.67 of the code requirements for buildings permitted under IECC 2012. This factor was applied to the baseline code LPD for the evaluation analysis to adjust for the study findings.

In addition, control savings should be included in this application since the lighting was verified to be controlled during the evaluator's site audit, and the control cost was included in the submitted invoices.

5.5.3 On-site inspection

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

5.5.3.1 Summary of on-site findings

The evaluators conducted a site visit and installed some kW loggers on March 23, 2021, and another visit with logger retrieval on May 26, 2021. During the site visits, the evaluators interviewed the director of energy and sustainability for the warehouse and verified the installed lighting with controls. During both site visits, the evaluator was able to collect the information below:

- This facility had a minor impact during the pandemic. The recent facility operation schedule was 24 hours from Sunday to Friday and 12 hours on Saturday. Site contact mentioned they would move Saturday to 24-hour operation soon. The operating hours are based on the metered data, which showed 24/7 operation but lower kW reading in Saturday and Sunday as Figure 2-2, 2-3 and 2-4 shown in section 2.4.1.

- Fixture quantities were verified using the visit.
- The high bay and stairwell lighting fixtures are controlled by both occupancy sensor and dimmer with a maximum level set to 60% based on a customer interview. Each aisle groups fixtures together uniform control. If any motion was detected, the closest fixture was turned to 60% dimming, and other fixtures in the same aisle were turned to 10% then 60% if the motion was detected. The fixture would be turned to 0% if no motion was detected. Other spaces with linear ambient, recessed 2x2 and 2x4 lights, have similar control logic, but the maximum dimming level was 100%. Detailed dimming information will be shown and discussed in the metered data in the next section.
- The warehouse area is not air-conditioned fans are being used for ventilation. Offices, dining area and rest area are cooled by rooftop units and heated by boilers but are not part of the scope of this application, therefore not considered for HVAC interactive effects.
- The evaluator verified the dimming levels with metering and from the lighting control system. An example of the control setting is as Figure 2-1 below. Also, note the 60% dimming setting for “Active” and 10% dimming setting for “Inactive” on the adjacent fixtures.

Figure 5-31. Lighting Control Settings – High Bay Fixture

5.5.3.2 Measured and Logged Data

During the site visit, the evaluator deployed data loggers to characterize the lighting operation and dimming levels from March 23, 2021, to May 26, 2021. Table 2-2 presents the logger deployment details. And the type of lighting it was metering is also shown in the last column.

Table 5-76. Data Logger Deployment Details

Data Logger Type	Description	Time Interval	Duration	Quantity
Dent Elite Pro power loggers XC1805013	Warehouse C2-201 (1)	15 minutes	65 days	1
	Warehouse C2-201 (2)	15 minutes	65 days	
	Warehouse C1-102	15 minutes	65 days	
	Bathroom	15 minutes	65 days	
Dent Elite Pro power loggers XC1907057	Dining Room B1-123	15 minutes	65 days	1
	Locker B1-135	15 minutes	65 days	
	Dining Room	15 minutes	65 days	
	Kitchen	15 minutes	65 days	

Please note that each Elite logger can record multiple loads simultaneously. For example, in

Table 5-76, logger XC1705013 recorded four different loads listed with a 15 minute time interval. The evaluator used the metered kW data to create a daily averaged weekly profile with both hours-of-use and demand (kW) when dimmed.

5.5.4 Evaluation methods and findings

5.5.4.1 Evaluated Installed demand kW

The evaluator metered Warehouse (3 sections), Bathroom, Locker and Kitchen spaces in the facility individually. The evaluator found that the operating profiles of “Warehouse C2-201 (1)”, “Warehouse C2-201 (2)”, and “Warehouse C1-102” from the raw data had very similar trends (comparing 3 sections), so the evaluator used an average load from the 3 sections of the metered Warehouse and classified it as “Group 1”. Group 1 operating profile was then applied to all Warehouse fixtures in the analysis. Similarly, two more groups were developed based on the raw data and classified into two groups as listed below and applied appropriately in the 8,760-lighting analysis.

1) Group 1: High bays (Warehouse and Stairwell)

2) Group 2: Other (Dining areas and Kitchen areas); LED recessed 2x2 and 2x4;

3) Group 3: Locker and Bathroom; Linear Ambient.

It is also important to note that these data in Groups 1-3 are captured with dimming, i.e., at 60% or 10% when occupied and close to 0% when unoccupied. Therefore, the evaluator created an average hourly daily operating profile by assuming the maximum reading from raw data to be 60% of the full load.

For example,

In the Warehouse C2-201 section, the maximum load was found to be 0.87 kW

Therefore, the full load for that breaker = 0.87/0.6 = 1.445 kW. Where, 0.6 is 60% dimming from when the space was occupied.

Then, an average daily weekly profile was developed for all three groups using 65-day metered data as shown in

Figure 5-32 through Figure 5-34. These profiles were then applied to installed fixtures in the evaluated lighting analysis.

Figure 5-32. Weekly Averaged Metered Operating Data – LED high bay

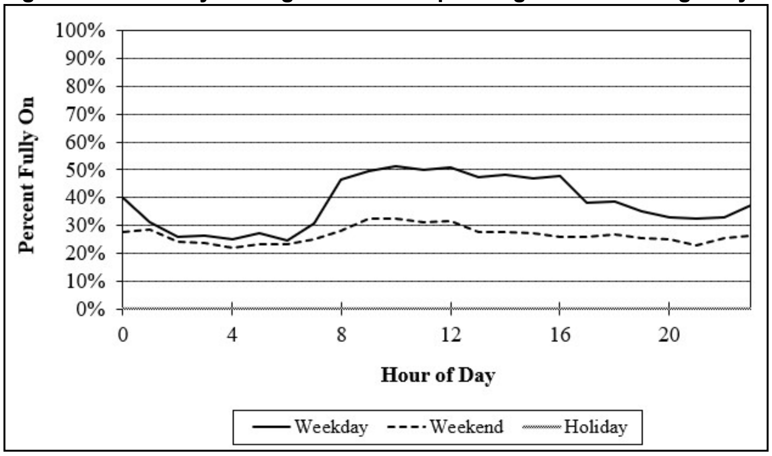


Figure 5-33. Logged Operating Data –Dining Areas and Kitchen

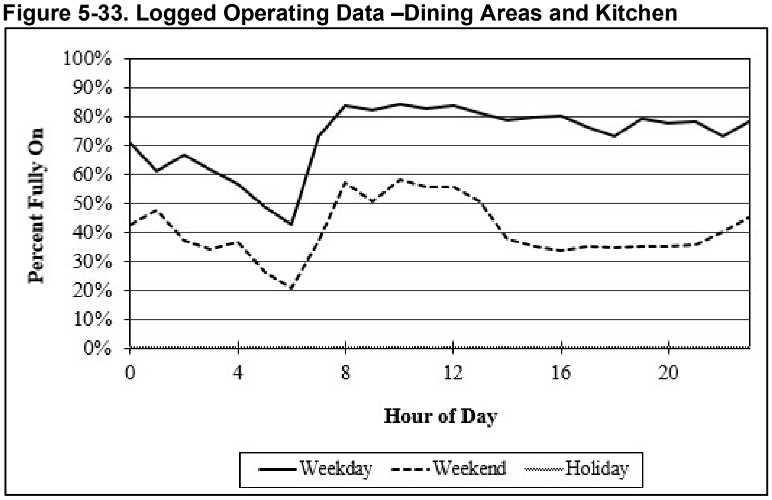
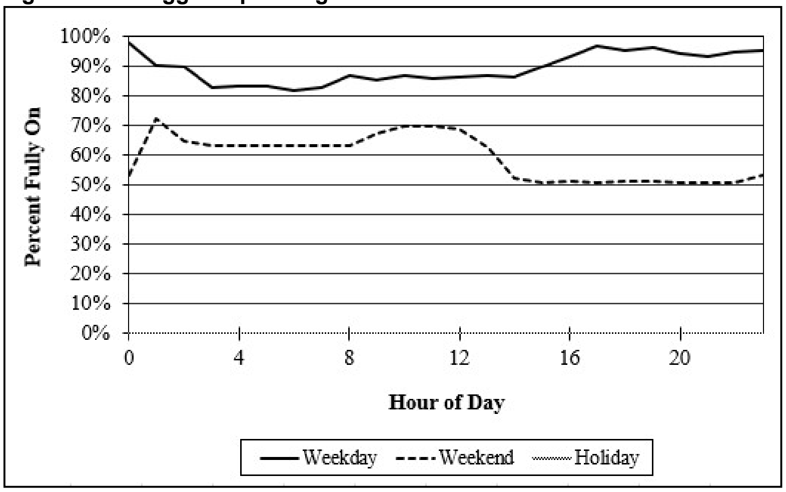


Figure 5-34. Logged Operating Data- Bathroom and Locker



5.5.4.2 Evaluated Baseline Demand

The evaluator reviewed the project files and interviewed the site contact to gather information on the baseline. The evaluator determined the measure to be a new construction baseline measure where the baseline is 0.6 W/sf LPD based on IECC 2012 code standard for a Warehouse. It is important to note that the applicant assumed a constant hours-of-use value for both baseline and installed conditions in tracking analysis (without controls), whereas the metered data was based on dimmed and occupancy sensors controlled lights in various spaces. The space level fixture wattages for the installed case are listed in Table 5-75, and to develop a proxy baseline wattage for each space, DNV calculated a Baseline factor as shown below.

From tracking calculations in Section 5.5.2.2:

Total tracking baseline demand (kW)

= (Total Annual Savings kWh /Annual Hours) + Total Tracking Proposed Demand kW

= (2,083,156/8,136) +85.80 =341.84 kW

Tracking baseline factor = Total Baseline Demand (kW)/ Total Tracking Proposed Demand (kW)

= 341.84/85.80 = 3.98

The evaluator developed the tracking proxy baseline wattages for each fixture by taking a product of each fixture's installed wattage with the tracking baseline factor (Table 5-77). But the evaluated baseline was then adjusted to 0.402 from 0.6 W/sf tracking baseline LPD based on the recent CDA study[26] (78% of the current 0.6W/SF) in the evaluation. Therefore, the total evaluated baseline demand kW is:

Evaluated baseline demand kW

= evaluated baseline LPD*Building Area/1000= 0.468*592,196 sf/1000= 277.15 kW.

evaluated baseline factor = total evaluated baseline demand kW/ total tracking baseline demand kW

= 277.15/341.84 = 0.81

Therefore, the evaluated proxy baseline for each fixture is 81% of the tracking proxy baseline wattage, as shown in Table 5-77 below. The evaluation used these estimates in calculating evaluated energy savings using an 8,760 DNV's custom lighting spreadsheet.

Table 5-77. Evaluated Lighting Parameters

Fixture Type	Type of Lamp	Group	Installed Wattage	Tracking Proxy Baseline Wattage	Evaluated Proxy Baseline Wattage	Operation Hours	Evaluated Operation Hours
A1	LED recessed 2x4	Other	32	127	103	8,760	5,599
A2	LED recessed 2x2	Other	28	111	90	8,760	5,599
C2	linear ambient	Locker + Bathroom	42	166	135	8,760	7,083
B1	LED high bay	High bay	151	601	487	8,760	3,564
B2	LED high bay	High bay	151	601	487	8,760	3,564
B3	LED high bay	High bay	151	601	487	8,760	3,564
B4	LED high bay	High bay	151	601	487	8,760	3,564
B5	LED high bay	High bay	190	757	614	8,760	3,564
B6	LED stairwell	High bay	52	207	168	8,760	3,564

5.5.4.3 Evaluation calculation method

The evaluator calculated the savings using a similar approach to the applicant. In addition, the evaluator used DNV's Custom Lighting tool to determine the evaluated savings. The savings algorithms are presented in Table 5-78 and Table 5-79 below.

Table 5-78 Evaluated Fixture Savings

	A	B	C	D	E	F	G=A*B*E /1000	H=C*D*E/1000	I=G-H
Space Type	**Baseline Quantity**	**Baseline Watts per Fixture**	**Installed Quantity**	**Installed Watts per Fixture**	**Annual Hours**	**Connected kW Savings**	**Baseline kWh**	**Installed kWh**	**kWh Fixture Savings**
Other	69	102.72	69	31.8	8,760	4.893	62,088	19,221	42,866
Other	11	89.80	11	27.8	8,760	0.682	8,653	2,679	5,974
Locker+Restroom	24	134.86	24	41.75	8,760	2.235	28,353	8,778	19,575
high bay	501	487.33	501	150.87	8,760	168.569	2,138,796	662,132	1,476,664
high bay	20	613.73	20	190	8,760	8.475	107,526	33,288	74,238
high bay	56	167.97	56	52	8,760	6.494	82,399	25,509	56,890
Total	**681**		**681**			**191.35**	**2,427,814**	**751,607**	**1,676,207**

Table 5-79 Evaluated Control Savings

Space Type	A	B	C= 8760- Evaluated Operation Hours	D=A*B/1000	E=C*D
	Installed Quantity	**Installed Watts per Fixture**	**Annual Hours Reduction**	**Connected kW**	**kWh Controls Savings**
Other	69	31.8	3,161	2.2	6,936
Other	11	27.8	3,161	0.3	967
Locker+Restroom	24	41.8	1,677	1.0	1,681
high bay	501	150.9	5,196	75.6	392,749
high bay	20	190.0	5,196	3.8	19,745
high bay	56	52.0	5,196	2.9	15,131
Grand Total	**681**	**494.2**	**23,588**	**85.8**	**437,209**

5.6 Final Results

The evaluated savings for the lighting project were less than the applicant reported savings due to a change in baseline LPD though the reduction in proposed operating hours due to the installed controls had a positive impact on the overall savings. All other parameters used in the evaluation were consistent with the application including quantity, and wattage. The main parameters impacting the analysis are summarized in The evaluated savings for the lighting project were slightly greater than the applicant-reported savings primarily due to a discrepancy stemming from heating and cooling interaction. Detailed values are shown in Table 5-196. Summary of Key Parameters, comparing changes in the baseline and proposed conditions for both the application and evaluation hours of use for each area.

Table 5-85.

Table 5-80. Summary of key parameters

End-use	Parameter	Applicant	Evaluated
Lighting	Baseline LPD	0.6	0.468
Lighting	Baseline Hours	8,136	8,760
Lighting	Proposed Hours	8,136 (no control)	From 3,055 to 7,083

5.6.1 Explanation of differences

Table 5-51 provides a summary of the differences between tracking and evaluated values.

Table 5-81. Summary of deviations

End-use	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
Lighting	Baseline	LPD	-25%	Decrease in savings due to the change in baseline LPD. The evaluator applied a 0.78 factor to code LPD based on the Massachusetts Commercial Energy Code Compliance and Baseline for IECC 2012 memo that suggests standard practices outpace code LPD.
Lighting Controls	Operation hours	Hours	+27%	Increased savings due to the reduced operating hours in the proposed situation where occupancy and dimming control not operational in the tracking estimate were found to be working in the evaluated case.

5.6.1.1 Ancillary impacts

There are no ancillary impacts associated with this measure.

RICE18L038

Program Administrator	National Grid	
Application ID(s)	7467749; 8544650	
Project Type	Retrofit	
Program Year	2018	
Evaluation Firm	DNV	DNV·GL
Analysis Type	NON-OPS (with HVAC interactivity)	
Evaluation Engineer	Laengheng Khoun	
Senior Engineer	Chad Telarico, Stephen Carlson	

4 Evaluated Site Summary and Results

This retrofit light project was completed in a university library. In total, 3049 fixtures were proposed to be replaced with 1,571 LEDs and the application also claims occupancy and daylight controls savings for all of the program fixtures that were installed. The total claimed savings from the project is 778,503 kWh per year. Program savings are due to the reduction in wattage when retrofitting baseline fixtures with LEDs and associated controls.

The site contact reported that the operation of the lighting at the site is currently affected by the COVID-19 pandemic. The library has reduced operating hours and reduced occupancy. The evaluators conducted a non-operational visit which included verification of relevant fixtures, controls and installation locations. During the visit, the site evaluator visually confirmed a sample of lights in different usage areas and installation locations.

The overall realization rate of energy savings for this project is 103.9%, with the small increase primarily due to including HVAC interactivity which the tracking estimate did not include. The site tracking estimated 778,503 kWh, 100.2 on peak summer kW, and 100.2 on peak winter kW. The evaluation estimate is 808,755 kWh, 114.9 on peak summer kW, and 100.2 on peak winter kW. The evaluation results are presented in Table 5-2.

Table 5-82. 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)
7467749; 8544650	Retrofit Lighting	Tracked	778,503	53%	100.2	100.2
		Evaluated	808,755	45%	114.9	100.2
		Realization Rate	103.9%	85%	115%	100%
Totals		**Tracked**	**778,503**	**53%**	**100.2**	**100.2**
		Evaluated	**808,755**	**45%**	**114.9**	**100.2**
		Realization Rate	**103.9%**	**85%**	**115%**	**100%**

4.1 Explanation of Deviations from Tracking

The evaluated savings are 3.9% more than the applicant-reported savings due to the addition of HVAC interactivity which is included in the evaluator's lighting tool but not in the applicant's analysis. Further details regarding deviations from the tracked savings are presented in Section 3-4.

4.2 Recommendations for Program Designers & Implementers

There are no recommendations for this project.

4.3 Customer Alert

There are no customer alerts.

5 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.

5.1 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. Both applicant and evaluated approaches calculated energy savings based on on-site findings and assumptions.

5.2 Applicant Description of Baseline

The applicant classified the measure as a retrofit with the baseline as the existing condition. The baseline fixtures/lamps are categorized the following fluorescent fixtures: 4 ft fluorescent T8, 4 ft fluorescent T12, or 2 ft fluorescent T8/T12. The applicant documentation claimed 3,049 light fixtures in the baseline case to be replaced with 1,571 proposed fixtures. Annual operating hours were split into usage groups of 7,560 hours, 3,530 hours, 4,260 hours, and 923 hours.

5.2.1 Applicant Description of Installed Equipment and Operation

The applicant proposed installing 1,571 LED lighting fixtures to replace the existing 3,049 fixtures. Annual operating hours were consistent with the baseline assumed hours for fixture usage groups for the calculation of fixture savings. Occupancy and daylighting controls savings from hours reductions were claimed for all fixtures.

5.2.2 Applicant Energy Savings Algorithm

The applicant used the National Grid Lighting tool to estimate the tracking savings. No savings from HVAC interactivity were claimed as part of this application. Controls savings were claimed in the applicant calculation methodology. The savings are calculated using the formulas shown below:

Baseline Fixture kWh = $\frac{Quantity_B * Watta \quad _B}{1000} * Applicant\ Operating\ Hours$

Proposed Fixture kWh = $\frac{Quantity_P * Wattage_P}{1000} * Applicant\ Operating\ Hours$

Fixture kWh Savings = $Baseline\ Fixture\ kWh\ - Proposed\ Fixture\ kWh$

Control kWh Savings = $(Proposed\ controlled\ Fixture\ kW) * Applicant\ Operating\ Hours * Hours\%$

Total kWh Savings = $Fixture\ kWh\ Savings + Control\ kWh\ Saving$

Where,

Hours % = 32% reduction due to occupancy and daylighting sensors

Table 5-83. Tracking System Fixture Inputs and kWh SavingsTable 5-56. Tracking System Fixture Inputs and kWh Savings below shows the tracking system inputs and savings calculations for the lighting retrofit.

Table 5-83. Tracking System Fixture Inputs and kWh Savings

	A	B	C	D	E	F=A*B*E /1000	G=C*D*E/1000	H	I=F-G	J=H+I
Space Type	**Baseline Quantity**	**Baseline Watts per Fixture**	**Installed Quantity**	**Installed Watts per Fixture**	**Annual Hours**	**Baseline kWh**	**Installed kWh**	**Control kWh Savings**	**kWh Fixture Savings**	**Total kWh Fixture Savings**
Usage Group D	3	37	2	20	923	102	37	12	66	77
Usage Group A	24	60	24	20	7,560	10,887	3,629	1,161	7,258	8,419
Usage Group A	1895	37	959	20	7,560	530,090	145,007	46,402	385,084	431,486
Usage Group A	576	62	289	20	7,560	269,993	43,699	13,984	226,295	240,278
Usage Group A	145	50	73	20	7,560	54,812	11,038	3,532	43,774	47,306
Usage Group B	2	60	2	20	3,530	424	141	45	282	328
Usage Group B	185	37	112	20	3,530	24,161	7,907	2,530	16,255	18,785
Usage Group B	4	62	2	20	3,530	875	141	45	734	779
Usage Group B	143	50	72	20	3,530	25,238	5,083	1,627	20,155	21,782
Usage Group C	72	37	36	20	4,260	11,348	3,067	981	8,281	9,262
Total	**3049**		**1571**			**927,932**	**219,748**	**70,319**	**708,184**	**778,503**

5.2.3 Evaluation Assessment of Applicant Methodology

The evaluator deemed the applicant savings calculation methodology and assumptions to be reasonable. However, the evaluator notes that the applicant methodology does not include savings from HVAC interactivity.

5.3 Inspection

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

5.3.1 Summary of Findings

DNV conducted a non-operational visit to the facility on May 13th, 2021. The facilities manager familiar with the project showed the evaluator the relevant lights listed in the documentation. The evaluator verified a sample of lights in each space type, install location and hour group in the library. The evaluator created a sample of about 20% of the lights claimed in the application grouped by location and operating hours. The evaluator was able to count and take photos of the relevant lights in the sample. The evaluator was able to verify lights in each install location and hour group. The evaluator confirmed all lights in the sample and in total verified 54% of the lights that were installed as part of the project. Areas that were claimed to have occupancy and daylighting controls were confirmed to have functioning occupancy and daylighting controls. The evaluator confirmed the installation of daylight sensors and observed lights were off in the presence of daylight.The site contact confirmed that those spaces had no prior controls before the fixtures were replaced. The site contact confirmed the hours assigned to specific usage groups for each space type were accurate for a typical year. The contact noted that their operating schedule this year was not typical because of changes related to COVID-19 safety. The contact reported library hours were reduced and there has been reduced occupancy on campus. However, since this evaluation did not include on-site EM&V metering and usage could not be verified, these claims could not be verified and could not be included as an evaluated discrepancy.

5.4 Evaluation Methods and Findings

5.4.1 Evaluation Description of Baseline

The evaluator reviewed the project files and interviewed the site contact to gather information on the baseline. The evaluator determined the lighting measure is a retrofit with a dual baseline measure, where the baseline would be the pre-existing fixtures identified in the lighting audit. The dual baseline for the analysis of lifetime savings follows the model where 1/3 lifetime is attributed to a baseline of the existing fixtures, and 2/3 will be assumed using a 60% of the baseline fixture wattage for that remaining period regardless of existing fixture age or reported condition.

5.4.2 Evaluation Calculation Method

The evaluator calculated the savings using a similar approach to the applicant. The evaluator used a similar approach to the applicant and used a custom lighting tool to determine the evaluated savings which includes HVAC interactivity. The savings algorithms used in the tool are as follows:

Baseline Fixture kWh = $\frac{Quantity_B * Wattage_B}{1000} * Evaluated\ Operating\ Hours$

Proposed Fixture kWh = $\frac{Quantity_P * Wattage_P}{1000} * Evaluated\ Operating\ Hours$

Fixture kWh Savings = $Baseline\ Fixture\ kWh\ - Proposed\ Fixture\ kWh$

HVAC Interactive Fixture Savings = $(pre\ connected\ kW - post\ connected\ kW) * Coincident\ Occupied\ Cooling\ Hours * \frac{0.8}{Cooling\ COP}$

Control kWh Savings = $Proposed\ Fixture\ kW\ * (Evaluated\ Operating\ Hours\ without\ controls - Evaluated\ EFL\ Operating\ Hours\ with\ controls)$

Total kWh Savings = $Fixture\ kWh\ Savings + HVAC\ Interactive\ Fixture\ Savings + Control\ kWh\ Savings$

All spreadsheets used to estimate evaluation savings will be made available to the PAs for review at their request. For site cooling hours, the evaluator assumed cooling would only occur between May and October. For each hourly interval within that range of months in the 8760 model, if dry bulb temperature taken from local TMY3 data was greater than or equal to the cooling balance point of 65°F, then that hour was determined to be a cooling hour. Cooling hours that coincided with the lighting hours were used to determine total annual cooling savings. The cooling COP is assumed to be 5.5 for the chillers that serve the library. Table 2-2 shows the evaluation inputs and savings calculations for the fixtures in the recreation center and arena, respectively.

Table 5-84. Evaluation Fixture Inputs and kWh Savings

	A	B	C	D	E	F	G=A*B*E/1000	H=C*D*E/1000	I=G-H	J	K	L	M=F*J*K*0.8/L	N=I+M
Space Type	**Baseline Quantity**	**Baseline Watts per Fixture**	**Installed Quantity**	**Installed Watts per Fixture**	**Annual Pre Hours**	**Connected kW Savings**	**Baseline kWh**	**Installed kWh**	**kWh Fixture Savings**	**% of Space Cooled**	**Annual Cooling Hours**	**Cooling COP**	**Interactive Cooling Savings**	**Total kWh Fixture Savings**
Usage Group D	3	37	2	20	923	0.071	102	37	66	100%	263	5.5	3	68
Usage Group A	24	60	24	20	7,560	0.960	10,887	3,629	7,258	100%	2,031	5.5	282	7,540
Usage Group A	1895	37	959	20	7,560	50.935	530,090	145,007	385,084	100%	2,031	5.5	14,976	400,060
Usage Group A	576	62	289	20	7,560	29.932	269,993	43,699	226,295	100%	2,031	5.5	8,801	235,095
Usage Group A	145	50	73	20	7,560	5.790	54,812	11,038	43,774	100%	2,031	5.5	1,702	45,477
Usage Group B	2	60	2	20	3,530	0.080	424	141	282	100%	700	5.5	8	290
Usage Group B	185	37	112	20	3,530	4.605	24,161	7,907	16,255	100%	700	5.5	467	16,722
Usage Group B	4	62	2	20	3,530	0.208	875	141	734	100%	700	5.5	21	755
Usage Group B	143	50	72	20	3,530	5.710	25,238	5,083	20,155	100%	700	5.5	579	20,734
Usage Group C	72	37	36	20	4,260	1.944	11,348	3,067	8,281	100%	957	5.5	269	8,550
Total	**3049**		**1571**			**100.24**	**927,932**	**219,748**	**708,184**				**27,108**	**735,292**

Table 5-3. Evaluation Controls Inputs and kWh Savings

	A	B	C	D=A*B/1000	E=C*D	F	G	H	I=D*F*G*0.8/H	J=E+X
Space Type	**Installed Quantity**	**Installed Watts per Fixture**	**Annual Hours Reduction**	**Connected kW**	**kWh Controls Savings**	**Percent of Space Cooled**	**Annual Cooling Hours Reduction**	**Cooling COP**	**Interactive Cooling Savings**	**Total kWh Controls Savings**
Usage Group A	24	20	2,419.30	0.48	1,161	100%	751	5.5	52	1,213
Usage Group A	959	20	2,419.30	19.18	46,402	100%	751	5.5	2,084	48,486
Usage Group A	289	20	2,419.30	5.78	13,984	100%	751	5.5	628	14,612
Usage Group A	73	20	2,419.30	1.46	3,532	100%	751	5.5	159	3,691
Usage Group B	2	20	1,129.54	0.04	45	100%	317	5.5	2	47
Usage Group B	112	20	1,129.54	2.24	2,530	100%	317	5.5	103	2,633
Usage Group B	2	20	1,129.54	0.04	45	100%	317	5.5	2	47
Usage Group B	72	20	1,129.54	1.44	1,627	100%	317	5.5	66	1,693
Usage Group D	2	20	295.30	0.04	12	100%	93	5.5	1	12
Usage Group C	36	20	1,363.12	0.72	981	100%	455	5.5	47	1,029
Total	**1,571**			**31.42**	**70,319**				**3,143**	**73,463**

6 Final Results

The evaluated savings for the lighting project were slightly greater than the applicant-reported savings primarily due to a discrepancy stemming from heating and cooling interaction. Detailed values are shown in Table 5-196. Summary of Key Parameters, comparing changes in the baseline and proposed conditions for both the application and evaluation hours of use for each area.

Table 5-85. Summary of Key Parameters

Parameter	Tracking Value(s)	Evaluation Value(s)
Baseline Fixture Quantity	3,049	3,049
Installed Fixture Quantity	1,571	1,571
HVAC interactive savings	Not Included	Heating: Steam Boiler Cooling: Chiller (COP 5.5)
Operating Hours	7,560, 3,530, 4,260, and 923 hours	7,560, 3,530, 4,260, and 923 hours

Table 5-86. Summary of Savings

ECM	Applicant Savings (kWh)	Evaluator Savings (kWh)
Lighting Retrofit	778,503	808,755

6.1 Explanation of Differences

The evaluation is 3.9% more than the applicant reported savings. Table 3-3 provides a summary of the primary differences between tracking and evaluated values.

Table 5-87. Summary of Energy Savings Deviations

End-use	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
Lighting	Interactive	HVAC Interactivity	+3.9%	**Increased Savings**- a difference of 30,251 kWh was determined by the inclusion of HVAC interactivity in the evaluator's savings algorithms.

6.1.1 Ancillary impacts

For this measure, electric HVAC interaction savings occur in retrofitting the fluorescent fixtures to LED. The tracking estimate did not include HVAC interactive effects. These effects resulted in an additional 30,251 kWh of savings.

Program	RICE2018
Application ID(s)	7423208
Project Type	Existing Building Retrofit
Program Year	2018
Evaluation Firm	DNV
Evaluation Engineer	Rulando Antoine
Senior Engineer	Jeffrey Zynda

7 Evaluated Site Summary and Results

This is a manufacturing facility that had its internal lighting systems retrofitted. In total, 100 metal halide fixtures were retrofitted with 200-watt LED fixtures. The fixtures serve the manufacturing floor and are controlled by two breaker panels. They are turned on and off manually at the beginning and end of each shift. The applicant's energy savings are derived from a reduction in wattage and did not consider HVAC interactive savings.

While conducting the site visit, the evaluator noticed essentially two operating schedules, unlike what is seen in the site documentation. Nine of the retrofitted fixtures are left on throughout the year, while the remaining fixtures follow the operating schedule mentioned above. The customer stated that the nine fixtures are left ON for security reasons. The evaluator also observed fixture descriptions and operating conditions that differ from what was noted in the tracking documentation and used to determine savings from this measure. The documentation says that baseline fixtures were "400W METAL HALIDE" and run at 455W. However, while onsite, the baseline fixtures were 6L4'T8 pendant mounted high performance fluorescent fixtures that operated at 224 watts. This aligns with documentation from the vendor included in project files. The site visit also found that the installed fixtures were 192-watt LEDs and not 200-watt LEDs, as stated in the site documentation.

The applicant's project savings calculation resulted in an annual fixture energy savings of 156,519 kWh. Summer On-peak demand savings was 25.5 kW, and winter was 25.5 kW. The evaluator calculated the annual energy savings to be 12,237 kWh, summer on-peak demand savings to be 1.74 kW, and winter on-peak demand savings to be 0.29 kW; due mostly to the technology adjustment described in the paragraph above and Section 2.3.1 below.

The Covid-19 pandemic did not impact this site. See Section 2.3 for further details.

The evaluation results are presented in Table 1-1.

Table 5-88: Evaluation Results Summary

PA Application ID	Measure Name		Annual Electric Energy (kWh)	Summer On-Peak Demand (kW)	Winter On-Peak Demand (kW)
7423208	Lighting Retrofit	Tracked	156,519	25.5	25.5
		Evaluated	12,237	1.74	0.29
		Realization Rate	**7.8%**	**6.8%**	**1.1%**

7.1 Explanation of Deviations from Tracking

The evaluated reported savings are zero because of the differences in the baseline and installed wattages observed while onsite compared to those noted in the site documentation.

7.2 Recommendations for Program Designers & Implementers

There are no recommendations currently.

7.3 Customer Alert

The customer requested a copy of the site report.

8 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 internal LED fixtures throughout the applicant's manufacturing floor.

8.1 Application Information and Applicant Savings Methodology

This section describes the applicant's application information, savings methodology, and evaluation assessment of the applicant's savings calculation algorithm. Project savings were generated from a reduction in fixture wattage.

8.2 Applicant Description of Baseline

This project is classified as a lighting retrofit project in the application. The site documentation reported that the baseline consisted of one hundred 400-watt metal halide fixtures that operated 455 watts. These fixtures had no advanced controls, were manually operated, and ran for 6,138 annual hours.

Table 5-89: Applicant baseline key parameters

		BASELINE		
Measure	**Parameter**	**Value(s)**	**Source of Parameter Value**	**Note**
Lighting Retrofit	Fixture Wattage	455W	Project Files	None
Lighting Retrofit	Fixture Quantity	100	Project Files	None
Lighting Retrofit	Operating Hours	6,138	Project Files	None

8.2.1 Applicant Description of Installed Equipment and Operation

The facility upgraded its lighting system by retrofitting older fixtures with 200-watt LEDs. Operating schedules and fixture counts observed in the baseline description are maintained for the installed fixtures. Project savings were generated from the installation of 200-watt pendant mounted LED fixtures.

Table 5-2: Application proposed key parameters

		PROPOSED		
Measure	**Parameter**	**Value(s)**	**Source of Parameter Value**	**Note**
Lighting Retrofit	Fixture Wattage	200W	Project Files	None

8.2.2 Applicant Energy Savings Algorithm

Savings were calculated using a custom lighting savings excel workbook using the following equations. The primary driver for this measure's energy savings is a reduction in fixture/lamp wattage. Energy savings algorithms are as follows:

$$\text{Pre-existing Fixture kWh} = \textit{Quantity*Wattage/1000*Pre-exisitng Operating Hours}$$
$$\text{Post-retrofit Fixture kWh} = \textit{Quantity*Wattage/1000*Post-retrofit Operating Hours}$$
$$\text{Total kWh Savings} = \textit{Baseline Fixture kWh -Proposed Fixture kWh}$$

Table 5-3: Applicant baseline key parameters

	A	B	C	D	E	F=A*B*E /1000	G=C*D*E/1000	H	H=F-G
Space Type	**Baseline Quantity**	**Baseline Watts per Fixture**	**Installed Quantity**	**Installed Watts per Fixture**	**Annual Hours**	**Baseline kWh**	**Installed kWh**	**Control kWh Savings**	**kWh Fixture Savings**
Main Floor	100	455	100	200	6,138	279,279	122,760	0	156,519
Total	**100**		**100**			**279,279**	**122,760**	**0**	**156,519**

8.2.3 Evaluation Assessment of Applicant Methodology

The evaluator agrees with the analysis approach used by the applicant.

8.3 Onsite Inspection

The evaluators conducted a site visit after confirming the following criteria:

- The site was safe to visit, and the site contact with knowledge of the project was available to assist with the evaluation site visit.
- Covid-19 did not impact the site's operations.
- There is no seasonality at this site, so metering equipment installed during the site visit was sufficient to capture typical operation data.

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

8.3.1 Summary of Site Visit Findings and Metering

With the facility manager and electrician's assistance, the first site visit and meter deployment was completed on January 22, 2021. While visiting the customer's facility, the evaluator confirmed facility daily and holiday operating schedules, lighting control types being utilized, fixture counts, and wattages. The engineer also gathered HVAC information and got further confirmation that Covid-19 had no impact on the site's operation.

While onsite, the evaluator noticed discrepancies between what was noted in the tracking documentation as the baseline equipment and what was utilized by the facility. The project's pre-existing fixture description was listed as being 400-watt metal halides that operated at 455 watts. However, while onsite, the evaluator observed several baseline fixtures fluorescent 6-lamp 32-watt 4' high performance T8s with a total wattage of 224 watts per fixture (as shown in Image 1 and Image 3). These lights are no longer operational, but the site contact stated that these fixtures were, in fact, the ones that were initially in use and are slowly being replaced by more efficient fixtures. The evaluator also observed one of the program-installed fixtures while onsite and found that the units operate at 192 watts and not at 200 watts, as reported in the site documentation. These fixtures use two LED Diodes that each run at 96W, as shown in Image 2.

Image 1: Pre-existing Fixture

Image 2: Post-retrofit Lighting Fixture

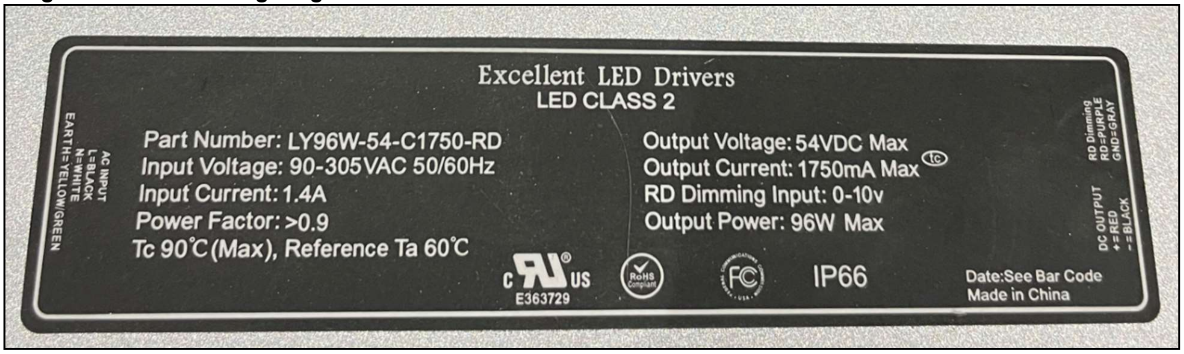
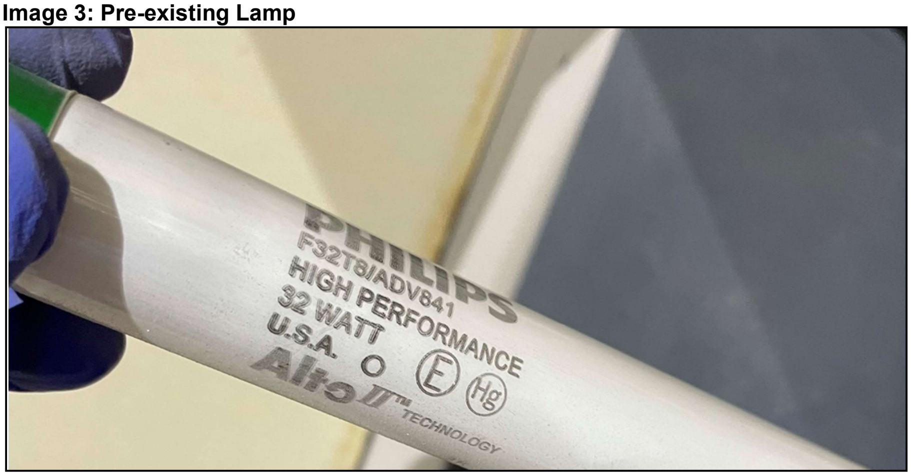


Image 3: Pre-existing Lamp



While onsite, the evaluator also observed fixture operating conditions that were not consistent with what was reported in the tracking documentation. Of the 100 fixtures used on the manufacturing floor, nine are left on all year, while the remaining fixtures follow operating conditions that see them run twelve hours/day Monday-Friday and for six hours on Saturdays. Two annual schedules were created in the evaluation analysis based on the metered data collected on-site, 8,760 hrs for nine fixtures and 3,336 for the remaining 91 fixtures. This estimate differs from the 6,138 annual operating hours used for all the fixtures in the site documentation.

The table below provides a quick summary of the evaluator's findings.

Table 5-4: Measure Verification

Measure Name	Verification Method	Verification Result
Lighting Retrofit	Verify fixture quantity, schedule, control, and wattage.	Changes were observed with the fixture schedule and wattage. Fixture control and quantity are consistent with what's seen in the tracking documentation.

2.3.2 Measured and Logged Data

The evaluator deployed two DentElite Pro loggers on circuits controlling these lights. Loggers were installed from January 22, 2021, to February 26, 2021.

Table 2-5 shows a summary of metering that was conducted at this site.

Table 5-5: Data Logger Deployment and Metering Details

Data Logger Type	Parameter	Time Interval	Duration	Quantity
DentElite Pro	Fixture operating parameters (V, A, kW and dPF) and run hours	5 Minute Data	35 days	2

The evaluator used the metered lighting data to create an operating profile to show when the fixtures were being used. The metered data was expanded to fit a weekly profile. The profiles depict an hourly percent ON value that shows the percent of the hourly interval where the fixture was in operation.

Below are examples of metered data collected for schedules utilized on the main floor.

Figure 35: Logger Operating Data – 8,760 Schedule

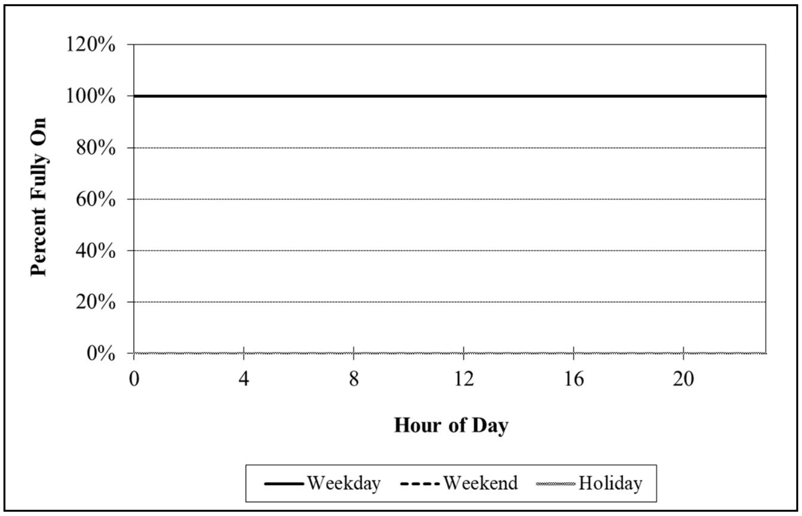
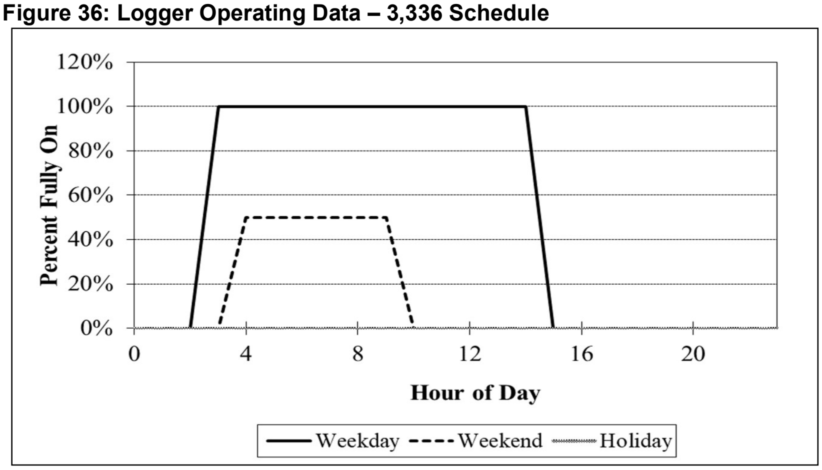


Figure 36: Logger Operating Data – 3,336 Schedule



8.4 Evaluation Methods and Findings

This section describes the evaluator methods and findings.

8.4.1 Evaluation Description of Baseline

The evaluator reviewed the project files, interviewed the site contact, and conducted a site visit to gather information on the baseline. The evaluator determined the lighting measure is a retrofit with a dual baseline measure, where the baseline would be the pre-existing fixtures identified in the lighting audit. The dual baseline for the analysis of lifetime savings follows the model where 1/3 lifetime is attributed to a baseline of the existing fixtures, and 2/3 will be assumed using a 60% of the baseline fixture wattage for that remaining period regardless of existing fixture age or reported condition. The evaluator will report this project as a dual baseline with a 15-year measure life.

8.4.2 Evaluation Metered Data and Analysis Methodology

The evaluator conducted a site visit to verify equipment technology and quantities. With the electrician's help, loggers were also deployed on fixtures throughout the facility to obtain operation data - V, A, kW, and PF and run hours. The evaluator also recorded spot measurements for voltage and power factor readings at the installation time and took a screenshot to capture this information. The metered data was then used to create yearly operating lighting profiles. In conjunction with the verified fixture count and type, the evaluated data is used to calculate evaluated energy savings. Evaluated energy savings were generated by comparing the logger data annual hours of use to the annual hours of use found in the application. There were no controls or HVAC cooling-related savings for this project.

The graph below depicts the fixture operating schedule for one week, January 22 through January 30. It shows the lights operating in line with what was mentioned by the site contact, which is 12hrs Mon-Fri and 6hrs on Saturday. Loggers were installed from January 22 to February 26.

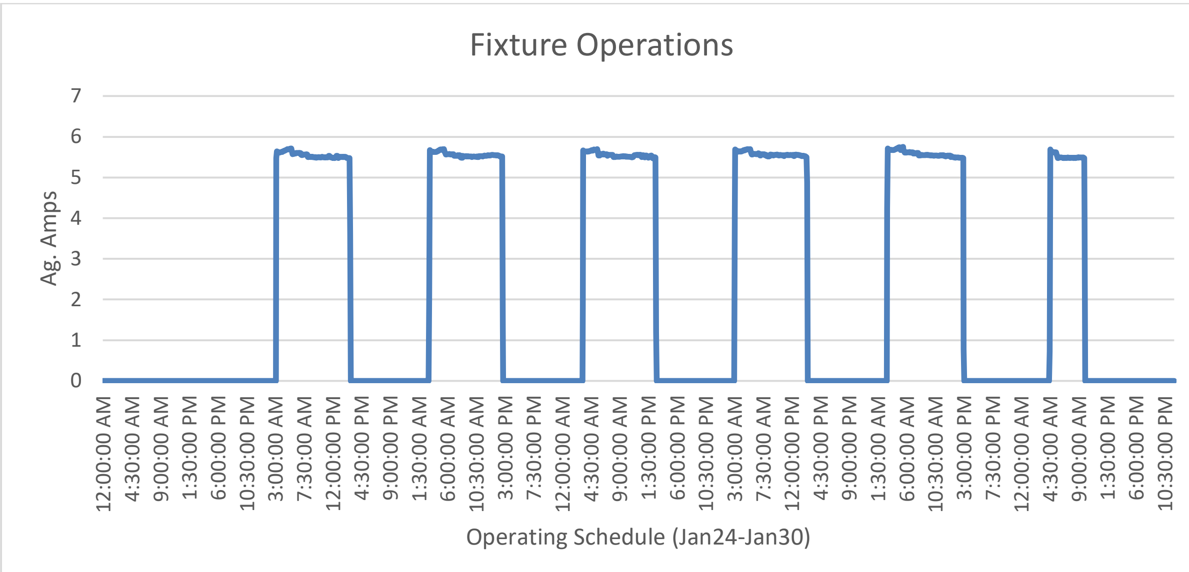


Figure 37: Fixture Schedule

The evaluator used the equations highlighted below to calculate the energy saving associated with this measure.

Pre-existing Fixture kWh = *Quantity*Wattage/1000*Evaluated Operating Hours*
Post-retrofit Fixture kWh = *Quantity*Wattage/1000*Evaluated Operating Hours*
Total kWh Savings = *Baseline Fixture kWh -Proposed Fixture kWh*

9 Final Results

This section will summarize the evaluation results determined in the analysis above. The evaluator's estimated savings values result from metered energy usage and observed changes to the applicant's pre and post-cases.

Table 3-1 summarises the energy usage values observed in the applicant's and evaluator's pre and post-case calculations.

Table 5-90. Energy Usage Summary

	Pre-existing		Post-retrofit	
Parameter	**Tracking Value(s)**	**Evaluation Value(s)**	**Tracking Value(s)**	**Evaluation Value(s)**
Lighting fixture usage	279,279 kWh	85,661 kWh	122,760 kWh	73,424 kWh

Table 3-2 below shows the evaluation inputs and savings calculations.

Table 3-2: Evaluation Fixture Inputs and kWh Savings

	A	B	C	D	E	F	G=A*B*E /1000	H=C*D*E/1000	I=G-H	J	K	L	M=F*J*K*0.8/L	N=I+M
Space Type	**Baseline Quantity**	**Baseline Watts per Fixture**	**Installed Quantity**	**Installed Watts per Fixture**	**Annual Hours**	**Connected kW Savings**	**Baseline kWh**	**Installed kWh**	**kWh Fixture Savings**	**Percent of Space Cooled**	**Annual Cooling Hours**	**Cooling COP**	**Interactive Cooling Savings**	**Total kWh Fixture Savings**
Main Floor	9	192	9	224	8,760	0.288	17,660	15,137	2,523	0%	0	0.0	0	2,523
Main Floor	91	192	91	224	3,336	2.912	68,001	58,287	9,714	0%	0	0.0	0	9,714
Total	**100**		**100**			**0.000**	**85,661**	**73,424**	**12,237**				**0**	**12,237**

9.1 Explanation of Differences

The significant factors that affect this project's energy-saving are changes observed in the fixture wattage and operating hours. The table below highlights the values used to calculate both the applicant's and evaluator's energy saving values.

Table 3-3 provides a summary of the differences between tracking and evaluated values.

Table 3-3: Summary of Key Parameters

	Applicant				Evaluation			
Space Description	**Annual Hours**	**Fixture Quantity**	**Baseline Watts per Fixture**	**Proposed Watts**	**Annual Hours**	**Fixture Quantity**	**Baseline Watts per Fixture**	**Proposed Watts**
Main Floor	6,138	91	455	200	3,336	91	224	192
Main Floor	6,138	9	455	200	8,760	9	224	192

Table 5-4: Summary of Deviations

Measure	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
7423208	Technology	Fixture Wattage	-87.5%	Decreased savings –Onsite observation resulted in changes to the baseline and installed fixture wattages.
7423208	Operation	Hours of Use	-4.7%	Decreased savings -Metered hours of use are lower than assumed in the tracking savings estimate.
Final RR				**7.8%**

9.1.1 Ancillary impacts

There are no fuel-based ancillary impacts associated with this project.

RICE18L065

Program Administrator	National Grid	
Application ID(s)	7353143	
Project Type	Retrofit	
Program Year	2018	
Evaluation Firm	DNV	DNV·GL
Evaluation Engineer	Vishnu Prakash	
Senior Engineer	Jeff Zynda	

Evaluated Site Summary and Results

This lighting retrofit project was done for a large commercial manufacturing facility. The space covered approximately 200,000 square feet and retrofitted 855 pre-existing fixtures with 854 LED fixtures, which were estimated to save 453,594 kWh annually. Occupancy sensors were installed on 420 of these fixtures and were assumed to reduce operating hours by 38% for a total annual savings of 168,813 kWh. Program savings are due to the reduction in wattage when retrofitting baseline fixtures with LEDs as well as a reduction in operating hours for fixtures with controls. The site contact reported that the operation of the lighting at the site was not affected by the COVID-19 pandemic, so full M&V was done with an assessment of operational adjustments.

The applicant's project savings calculation resulted in an annual energy savings of 622,407 kWh. Summer On-peak demand savings was 55.1 kW, and winter was 59.7 kW. The evaluator calculated the annual energy savings to be 762,968 kWh, summer on-peak demand savings to be 89.9 kW, and winter on-peak demand savings to be 88.8 kW. The evaluation results are presented in Table 5-2.

Table 5-91. 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)
7353143	Retrofit Lighting	Tracked	453,594	49.0%	55.09	59.70
		Evaluated	443,174	47.8%	52.67	52.63
		Realization Rate	97.7%	97.6%	95.6%	88.2%
	Lighting Controls	Tracked	168,813	49.0%	0.0	0.0
		Evaluated	319,794	45.3%	37.18	36.22
		Realization Rate	189.4%	92.5%	N/A	N/A
Evaluation Totals		**Tracked**	**622,407**	**49.0%**	**55.09**	**59.70**
		Evaluated	**762,968**	**46.8%**	**89.86**	**88.85**
		Realization Rate	**122.6%**	**95.5%**	**163.0%**	**148.9%**

Explanation of Deviations from Tracking

The evaluated savings are 22.6% higher than the applicant-reported savings primarily due to an increase in the hours of use reduction caused by the occupancy sensors installed through the program. Further details regarding deviations from the tracked savings are presented in Section 3-4.

Recommendations for Program Designers & Implementers

There are no recommendations for this project.

Customer Alert

There are no customer alerts.

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.

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. Both applicant and evaluated approaches calculated energy savings based on on-site findings and assumptions.

Applicant Description of Baseline

The applicant classified the measure as a retrofit with the baseline as the existing condition. The majority (99.3%) of the baseline fixtures are categorized as T8 fluorescents (75.3%) and T5HO fluorescents (24.0%). The remaining baseline fixtures were categorized as LEDs and CFLs. The applicant documentation claimed 855 light fixtures in the baseline case to be replaced with 854 proposed fixtures. Annual operating hours were split into 10 different usage groups of varying hours ranging from 923 to 8,760.

Applicant Description of Installed Equipment and Operation

The applicant proposed installing 854 LED lighting fixtures to replace the existing 855 fixtures. Annual operating hours were consistent with the baseline assumed hours except for the 420 fixtures with controls, for which a 38% reduction in operating hours was assumed.

Applicant Energy Savings Algorithm

The applicant used the National Grid Lighting tool to estimate the tracking savings. No savings from HVAC interactivity were claimed as part of this application. Controls savings were claimed in the applicant calculation methodology. The savings are calculated using the formulas shown below:

Baseline Fixture kWh = $\frac{Quantity_B * Wattage_{\boldsymbol{B}}}{1000} * Applicant\ Operating\ Hours\ without\ Controls$

Proposed Fixture kWh = $\frac{Quantity_P * Wattage_{\boldsymbol{P}}}{1000} * Applicant\ Operating\ Hours\ without\ Controls$

Fixture kWh Savings = $Baseline\ Fixture\ kWh\ - Proposed\ Fixture\ kWh$

Control kWh Savings = $(Proposed\ controlled\ Fixture\ kW) * Applicant\ Operating\ Hours\ without\ Controls * 38\%$

Total kWh Savings = $Fixture\ kWh\ Savings + Control\ kWh\ Savings$

Table 5-83. Tracking System Fixture Inputs and kWh SavingsTable 5-56. Tracking System Fixture Inputs and kWh Savings below shows the tracking system inputs and savings calculations for the lighting retrofit.

Table 5-92. Tracking System Fixture Inputs and kWh Savings

	A	B	C	D	E	F=A*B*E/1000	G=C*D*E/1000	H=F-G	I	J=H+I
Usage Group	Baseline Quantity	Baseline Watts per Fixture	Installed Quantity	Installed Watts per Fixture	Annual Hours	Baseline kWh	Installed kWh	kWh Fixture Savings	Controls kWh Savings	Total kWh Savings
G	3	60	3	36	4,381	789	473	315	0	315
B	4	112	4	42	923	414	155	258	0	258
B	2	112	2	135	923	207	249	-42	95	52
B	11	60	11	36	923	609	366	244	0	244
B	20	224	20	135	923	4,135	2,492	1,643	947	2,590
B	1	30	1	45	923	28	42	-14	16	2
B	2	15	2	25	923	28	46	-18	0	-18
D	6	112	6	36	2,488	1,672	537	1,134	0	1,134
D	14	60	14	36	2,488	2,090	1,254	836	0	836
F	15	60	15	36	3,531	3,177	1,906	1,271	0	1,271
F	1	60	1	45	3,531	212	159	53	60	113
F	4	224	4	135	3,531	3,163	1,906	1,257	724	1,981
J	3	112	3	42	8,761	7,849	5,606	2,243	2,130	4,373
J	30	60	30	36	8,761	2,943	1,104	1,840	0	1,840
J	4	60	3	42	8,761	15,768	9,461	6,307	0	6,307
J	47	224	47	42	8,761	2,102	1,104	999	0	999
J	1	37	1	36	8,761	526	1,183	-657	449	-208
J	8	112	8	80	8,760	92,225	17,292	74,933	0	74,933
J	1	60	1	135	8,760	178,564	107,617	70,947	40,894	111,842
J	91	224	91	135	8,760	256,230	147,825	108,405	56,174	164,579
J	125	234	125	135	8,760	324	315	9	0	9
J	4	250	4	135	8,760	8,760	4,730	4,030	1,798	5,827
E	2	112	2	36	2,905	651	209	442	0	442
E	8	112	8	42	2,905	2,603	976	1,627	0	1,627
E	60	60	60	36	2,905	10,457	6,274	4,183	0	4,183
E	3	60	3	45	2,905	523	392	131	149	280
C	4	60	4	36	1,184	284	170	114	0	114
I	8	112	8	42	7,963	7,135	2,676	4,459	0	4,459
I	8	60	8	36	7,963	3,822	2,293	1,529	0	1,529
I	160	224	160	135	7,963	285,403	172,006	113,397	65,362	178,759
A	2	60	2	36	4,381	526	315	210	0	210
A	70	234	70	150	4,381	71,754	45,996	25,758	0	25,758
A	10	325	10	150	4,381	14,237	6,571	7,666	0	7,666
H	6	112	6	36	5,512	3,704	1,191	2,514	0	2,514
H	1	112	1	42	5,512	617	232	386	0	386
H	112	60	112	36	5,512	37,042	22,225	14,817	0	14,817
H	4	60	4	42	5,512	1,323	926	397	0	397

Total	**855**		**854**			**1,021,894**	**568,276**	**453,619**[27]	**168,799**[28]	**622,418**

[27] The site documentation energy savings calculation for fixtures was 25 kWh or 0.01% higher than the tracking system savings estimate. This discrepancy cannot be explained.
[28] The site documentation energy savings calculation for controls was 14 kWh or 0.01% lower than the tracking system savings estimate. This discrepancy cannot be explained.

Evaluation Assessment of Applicant Methodology

The evaluator deemed the applicant savings calculation methodology and assumptions to be reasonable. However, the evaluator notes that the applicant methodology does not include savings from HVAC interaction.

Inspection

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

Summary of Findings

DNV conducted a visit to the facility on February 24th, 2021. During the site visit, the evaluator interviewed the store energy manager and verified the applicant inputs by performing a site audit and installing long term HOBO lighting loggers, DENT CT Loggers, and DENT power meters to capture dimmed operation. The site contact confirmed that the relevant spaces had no prior controls before the fixtures were replaced. The evaluators installed DENT power meters on the manufacturing floor, including walking aisles and lights over machinery. DENT power meters were also installed in the factory floor and storage areas. CT amp loggers were installed for the perimeter lights, dock lights, exterior lights, and storage area. Lighting loggers were installed in office areas to capture time of use.

Measured and Logged Data

The evaluator deployed thirty-one data loggers to characterize the operating profile for the lighting fixtures in different areas from February 24th, 2021 to May 26th, 2021. Table 5-93 and Table 5-94 present the logger deployment details and data received.

Table 5-93. Evaluation Data Collection – Installed Equipment

Parameter	M&V Equipment Brand and Model	Metering Start/Stop Dates	Metering Interval
Interior Office lighting operating schedules	20 Dent lighting logger TOU	2/24/2021-5/27/2021	15 Minute
Interior Office lighting operating schedules	1 Onset lighting logger TOU & Occupancy	2/24/2021-5/27/2021	5 Minute
Interior Office lighting operating schedules	1 Onset lumen logger	2/24/2021-5/27/2021	1 Minute
Interior Warehouse and Manufacturing lighting operating schedules	3 Dent ELITEpro XC power logger	2/24/2021-5/27/2021	1 Minute
Interior Warehouse and Manufacturing lighting operating schedules	2 Dent CT Loggers	2/24/2021-5/27/2021	15 Minute
Exterior Warehouse and Manufacturing lighting operating schedules	4 Dent CT Loggers	2/24/2021-5/27/2021	15 Minute

Table 5-94. Evaluation Data Collection – Data Received

Source	Parameter	Interval	Duration
Lighting loggers	Time of use	15 Minute	14 Weeks
Power logger	Dimming wattage reduction	1 Minute	14 Weeks
CT Logger	Dimming wattage reduction	15 Minute	14 Weeks

The evaluator used the metered lighting TOU data to calculate an operating profile to show when the fixtures were being in use. Metered hourly data was expanded to fit a weekly profile. The profiles depict an hourly percent on value that shows the percent of the hourly interval where the fixture was in operation. An example of a logged operating schedule is shown below in

Figure 5-38. Logged Operating Data – developed from one of the power loggers monitoring the storage warehouse. Figure 5-39 shows the baseline schedule for this space.

Figure 5-38. Logged Operating Data – Storage Warehouse

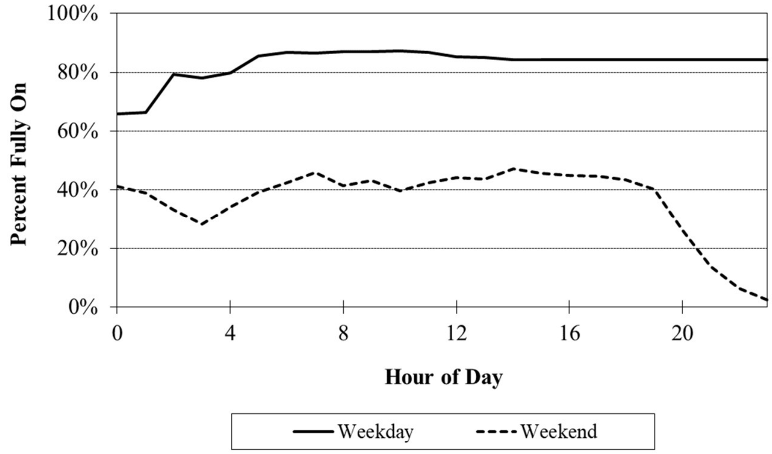


Figure 5-39. Baseline Operation – Storage Warehouse

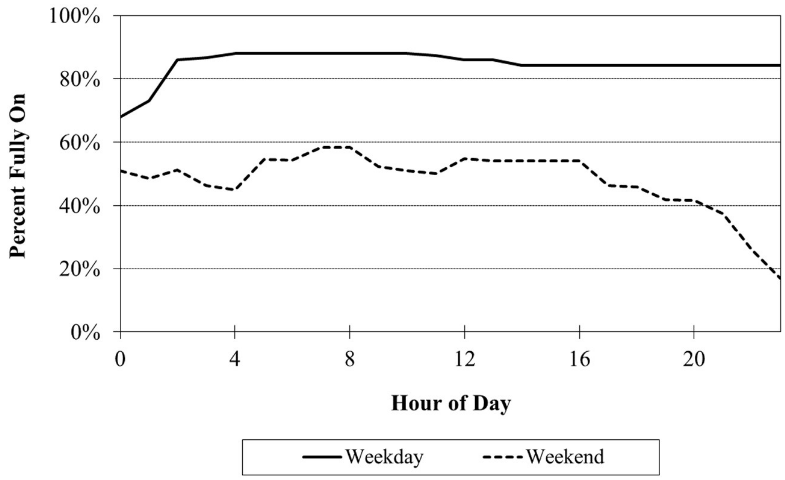


Figure 5-38 above depicts the operating profile developed from the metered data. The process for developing the baseline schedules will be discussed in the following section. The weekly expanded schedules corroborate with the schedules provided by the site contact. For the analysis, the evaluator expanded the logger data set to an 8,760-operating profile. Table 5-95 below lists the expanded annual operating hours for all metered data sets and baselines operating hours developed from this data for fixture with controls. All “XC” mentions under the “Logger #” column reference circuits captured by the power logger.

Table 5-95. Logged Data Schedules

Schedule ID	Logger #	Description	Annual Hours	On-Peak Hours
1	CT08010051	Panel 107: Storage Lights	6,038	3,422
2	CT12110127	Panel 107: Perimeter Lights 1	3,440	1,306
3	CT12120025	Panel 107: Perimeter Lights 2	3,439	1,308
4	CT12120026	Panel 107: Dock Lights	7,280	3,542
5	CT12120038	Panel 107: Perimeter Lights 3	3,440	1,306
6	CT13040099	Panel 111: Storage Floor	6,858	3,539
7	LL06050069	TOU-Break Room	72	58
8	LL08030140	TOU-Men's Bathroom	7,678	3,565
9	LL08041044	TOU-Hallway	7,671	3,558
10	LL08041194	TOU-Utility / Storage	2,652	1,418
11	LL08041929	TOU-Private Office 1	2,352	1,912
12	LL08050354	TOU-Computer Room	89	80

13	LL08050616	TOU-Sales Class Room	1,784	1,077
14	LL08050882	TOU-Copy Room	2,738	1,926
15	LL08100546	TOU-Supervisors Office	6,219	3,495
16	LL08100935	TOU-Private Office Gibbison	2,711	1,962
17	LL08101948	TOU-Coffee Room	6,216	3,205
18	LL08102070	TOU-Main Office	7,681	3,565
19	LL08102828	TOU-Copy room	4,454	2,649
20	LC09060017	TOU-Women's Bathroom	2,849	1,513
21	LL10110086	TOU-Private Office 2	2,991	1,922
22	LL10120260	TOU-Conference Room (big)	1,065	748
23	LL11010209	Lumen-Stairs	7,559	3,551
24	LL11020096	TOU-Men's Locker	6,254	3,370
25	LL11030150	TOU-Supervisors Office	6,740	3,532
26	XC1803038	ELITE-Panel 111: Storage Floor (Storage Area)	999	605
27	XC1803038	ELITE-Panel 111: Storage Floor (Storage Area)	1,215	718
28	XC1803038	ELITE-Panel 111: Storage Floor (Storage Area)	1,215	718
29	XC1803038	ELITE-Panel 111: Storage Floor (Storage Area)	1,115	708
30	XC1803121	ELITE-Panel LP1-Factory Lights	4,219	1,998
31	XC1803121	ELITE-Panel LP1-Factory Lights	4,905	2,360
32	N/A	Schedule 1 Baseline	8,335	4,016
33	N/A	Schedule 4 Baseline	8,687	4,016
34	N/A	Schedule 6 Baseline	8,687	4,016
35	N/A	Schedule 10 Baseline	8,684	4,016
36	N/A	Schedule 13 Baseline	5,395	2,354
37	N/A	Schedule 14 Baseline	6,943	3,583
38	N/A	Schedule 15 Baseline	8,118	4,016
39	N/A	Schedule 26 Baseline	8,683	4,016
40	N/A	Schedule 27 Baseline	8,061	4,016
41	N/A	Schedule 28 Baseline	8,061	4,016
42	N/A	Schedule 29 Baseline	7,591	4,016
43	N/A	Schedule 30 Baseline	8,685	4,016
44	N/A	Schedule 31 Baseline	8,685	4,016

Table 5-96 provides an example of how the baseline hours of use were derived from the logger data for with occupancy sensor controls. The baseline value is calculated using the percent on from the logger data for the hour of interest and the hour before and/or after. If the logger data for the hour of interest is greater than 0% and is 0% for the hour before, the baseline percent on at that hour equals the percent on from the logger data (see hour two). If the logger data for the hour of interest and the hours before and after are all greater than 0%, the baseline value is set to 100%, which assumes that the fixture(s) would have operated 100% of the time during this hour when manually controlled (see hour three). If the logger data for the hour of interest is greater than 0% and but is 0% for the hour after, the baseline percent on at that hour equals the percent on from the logger data (see hour four).

Table 5-96. Derivation of Occupancy Sensor Control Baseline

Hour	Logger Data Percent On	Baseline Percent On
1	0%	0%
2	64%	64%
3	52%	100%
4	52%	52%
5	0%	0%
6	0%	0%
7	48%	48%
8	56%	100%

Evaluation Methods and Findings

Evaluation Description of Baseline

Baseline conditions for this project consisted mostly of T8 fluorescents (75.3%) and T5HO fluorescents (24.0%). The remaining baseline fixtures were categorized as LEDs and CFLs. The site documentation reported that the baseline consisted of 855 fixtures with varying wattages from 15 to 325 watts. Application baseline usage hours ranged from 923 to 8,760 annual hours. These fixtures had no controls and were manually operated.

The evaluator reviewed the project files and interviewed the site contact and conducted a site visit to confirm the baseline information provided in the application.

Evaluation Calculation Method

The evaluator calculated the savings using a similar approach to the applicant and used a custom lighting tool to determine the evaluated savings which includes HVAC interactivity. The savings algorithms used in the tool are as follows:

Baseline Fixture kWh = $\frac{Quantity_B * Wattage_B}{1000} * Evaluated\ Operating\ Hours\ without\ Controls$

Proposed Fixture kWh = $\frac{Quantity_P * Wattage_P}{1000} * Evaluated\ Operating\ Hours\ without\ Controls$

Fixture kWh Savings = $Baseline\ Fixture\ kWh\ - Proposed\ Fixture\ kWh$

Control kWh Savings = $Proposed\ Fixture\ kW\ * (Evaluated\ Operating\ Hours\ without\ controls - Evaluated\ Operating\ Hours\ with\ controls)$

HVAC Interactive Fixture Savings = $(pre\ connected\ kW - post\ connected\ kW) * Coincident\ Occupied\ Cooling\ Hours * \frac{0.8}{Cooling\ COP}$

HVAC Interactive Control Savings = $Proposed\ fixture\ kW * \%\ of\ space\ cooled * Coincident\ Occupied\ Cooling\ Hours * \frac{0.8}{Cooling\ COP}$

Total kWh Savings = $Fixture\ kWh\ Savings\ + Control\ kWh\ Savings + HVAC\ Interactive\ Fixture\ Savings + HVAC\ Interactive\ Control\ Savings$

All spreadsheets used to estimate evaluation savings will be made available to the PAs for review at their request. For site cooling hours, the evaluator assumed cooling would only occur between May and October. For each hourly interval within that range of months in the 8760 model, if dry bulb temperature taken from local TMY3 data was greater than or equal to the cooling balance point of 65°F, then that hour was determined to be a cooling hour. Cooling hours that coincided with the lighting hours were used to determine total annual cooling savings. The cooling COP is assumed to be 2.9 for the packaged Dx system that serves parts of this facility. Table 5-97 and Table 5-98 show the evaluation inputs and savings calculations for fixtures and controls, respectively.

Table 5-97. Evaluation Fixture Inputs and kWh Savings

		A	B	C	D	E	F	G=A*B*E/1000	H=C*D*E/1000	I=G-H	J	K	L	M=F*J*K*0.8/L	N=I+M
Usage Group	Schedule ID	Baseline Quantity	Baseline Watts per Fixture	Installed Quantity	Installed Watts per Fixture	Annual Hours	Connected kW Savings	Baseline kWh	Installed kWh	kWh Fixture Savings	% of Space Cooled	Annual Cooling Hours	Cooling COP	Interactive Cooling Savings	Total kWh Fixture Savings
G	18	3	60	3	36	7,681	0.072	1,383	830	553	100%	1,150	2.9	23	576
B	22	2	112	2	42	1,065	0.140	239	89	149	100%	193	2.9	7	156
B	7	1	60	1	36	72	0.024	4	3	2	100%	16	2.9	0	2
B	7	2	112	2	42	72	0.140	16	6	10	100%	16	2.9	1	11
B	14	2	60	2	36	2,738	0.048	329	197	131	100%	511	2.9	7	138
B	12	7	60	7	36	89	0.168	37	22	15	100%	18	2.9	1	16
B	10	1	60	1	36	2,652	0.024	159	95	64	100%	383	2.9	3	66
B	33	2	112	2	135	8,687	-0.046	1,946	2,346	-400	100%	1,305	2.9	-16	-416
B	33	12	224	12	135	8,687	1.068	23,352	14,074	9,278	100%	1,305	2.9	380	9,659
B	41	4	224	4	135	8,061	0.356	7,222	4,353	2,870	0%	N/A	N/A	0	2,870
B	39	4	224	4	135	8,683	0.356	7,780	4,689	3,091	0%	N/A	N/A	0	3,091
B	4	2	15	2	25	7,280	-0.020	218	364	-146	100%	1,090	2.9	-6	-152
B	37	1	30	1	45	6,943	-0.015	208	312	-104	100%	1,131	2.9	-5	-109
D	7	1	60	1	36	72	0.024	4	3	2	100%	16	2.9	0	2
D	20	2	60	2	36	2,849	0.048	342	205	137	100%	450	2.9	6	143
D	20	1	112	1	36	2,849	0.076	319	103	217	100%	450	2.9	9	226
D	8	5	60	5	36	7,678	0.120	2,303	1,382	921	100%	1,149	2.9	38	959
D	8	1	112	1	36	7,678	0.076	860	276	584	100%	1,149	2.9	24	607
D	24	6	60	6	36	6,254	0.144	2,252	1,351	901	100%	944	2.9	37	938
D	24	4	112	4	36	6,254	0.304	2,802	901	1,901	100%	944	2.9	78	1,980
F	18	9	60	9	36	7,681	0.216	4,148	2,489	1,659	100%	1,150	2.9	68	1,727
F	25	4	60	4	36	6,740	0.096	1,618	971	647	100%	1,021	2.9	27	674
F	14	2	60	2	36	2,738	0.048	329	197	131	100%	511	2.9	7	138
F	43	4	224	4	135	8,685	0.356	7,781	4,690	3,092	0%	N/A	N/A	0	3,092
F	44	1	60	1	45	8,685	0.015	521	391	130	0%	N/A	N/A	0	130
J	18	2	112	2	42	7,681	0.140	1,721	645	1,075	100%	1,150	2.9	44	1,119

J	7	8	60	8	36	72	0.192	35	21	14	100%	16	2.9	1	15
J	25	1	60	1	36	6,740	0.024	404	243	162	0%	N/A	N/A	0	162
J	9	4	60	4	36	7,671	0.096	1,841	1,105	736	100%	1,148	2.9	30	766
J	9	4	224	4	42	7,671	0.728	6,873	1,289	5,584	100%	1,148	2.9	228	5,812
J	21	6	60	6	36	2,991	0.144	1,077	646	431	100%	521	2.9	20	451
J	21	4	60	3	42	2,991	0.114	718	377	341	100%	521	2.9	16	357
J	2	3	60	3	36	3,440	0.072	619	371	248	100%	349	2.9	7	255
J	3	5	60	5	36	3,439	0.120	1,032	619	413	100%	349	2.9	11	424
J	43	8	112	8	80	8,685	0.256	7,781	5,558	2,223	0%	N/A	N/A	0	2,223
J	43	79	224	79	135	8,685	7.031	153,684	92,622	61,062	0%	N/A	N/A	0	61,062
J	43	4	250	4	135	8,685	0.460	8,685	4,690	3,995	100%	1,305	2.9	164	4,159
J	17	43	224	43	42	6,216	7.826	59,868	11,225	48,643	0%	N/A	N/A	0	48,643
J	39	125	234	125	135	8,683	12.375	253,970	146,521	107,449	0%	N/A	N/A	0	107,449
J	42	1	60	1	135	7,591	-0.075	455	1,025	-569	0%	N/A	N/A	0	-569
J	30	1	112	1	42	4,219	0.070	473	177	295	0%	N/A	N/A	0	295
J	36	12	224	12	135	5,395	1.068	14,501	8,739	5,761	100%	802	2.9	234	5,995
J	23	3	60	3	36	7,559	0.072	1,361	816	544	100%	1,133	2.9	22	566
J	23	1	37	1	36	7,559	0.001	280	272	8	100%	1,133	2.9	0	8
E	18	11	60	11	36	7,681	0.264	5,070	3,042	2,028	100%	1,150	2.9	83	2,111
E	18	2	112	2	42	7,681	0.140	1,721	645	1,075	100%	1,150	2.9	44	1,119
E	7	18	60	18	36	72	0.432	78	47	31	100%	16	2.9	2	33
E	21	12	60	12	36	2,991	0.288	2,154	1,292	861	100%	521	2.9	41	902
E	21	2	112	2	42	2,991	0.140	670	251	419	100%	521	2.9	20	439
E	11	7	60	7	36	2,352	0.168	988	593	395	100%	442	2.9	20	415
E	1	2	60	2	36	6,038	0.048	725	435	290	0%	N/A	N/A	0	290
E	19	2	60	2	36	4,454	0.048	534	321	214	100%	702	2.9	9	223
E	24	4	112	4	42	6,254	0.280	2,802	1,051	1,751	100%	944	2.9	72	1,823
E	32	2	60	2	45	8,335	0.030	1,000	750	250	0%	N/A	N/A	0	250
E	38	1	60	1	45	8,118	0.015	487	365	122	100%	1,243	2.9	5	127
E	15	8	60	8	36	6,219	0.192	2,985	1,791	1,194	100%	946	2.9	50	1,244
E	15	2	112	2	36	6,219	0.152	1,393	448	945	100%	946	2.9	39	984
C	22	4	60	4	36	1,065	0.096	256	153	102	100%	193	2.9	5	107
I	21	8	60	8	36	2,991	0.192	1,436	861	574	100%	521	2.9	27	602
I	21	8	112	8	42	2,991	0.560	2,680	1,005	1,675	100%	521	2.9	80	1,755
I	44	48	224	48	135	8,685	4.272	93,382	56,280	37,103	0%	N/A	N/A	0	37,103
I	33	6	224	6	135	8,687	0.534	11,676	7,037	4,639	100%	1,305	2.9	190	4,829
I	34	1	224	1	135	8,687	0.089	1,946	1,173	773	0%	N/A	N/A	0	773
I	40	15	224	15	135	8,061	1.335	27,084	16,323	10,761	0%	N/A	N/A	0	10,761
I	42	57	224	57	135	7,591	5.073	96,926	58,415	38,511	0%	N/A	N/A	0	38,511
I	35	33	224	33	135	8,684	2.937	64,193	38,688	25,505	0%	N/A	N/A	0	25,505
A	2	12	234	12	150	3,440	1.008	9,658	6,191	3,467	0%	N/A	N/A	0	3,467

A	2	7	325	7	150	3,440	1.225	7,825	3,612	4,213	0%	N/A	N/A	0	4,213
A	3	13	234	13	150	3,439	1.092	10,463	6,707	3,756	0%	N/A	N/A	0	3,756
A	3	3	325	3	150	3,439	0.525	3,354	1,548	1,806	0%	N/A	N/A	0	1,806
A	30	9	234	9	150	4,219	0.756	8,885	5,696	3,190	0%	N/A	N/A	0	3,190
A	31	10	234	10	150	4,905	0.840	11,478	7,358	4,120	0%	N/A	N/A	0	4,120
A	23	2	60	2	36	7,559	0.048	907	544	363	0%	N/A	N/A	0	363
A	23	26	234	26	150	7,559	2.184	45,988	29,480	16,509	0%	N/A	N/A	0	16,509
H	18	20	60	20	36	7,681	0.480	9,217	5,530	3,687	100%	1,150	2.9	151	3,838
H	22	12	60	12	36	1,065	0.288	767	460	307	100%	193	2.9	15	322
H	7	2	60	2	36	72	0.048	9	5	3	100%	16	2.9	0	4
H	7	4	60	4	42	72	0.072	17	12	5	0%	N/A	N/A	0	5
H	7	4	112	4	36	72	0.304	32	10	22	100%	16	2.9	1	23
H	7	1	112	1	42	72	0.070	8	3	5	0%	N/A	N/A	0	5
H	11	15	60	15	36	2,352	0.360	2,117	1,270	847	100%	442	2.9	43	890
H	20	4	60	4	36	2,849	0.096	684	410	273	100%	450	2.9	12	285
H	20	1	112	1	36	2,849	0.076	319	103	217	100%	450	2.9	9	226
H	8	3	60	3	36	7,678	0.072	1,382	829	553	100%	1,149	2.9	23	575
H	8	1	112	1	36	7,678	0.076	860	276	584	100%	1,149	2.9	24	607
H	2	8	60	8	36	3,440	0.192	1,651	991	660	100%	349	2.9	18	679
H	3	8	60	8	36	3,439	0.192	1,651	991	660	100%	349	2.9	18	679
H	5	5	60	5	36	3,440	0.120	1,032	619	413	100%	349	2.9	11	424
H	13	35	60	35	36	1,784	0.840	3,747	2,248	1,499	100%	295	2.9	68	1,567
Total		**855**		**854**			**62.801**	**1,023,784**	**583,157**	**440,627**				**2,547**	**443,174**

Table 5-98. Evaluation Controls Inputs and kWh Savings

					A	**B**	**C**	**D=A*B/1000**	**E=C*D**	**F**	**G**	**H**	**I=D*F*G*0.8/H**	**J=E+I**
Usage Group	**Baseline Schedule ID**	**Baseline Hours of Use**	**Installed Schedule ID**	**Installed Hours of Use**	**Installed Quantity**	**Installed Watts per Fixture**	**Annual Hours Reduction**	**Connected kW**	**kWh Controls Savings**	**Percent of Space Cooled**	**Annual Cooling Hours Reduction**	**Cooling COP**	**Interactive Cooling Savings**	**Total kWh Controls Savings**
B	33	8,687	4	7,280	2	135	1,407	0.27	380	100%	215	2.9	16	396
B	33	8,687	4	7,280	12	135	1,407	1.62	2,280	100%	215	2.9	95	2,375
B	41	8,061	28	1,215	4	135	6,846	0.54	3,697	0%	1,036	N/A	0	3,697
B	39	8,683	26	999	4	135	7,684	0.54	4,149	0%	1,149	N/A	0	4,149
B	37	6,943	14	2,738	1	45	4,205	0.05	189	100%	620	2.9	8	197

F	43	8,685	30	4,219	4	135	4,466	0.54	2,411	0%	668	N/A	0	2,411
F	44	8,685	31	4,905	1	45	3,780	0.05	170	0%	547	N/A	0	170
J	43	8,685	30	4,219	8	80	4,466	0.64	2,858	0%	668	N/A	0	2,858
J	43	8,685	30	4,219	79	135	4,466	10.67	47,626	0%	668	N/A	0	47,626
J	43	8,685	30	4,219	4	135	4,466	0.54	2,411	100%	668	2.9	98	2,510
J	39	8,683	26	999	125	135	7,684	16.88	129,662	0%	1,149	N/A	0	129,662
J	42	7,591	29	1,115	1	135	6,476	0.14	874	0%	962	N/A	0	874
J	36	5,395	13	1,784	12	135	3,610	1.62	5,849	100%	507	2.9	224	6,073
E	32	8,335	1	6,038	2	45	2,298	0.09	207	0%	350	N/A	0	207
E	38	8,118	15	6,219	1	45	1,899	0.05	85	100%	298	2.9	4	89
I	44	8,685	31	4,905	48	135	3,780	6.48	24,494	0%	547	N/A	0	24,494
I	33	8,687	4	7,280	6	135	1,407	0.81	1,140	100%	215	2.9	47	1,187
I	34	8,687	6	6,858	1	135	1,830	0.14	247	0%	287	N/A	0	247
I	40	8,061	27	1,215	15	135	6,846	2.03	13,863	0%	1,036	N/A	0	13,863
I	42	7,591	29	1,115	57	135	6,476	7.70	49,835	0%	962	N/A	0	49,835
I	35	8,684	10	2,652	33	135	6,032	4.46	26,874	0%	922	N/A	0	26,874
Total					**420**			**55.81**	**319,302**				**492**	**319,794**

Final Results

The evaluated savings for the lighting project were greater than the applicant-reported savings primarily due to an increase in the hours of use reduction caused by the occupancy sensors installed through the program. Detailed values are shown in Table 5-99, comparing changes in the baseline and proposed conditions for both the application and evaluation hours of use for each area for controls.

Table 5-99. Summary of Key Parameters

Usage Group	Qty of Controlled Fixtures	Baseline Hours	Proposed Hours	Qty of Controlled Fixtures	Baseline Hours	Proposed Hours
B	14	923	572	14	8,687	7,280
B	4	923	572	4	8,061	1,215
B	4	923	572	4	8,683	999
B	1	923	572	1	6,943	2,738
F	4	3,531	2,189	4	8,685	4,219
F	1	3,531	2,189	1	8,685	4,905
J	91	8,760	5,431	91	8,685	4,219
J	125	8,760	5,431	125	8,683	999
J	1	8,760	5,431	1	7,591	1,115
J	12	8,760	5,431	12	5,395	1,784
E	2	2,905	1,801	2	8,335	6,038
E	1	2,905	1,801	1	8,118	6,219
I	48	7,963	4,937	48	8,685	4,905
I	6	7,963	4,937	6	8,687	7,280
I	1	7,963	4,937	1	8,687	6,858
I	15	7,963	4,937	15	8,061	1,215
I	57	7,963	4,937	57	7,591	1,115
I	33	7,963	4,937	33	8,684	2,652
Total	**420**			**420**		

Explanation of Differences

The evaluation is 22.6% more than the applicant reported savings. Table 5-100 provides a summary of the primary differences between tracking and evaluated values.

Table 5-100. Summary of Energy Savings Deviations

Measure	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
Lighting Controls	Operation	Hours of Use Reduction	+24.2%	**Increased Savings** – an increase in the hours of use reduction from occupancy sensors.
Lighting Fixtures	Operation	Hours of Use	-2.1%	**Decreased Savings** – a decrease in the hours of use for fixtures.
Lighting Fixtures	HVAC Interaction	Electric Cooling	+0.4%	**Increased Savings** – inclusion of HVAC interactive cooling savings.
Lighting Controls	HVAC Interaction	Electric Cooling	+0.1%	**Increased Savings** – inclusion of HVAC interactive cooling savings.

Ancillary impacts

There are no fuel-based ancillary impacts associated with this project.

RICE18L098

Report Date: 06/02/2021

Program	RICE2018	
Application ID(s)	7599855	
Project Type	Existing Building Retrofit	
Program Year	2018	
Evaluation Firm	DNV	DNV
Evaluation Type	Desk Review only	
Evaluation Engineer	Laengheng Khoun	
Senior Engineer	Srikar Kaligotla	

Evaluated Site Summary and Results

This 65,000 sqft gymnasium retrofitted its internal lighting system in 2018. The measure installed both lighting fixtures and controls at the facility. In total, the facility retrofitted 480 CFLs, fluorescent 4-8FT T8 and T5 bulbs/fixtures, and metal halide fixtures. Occupancy sensors were predicted to reduce run hours by 24% and were placed on 24 of the 480 lamps/fixtures. This project reported annual estimated savings of 150,913 kWh, winter, and summer peak demand savings of 23.90 and 28.80 kW, respectively. The customer became unresponsive after an initial callback showing some interest in being evaluated, therefore, the results presented in this report are based on a desk review only. The evaluation was unable to verify the quantities, technologies, and operation of the installed measures.

The evaluation results are presented in Table 1-1.

Table 5-101: Evaluation Results Summary

PA Application ID	Measure Name		Annual Electric Energy (kWh)	Summer On-Peak Demand (kW)	Winter On-Peak Demand (kW)	%On Peak Energy
7599855	**Lighting Retrofit**	**Tracked**	**150,913**	**28.80**	**23.90**	**70%**
		Evaluated	**150,913**	**28.80**	**23.90**	**70%**
		Realization Rate	**100%**	**100%**	**100%**	**100%**

Explanation of Deviations from Tracking

No deviations were found in the desk review.

Recommendations for Program Designers & Implementers

There are no recommendations currently.

Customer Alert

There are no customer alerts.

COVID Impact

The evaluation engineer could not conduct a site visit because the applicant was unresponsive to DNV's recruitment efforts. The findings from the desk reviews will be included in the expansion analysis.

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 indoor LED fixtures throughout the applicant's gymnasium and recreational facility

Application Information and Applicant Savings Methodology

This section describes the applicant's application information, savings methodology, and evaluation assessment of the applicant's savings calculation algorithm. Project savings were generated from a reduction in fixture wattage and reduction in run hours from controls.

Applicant Description of Baseline

This project is classified as a lighting retrofit project in the application. The site documentation reported that the baseline consisted of 480 CFLs, fluorescent 4-8FT T8 and T5 bulbs/fixtures, and metal halide fixtures that operated varying watts from 28 to 455 watts. These fixtures ran from 500 to 6,205 annual hours.

Table 5-102: Applicant baseline key parameters

BASELINE

Measure	Parameter	Value(s)	Source of Parameter Value	Note
Lighting Retrofit	**Fixture Wattage**	**28,30,57,64,86,109,120,218,234,455**	**Project Files**	**None**
Lighting Retrofit	**Fixture Quantity**	**100, 11,65,2,75,138,11,51,16,11 (total = 480)**	**Project Files**	**None**
Lighting Retrofit	**Average Operating Hours**	**3734,6204,4401,500,3425,4352,4498,6204,6204,4498**	**Project Files**	**None**

Applicant Description of Installed Equipment and Operation

The facility upgraded its lighting system by retrofitting older fixtures with LEDs of varying wattages. Operating schedules and fixture counts observed in the baseline description are maintained for the installed fixtures. Project savings were generated from the installation of LED fixtures.

Table 5-2: Application proposed key parameters

PROPOSED				
Measure	**Parameter**	**Value(s)**	**Source of Parameter Value**	**Note**
Lighting Retrofit	Fixture Wattage	8,12,13,24,30,36,48,60,80,95,112	Project Files	None
Lighting Retrofit	Fixture Quantity	62,11,38,55,23,75,126,12,11,51,16 (total = 480)	Project Files	None
Lighting Retrofit	Average Operating Hours	3734,6204,3640,3499,3450,3735,6204,4498,6204,6204	Project Files	None

Applicant Energy Savings Algorithm

Savings were calculated using a custom lighting savings excel workbook using the following equations. The primary driver for this measure's energy savings is a reduction in fixture/lamp wattage. Energy savings algorithms are as follows:

Pre-existing Fixture kWh = $Quantity * Wattage/1000 * Evaluated\ Operating\ Hours\ without\ \ controls$

Post-retrofit Fixture kWh = $Quantity * Wattage/1000 * Evaluated\ Operating\ Hours\ without\ controls$

Control Savings kWh= Post-retrofit Fixture kWh *%hours reduction[29]

Total kWh Savings = *Pre-existing Fixture kWhPost-retrofit Fixture kWh*+ $Control\ Savings\ kWh$

[29] NGRID Custom Ligthing Tool Controls Lookup for Occupancy Sensors (Quantifying National Energy Savings Potential of Lighting Controls in Commercial Buildings, ACEEE 2012)

Table 5-3: Applicant baseline key parameters

	A	B	C	D	E	F=A*B*E /1000	G=C*D*E/1000	H	I=G*H	J=F-G+I
Space Type	**Baseline Quantity**	**Baseline Watts per Fixture**	**Installed Quantity**	**Installed Watts per Fixture**	**Annual Hours**	**Baseline kWh**	**Installed kWh**	**Percent Hours Reduction**	**Control kWh Savings**	**Total Fixture and Controls Savings**
Lower Women Restroom	**6**	**28**	**6**	**8**	**500**	**84**	**24**		**-**	**60**
Lower Mens Bathroom	**2**	**64**	**2**	**24**	**500**	**64**	**24**		**-**	**40**
Various	**11**	**57**	**11**	**24**	**2,501**	**1,568**	**660**		**-**	**908**
Various	**3**	**57**	**3**	**24**	**4,498**	**769**	**324**	**24% (OS)**	**78**	**523**
Various	**9**	**57**	**9**	**24**	**4,498**	**2,307**	**972**		**-**	**1,336**
Various	**30**	**57**	**30**	**24**	**6,205**	**10,610**	**4,467**		**-**	**6,143**
Maintenance	**12**	**57**	**12**	**30**	**2,501**	**1,711**	**900**		**-**	**810**
Community/Kitchen	**11**	**86**	**11**	**36**	**500**	**473**	**198**		**-**	**275**
Various	**19**	**86**	**19**	**36**	**2,501**	**4,086**	**1,711**		**-**	**2,376**
Various	**6**	**86**	**6**	**36**	**2,501**	**1,290**	**540**	**24% (OS)**	**130**	**880**
Various	**11**	**86**	**11**	**36**	**4,498**	**4,255**	**1,781**	**24% (OS)**	**427**	**2,901**
Various	**2**	**86**	**2**	**36**	**4,498**	**774**	**324**		**-**	**450**

Various	**26**	**86**	**26**	**36**	**6,205**	**13,874**	**5,808**		**-**	**8,066**
Various	**6**	**109**	**6**	**48**	**2,501**	**1,636**	**720**		**-**	**915**
Various	**42**	**109**	**42**	**48**	**2,501**	**11,449**	**5,042**		**-**	**6,407**
Various	**78**	**109**	**78**	**48**	**6,205**	**52,752**	**23,230**		**-**	**29,522**
Pool	**16**	**234**	**16**	**112**	**6,205**	**23,230**	**11,119**		**-**	**12,111**
Pool	**12**	**109**	**12**	**60**	**6,205**	**8,116**	**4,467**		**-**	**3,648**
Well ness Bathroom	**4**	**28**	**4**	**8**	**4,498**	**504**	**144**	**24% (OS)**	**35**	**394**
Various	**52**	**28**	**52**	**8**	**6,205**	**9,034**	**2,581**		**-**	**6,453**
Various	**11**	**30**	**11**	**12**	**6,205**	**2,048**	**819**		**-**	**1,229**
Various	**38**	**28**	**38**	**13**	**6,205**	**6,602**	**3,065**		**-**	**3,537**
Exterior	**11**	**120**	**11**	**30**	**4,498**	**5,937**	**1,484**		**-**	**4,453**
Parking Pole Lights	**11**	**455**	**11**	**80**	**4,498**	**22,512**	**3,958**		**-**	**18,554**
Gym	**51**	**218**	**51**	**95**	**6,205**	**68,983**	**30,062**		**-**	**38,922**
Total	**480**		**480**			**254,668**	**104,424**		**669**	**150,913**

Evaluation Assessment of Applicant Methodology

The evaluator agrees with the analysis approach used by the applicant.

Onsite Inspection

Since the customer was unresponsive, we could not schedule a site visit. Instead, we completed a desk review. The results for the desk review are provided below.

Summary of Site Visit Findings and Metering

See section 2.3.

2.3.2 Measured and Logged Data

See section 2.3.

Evaluation Methods and Findings

This section describes the evaluator methods and findings.

Evaluation Description of Baseline

The baseline condition for this retrofit project consisted of CFLs, 4-8FT T8, T5 systems and metal halide fixtures. The application does not include savings due to HVAC interactive effects. The application documentation does not list pre-existing lighting controls. A site visit to gather information on the baseline was not conducted. The evaluator determined the lighting measure is a retrofit with a dual baseline measure, where the baseline would be the pre-existing fixtures identified in the lighting audit.

Evaluation Metered Data and Analysis Methodology

Since the site contacts were unresponsive, a site visit was not scheduled to verify equipment technology and quantities and deploy loggers on fixtures throughout the facility to obtain operation data - V, A, kW, and PF and run hours. As a result, there is no data to evaluate and use to calculate evaluated energy savings. Evaluated energy savings were not generated by comparing the logger data annual hours of use to the annual hours of use found in the application. The evaluator agrees with the applicant analysis methodology.

Final Results

This section will summarize the evaluation results determined in the analysis above. The evaluator's estimated savings values result from observed changes to the applicant's pre and post-cases. Table 3-1 summarizes the energy usage values observed in the applicant's and evaluator's pre and post-case calculations. No adjustments were made on the tracking estimations in the desk review.

Table 5-103. Energy Usage Summary

	Pre-existing		Post-retrofit	
Parameter	Tracking Value(s)	Evaluation Value(s)	Tracking Value(s)	Evaluation Value(s)
Lighting fixture usage	150, 913 kWh	150, 913 kWh	150, 913 kWh	150, 913 kWh

Explanation of Differences

None.

RICE18L110

Report Date: 06/14/2021

Program	RICE2018	
Application ID(s)	7928379	
Project Type	Existing Building Retrofit	
Program Year	2018	
Evaluation Firm	DNV	DNV
Evaluation Engineer	Vishnu Prakash	
Senior Engineer	Jeff Zynda, Srikar Kaligotla	

Evaluated Site Summary and Results

This lighting project was done at a supermarket where mostly T8 fluorescent fixtures were retrofitted with LEDs with controls. The lights are controlled using a combination of occupancy sensors and dimmers. The dimmers are placed near the perishable items and in the aisles, while occupancy sensors are in areas such as coolers/freezers, breakroom and manager's office. Dimmers operate on a three-tiered power reduction system. The applicant's energy savings are derived from a reduction in wattage and run hours did not consider HVAC interactive savings.

Project files indicate that 235 fixtures were installed, 197 installed with controls, which amounted to an annual fixture kWh savings of 144,973 and control savings of 85,019. The applicant's total project savings calculation was 229,992 kWh. Summer on-peak demand savings was 24.90 kW, and winter on-peak demand savings was 24.90 kW. The evaluator calculated the total annual energy savings to be 199,923 kWh, summer on-peak demand savings to be 29.22 kW, and winter on-peak demand savings to be 25.03 kW.

The Covid-19 pandemic did not impact this site. See Section 9.6 for further details.

The evaluation results are presented in Table 1-1.

Table 5-104: Evaluation Results Summary

PA Application ID	Measure Name		Annual Electric Energy (kWh)	Summer On-Peak Demand (kW)	Winter On-Peak Demand (kW)
7928379	**Lighting Retrofit**	**Tracked**	**144,973**	**24.90**	**24.90**
		Evaluated	**162,233**	**29.82**	**24.67**
		Realization Rate	**111.9%**	**119.8%**	**99.1%**
7928379	**Lighting Controls**	**Tracked**	**85,019**	**0.00**	**0.00**
		Evaluated	**37,690**	**-0.60**	**0.36**
		Realization Rate	**44.3%**	**N/A**	**N/A**
Total	**Total**	**Tracked**	**229,992**	**24.90**	**24.90**
		Evaluated	**199,923**	**29.22**	**25.03**
		Realization Rate	**86.9%**	**117.4%**	**100.5%**

N/A = Not applicable

9.2 Explanation of Deviations from Tracking

The evaluated savings are 13% lower than the applicant-reported savings, primarily due to decreased hours of use reduction caused by the occupancy sensors and a lower than predicted decrease in the equivalent full load (EFL) hour reduction caused by the dimming controls. Further details regarding deviations from the tracked savings are presented in Section 9.7

Recommendations for Program Designers & Implementers

It is recommended to include HVAC interaction in the analysis approach for lighting projects as savings are impacted by the change in cooling load when retrofitting to lower wattage fixtures.

9.3 Customer Alert

The customer requested a copy of the site report.

Evaluated Measures

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

The project consisted of installing interior LED fixtures with occupancy sensors or dimming controls installed on most fixtures.

9.4 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. Both applicant and evaluated approaches calculated energy savings based on onsite findings and assumptions. Project savings were primarily based upon the fixture wattage reduction and dimming for fixtures with dimming controls and reduced hours of operation for fixtures with occupancy sensors.

9.5 Applicant Description of Baseline

This project is classified as a lighting retrofit and controls project in the application. The site documentation reported that the baseline consisted of T8 fluorescent troffers and jelly jar-type LED fixtures. The following table summarizes fixture wattages and operating hours utilized throughout the facility. These fixtures had no advanced controls, were manually operated, and ran for 4,380-8,760 hours annually.

Table 5-105. Applicant baseline key parameters

Location	Fixture Description	Unit Watts	Annual Hours	Qty.
Store Floor	4F32/1EB/8'SF	112	8,760	169
Store Floor	4F32/1EB/8'SF, 4F32/1EB/PR	112	4,680	173
Restrooms	3F32/1EB/PR	88	8,760	6
Produce Prep	LED13/JELLY-JAR	13	4,680	17
Grocery Freezer	LED13/JELLY-JAR	13	8,760	13
Stockroom	MH400/HB	430	8,760	6
Cash Office	2F32/1EB/4'SF	60	4,680	1
Front Canopy	2F96HO/1SB/8'VT	227	4,380	10

9.5.1 Applicant Description of Installed Equipment and Operation

The facility's pre-existing fixtures were replaced with LED fixtures and lamps, with most fixtures being placed on dimming or occupancy control. Table 5-106 below summarizes the new fixture wattages and operating hours currently being utilized throughout the facility. Using the tracking inputs provided in Table 5-107, the annual post EFL hours for dimming controls are calculated as the sum-product of the dimming percent (columns I, M, and Q) and the hours per year (columns L, P, and T) at each level[30]. For occupancy sensors, the EFL hours are simply the hours provided in column L.

Table 5-106. Application proposed key parameters

Location	Fixture Description	Controls Description	Unit Watts	Annual Baseline Hours	Annual EFL Hours for Controls	Qty.
Store Floor	CLX-L96-14000LM	Dimming	86	8,760	3,092	127
Store Floor	CLX-L96-14000LM	Dimming	86	8,760	2,898	28
Store Floor	CLX-L96-14000LM	Dimming	86	8,760	3,443	12

[30] For the front end space (for example) this is 52%*3650+43%*1095+18%*4,015) = 3,092 annual FLH.

Store Floor	CLX-L96-8000LM	Manual	49	8,760	N/A	2
Store Floor	CLX-L96-8000LM	Occupancy Sensors	49	8,760	6,658	4
Store Floor	2GTL-4-40L	Manual	39	4,680	N/A	4
Store Floor	CLX-L96-8000LM	Manual	49	4,680	N/A	3
Store Floor	CLX-L96-8000LM	Occupancy Sensors	49	4,680	3,557	3
Restrooms	2GTL-4-40L	Manual	39	8,760	N/A	6
Produce Prep	LXEM4-40VW	Manual	28	4,680	N/A	9
Meat Cooler	LXEM4-40VW	Occupancy Sensors	28	4,680	3,557	4
Produce Cooler	LXEM4-40VW	Occupancy Sensors	28	8,760	6,658	4
Grocery Freezer	LXEM4-40VW	Occupancy Sensors	28	8,760	6,658	6
Stockroom	CLX-L96-18000LM	Manual	117	8,760	N/A	3
Stockroom	CLX-L96-18000LM	Occupancy Sensors	117	8,760	6,658	9
Cash Office	CLX-L48-4000LM	Manual	25	4,680	N/A	1
Front Canopy	LXEM8-40VW-RFA	Manual	54	4,380	N/A	10

9.5.2 Applicant Energy Savings Algorithm

For lighting, the applicant calculated the savings using a similar custom lighting analysis spreadsheet provided by the Program Administrators using the findings from the lighting audit as inputs. The tool determines energy savings by using the following formulas.

$$Baseline\ Fixture\ kWh = \frac{Quantity_B * Wattage_B}{1000} * Baseline\ Operating\ Hours\ without\ controls$$

$$Proposed\ Fixture\ kWh = \frac{Quantity_P * Wattage_P}{1000} * Baseline\ Operating\ Hours\ \text{without controls}$$

$$Fixture\ kWh\ Savings = Baseline\ Fixture\ kWh - Proposed\ Fixture\ kWh$$

$$Dimming\ Control\ kWh\ Savings = Proposed\ Fixture\ kW * (Applicant\ PreControl\ Operating\ Hours) - (\sum Proposed\ Fixture\ kW\ in\ each\ dimming\ level \times Operation\ Hours\ in\ each\ dimming\ level\ )$$

$$Occupancy\ Sensor\ Control\ kWh\ Savings = Proposed\ Fixture\ kW * (Applicant\ PreControl\ Operating\ Hours - Applicant\ PostControl\ Operating\ Hours)$$

$$Total\ kWh\ Savings = Fixture\ kWh\ Savings + Dimming\ Control\ kWh\ Savings + Occupancy\ Sensor\ Control\ kWh\ Savings$$

The energy consumption reduction from the dimming controls is achieved from the power reduction by different levels on different schedules. By grouping lighting with different areas, energy savings from lighting controls can be seen in Table 5-107 below.

Table 5-107. Tracking Fixture and Control Inputs and kWh Savings

	A	B	C	D	E	F	G=A*B*E/1000	H=C*D*F/1000	I	J=I*D	K	L=K*F	M	N=M*D	O	P=O*F	Q	R=Q*D	S	T=S*F	U=C*(J*L+N*P+R*T)/1000	V=G-H	W=H-U	X=V+W
Space Type	Baseline Quantity	Baseline Watts per Fixture	Installed Quantity	Installed Watts per Fixture	Baseline Annual Hours	Installed Annual Hours	Baseline kWh	Installed kWh	Level 1 Dimming %Power	Level 1 Watt	Level 1 Dimming %Hrs	Level 1 Hrs per yr	Level 2 Dimming %	Level 2 Watt	Level 2 %Hrs	Level 2 Hrs per yr	Level 3 Dimming %	Level 3 Watt	Level 3 %Hrs	Level 3 Hrs per yr	Proposed kWh	Lighting Only Saving kWh	Control Saving kWh	Total Saving
FRONT END (D)*	40	112	37	86	8,760	8,760	39,245	27,874	52%	45	42%	3,650	43%	37	13%	1,095	18%	15	46%	4,015	9,837	11,370	18,037	29,407
FRONT END (D&N)	40	112		0	4,680	4,680	20,966	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0	20,966	0	20,966
PERISHABLES (D)*	22	112	28	86	8,760	8,760	21,585	21,094	47%	40	42%	3,650	42%	36	13%	1,095	18%	15	46%	4,015	6,979	491	14,115	14,606
PERISHABLES(D&N)	22	112		0	4,680	4,680	11,532	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0	11,532	0	11,532
REAR AISLE (D)*	11	112	12	86	8,760	8,760	10,792	9,040	52%	45	42%	3,650	43%	37	13%	1,095	27%	23	46%	4,015	3,553	1,752	5,488	7,240
REAR AISLE (D&N)	12	112		0	4,680	4,680	6,290	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0	6,290	0	6,290
AISLE 1 - 10 (D)*	90	112	90	86	8,760	8,760	88,301	67,802	52%	45	42%	3,650	43%	37	13%	1,095	18%	15	46%	4,015	23,929	20,498	43,874	64,372
AISLE 1 – 10 (D&N)	90	112		0	4,680	4,680	47,174	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0	47,174	0	47,174
CUSTOMER RESTROOMS (2)	2	88	2	39	8,760	8,760	1,542	683	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0	858	0	858
VESTIBULE	4	112	4	39	4,680	4,680	2,097	730	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0	1,367	0	1,367
SECURITY MANAGERS OFFICE	1	112	1	49	4,680	4,680	524	229	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0	295	0	295
PRODUCE PREP	9	13	9	28	4,680	4,680	548	1,179	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0	-632	0	-632
MEAT COOLER#	8	13	4	28	4,680	4,680	487	524	100%	28	76%	3,557	0%	0	24%	1,123	0%	0	0%	0	398	-37	126	89
PRODUCE COOLER#	4	13	4	28	8,760	4,680	456	981	100%	28	76%	6,658	0%	0	24%	2,102	0%	0	0%	0	746	-526	235	-291
STOCKROOM	3	430	3	117	8,760	8,760	11,300	3,075	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0	8,226	0	8,226
STOCKROOM#	3	430	9	117	8,760	8,760	11,300	9,224	100%	117	76%	6,658	0%	0	24%	2,102	0%	0	0%	0	7,010	2,076	2,214	4,290
GROCERY FREEZER#	9	13	6	28	8,760	8,760	1,025	1,472	100%	28	76%	6,658	0%	0	24%	2,102	0%	0	0%	0	1,118	-447	353	-94
BREAKROOM HALL	2	112	2	49	8,760	8,760	1,962	858	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0	1,104	0	1,104
BREAKROOM#	4	112	4	49	8,760	8,760	3,924	1,717	100%	49	76%	6,658	0%	0	24%	2,102	0%	0	0%	0	1,305	2,208	412	2,620
EMPLOYEE RESTROOMS (2)	4	88	4	39	8,760	8,760	3,084	1,367	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0	1,717	0	1,717
TRAINING ROOM#	1	112	1	49	4,680	4,680	524	229	100%	49	76%	3,557	0%	0	24%	1,123	0%	0	0%	0	174	295	55	350
CASH OFFICE	2	112	2	49	4,680	4,680	1,048	459	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0	590	0	590
CASH OFFICE	1	60	1	25	4,680	4,680	281	117	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0	164	0	164
DEPT MANAGERS OFC#	1	112	2	49	4,680	4,680	524	459	100%	49	76%	3,557	0%	0	24%	1,123	0%	0	0%	0	349	66	110	176
FRONT CANOPY	10	227	10	54	4,380	4,380	9,943	2,365	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0	7,577	0	7,577
Total	**395**		**235**				**296,453**	**151,480**													**55,398**	**144,973**	**85,019**	**229,992**

*** Spaces with dimming controls**
 # Spaces with occupancy sensors

9.5.3 Evaluation Assessment of Applicant Methodology

The applicant correctly used the custom lighting tool, and the evaluator determined the application calculation methodology reasonable.

9.6 Onsite Inspection

The evaluators conducted a site visit after confirming the following criteria:

- The site was safe to visit, and the site contact with knowledge of the project was available to assist with the evaluation site visit.
- Covid-19 did not impact the site's operations.

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

9.6.1 Summary of Site Visit Findings and Metering

With the facility manager and electrician's assistance, the first site visit and metering deployment was completed on January 22, 2021. The evaluator discussed the site's operating schedule during the visit and obtained a verbal estimation of weekly operation hours, including holidays. The evaluator also confirmed the lighting fixture counts and wattages and gathered HVAC information.

With the help of the electrician, the evaluator installed Dent Elite data loggers in the appropriate electrical panels to gather operation data (V, A, kW, PF) and run hours on all fixtures. Dent TOU loggers are also deployed throughout the facility to gather redundant lighting usage data. TOU loggers were installed in all the major locations listed in the applicant's baseline section above.

The analysis was performed by comparing the logged data to operating conditions found in the applicant's baseline. The metered kW usage at each percent power was used to generate an operating profile for each fixture group.

The loggers were installed for approximately three months. Table 5-108 below provides a quick summary of the evaluator's findings.

Table 5-108. Measure Verification

Measure Name	Verification Method	Verification Result
Lighting Retrofit	Verify fixture quantity, schedule, control, and wattage.	Changes were observed with the fixture schedules. All 235 program installed fixtures were observed. Fixture controls, wattages, and quantity were consistent with the application.

9.6.2 Measured and Logged Data

The evaluator deployed five data loggers to characterize the operating profile for the lighting fixtures in different areas from January 22, 2021, to April 27, 2021. Table 5-109 presents the logger deployment details.

Table 5-109. Evaluation Data Collection – Installed Equipment

Parameter	M&V Equipment Brand and Model	Metering Start/Stop Dates	Metering Interval
Interior lighting operating schedules	3 Dent TOU Logger	1/22/2021 – 4/27/2021	On/off
Area dimming operation (8 Breakers with multiple fixtures on each).	2 Dent ELITEpro power Logger	1/22/2021 – 4/27/2021	5 minutes

The evaluator used the metered power and TOU data to calculate an operating profile to show when the fixtures were used. Metered hourly data was expanded to fit a weekly profile. Figure 5-40 depicts operating profile with Occ. Sensors from the Stock Room metered data.

Figure 5-40. Logged Operating Data -Stock Room (Occ)

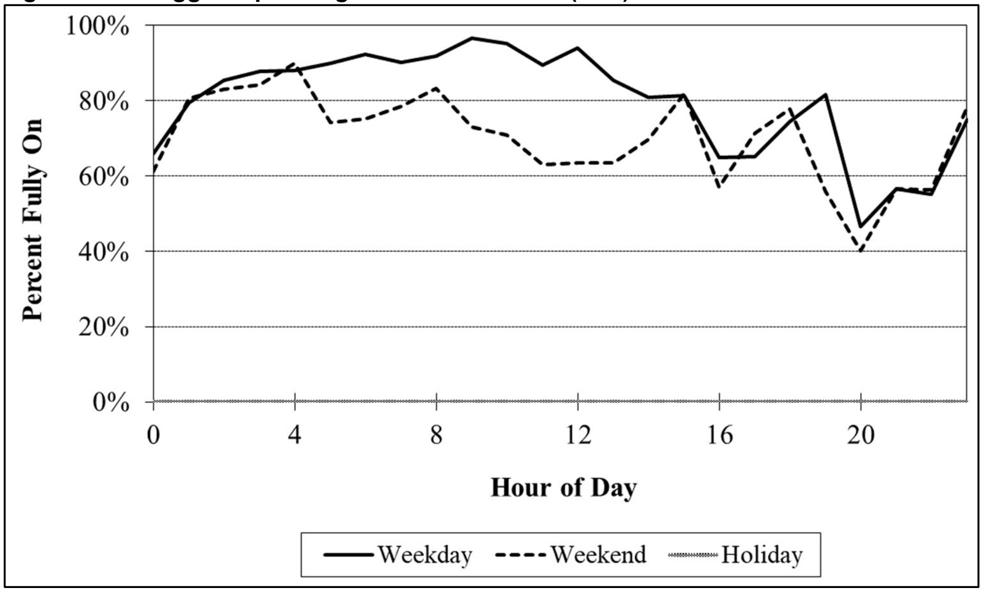
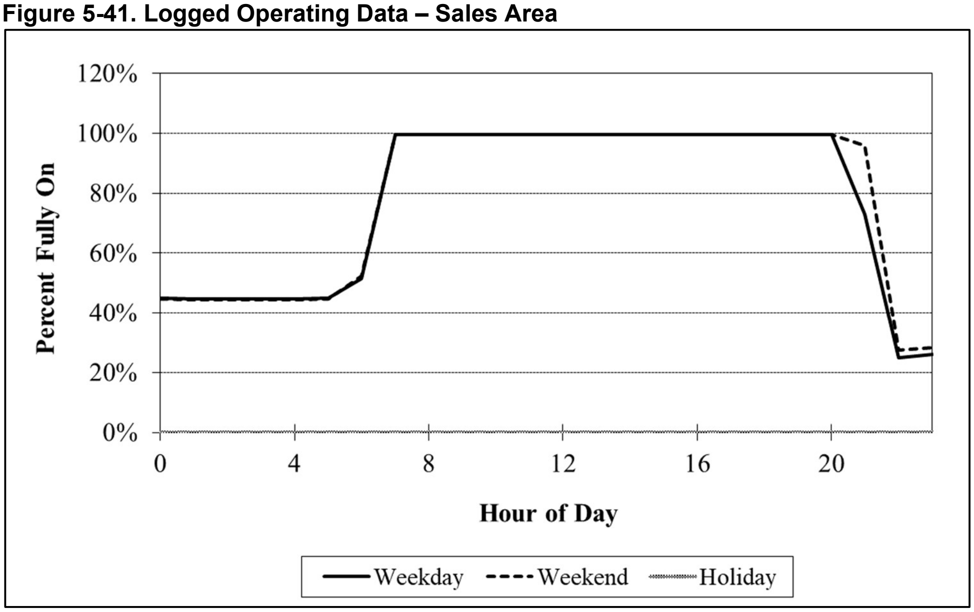


Figure 5-41. Logged Operating Data – Sales Area



The evaluation analysis assumed rated fixture power as the installed power which is the same as tracking analysis assumption but used the %dimming from the metered data for dimmed fixtures. Figure 5-41 shows averaged daily %ON for fixtures in Sales Area.

Table 5-110 below shows the expanded annual operating hours and EFL hours for all metered spaces. The EFL hours were calculated by taking the kW draw from the power loggers, dividing it by the maximum recorded power for each hour when the fixtures are operating, and summing these values for each hour of the year. Subtracting the EFL hours from baseline hours yields a reduction in full-load equivalent hours from installing the dimming controls.

Table 5-110. Logged Data Schedules

Schedule ID	Logger Type and ID #	Space Description	Control Type	Annual Equivalent Full	Annual on Hours

				Load Hours (power logger)	(TOU logger)
1	TOU-LL08040369	Cash Office	Manual	-	3,997
2	TOU-LL08101616	Stock Room	Occupancy Sensors	-	6,578
3	TOU-LL11010162	Produce Cooler	Occupancy Sensors	-	8,544
3	Elite-XC1803127 (Channel 1)	Sales Area (3 rows of 9 fixtures)	Dimming Controls	6,063	-
4	Elite-XC1803127 (Channel 2)	Sales Area (3 rows of 9 fixtures)	Dimming Controls	5,969	-
5	Elite-XC1803127 (Channel 3)	Sales Area (3 rows of 9 fixtures)	Dimming Controls	5,969	-
6	Elite-XC1803127 (Channel 4)	Sales Area (3 rows of 9 fixtures)	Dimming Controls	7,876	-
7	Elite-XC1803128 (Channel 1)	Sales Area (3 rows of 9 fixtures)	Dimming Controls	6,588	-
8	Elite-XC1803128 (Channel 2)	Exterior (Canopy)	Manual	5,168	-
9	Elite-XC1803128 (Channel 3)	Sales Area (2 rows of 9 fixtures)	Dimming Controls	7,876	-
10	Elite-XC1803128 (Channel 4)	Sales Area (3 rows of 9 fixtures)	Dimming Controls	6,065	-

9.7 Evaluation Methods and Findings

This section describes the evaluator methods and findings.

9.7.1 Evaluation Description of Baseline

The evaluator reviewed the project files, interviewed the site contact, and conducted a site visit to gather information on the baseline. As a result, the evaluator determined the lighting measure is a retrofit with a single baseline, where the baseline would be the pre-existing fixtures identified in the site documentation without controls.

Baseline schedules for fixtures with dimming controls were developed assuming that for every hour the fixtures were operating based on the logger data, regardless of dimming level, they would've been operating at 100% output for that hour in the baseline condition. For fixtures controlled by occupancy sensors, conditional formats were applied to the metered data to check for continuous hours of operation. If there were consecutive operational hours, the baseline schedule would recognize the non-shoulder hours and assume the baseline lights would have been left on before controls were installed. Shoulder hours were assumed to be the same between baseline and metered schedules. A visual example using an arbitrary schedule can be seen in Table 5-111. Baseline schedule example below, where shoulder hours include hours 1, 4, and 6 while continuous hours include 2, 3, and 7. This method's theory assumes that the fixtures would have been left on for consecutive non-zero operating hours for occupancy-controlled fixtures. For dimming, EFLHs were converted from EMS kW data. The same theory shows that for consecutive non-zero hours, fixtures would have been operating at full output, which is equal to being on 100% for that hour. The evaluator used the rated wattage of each specific fixture to represent 100% output, so anything less would represent a dimmed schedule.

Table 5-111. Baseline schedule example

Hour	Controlled Schedule	Baseline Schedule
1	25%	25%
2	45%	100%
3	50%	100%
4	25%	25%
5	0%	0%
6	25%	25%
7	50%	100%

Table 5-112 presents tracking and evaluated hours of use assumptions used in the analysis. Tracking estimated 24% hours reduction for spaces with Occupancy sensor while the evaluated analysis estimates it to be 20% (weighted[30]).

Table 5-112: Tracking and Evaluated hours of use and %reduction

		Tracking			Evaluated		
Space Type	**Control Type**	**Baseline Hours**	**Proposed Hours**	**Reduction in Hours (% Reduction)**	**Baseline Hours**	**Proposed Hours**	**Reduction in Hours (% Reduction)**
Sales Floor[31]	**Dimming**	**8,760**	**3,084**	**5,676 (65%)**	**8,760**	**6,567**	**2,193 (25%)**
Meat Cooler	**Occupancy Sensors**	**4,680**	**3,557**	**1,123 (24%)**	**8,760**	**8,544**	**216 (2%)**
Produce Cooler	**Occupancy Sensors**	**8,760**	**6,658**	**2,102 (24%)**	**8,760**	**8,544**	**216 (2%)**
Grocery Freezer	**Occupancy Sensors**	**8,760**	**6,658**	**2,102 (24%)**	**8,760**	**8,544**	**216 (2%)**
Stockroom	**Occupancy Sensors**	**8,760**	**6,658**	**2,102 (24%)**	**8,760**	**6,578**	**2,182 (25%)**
Break Room	**Occupancy Sensors**	**8,760**	**6,658**	**2,102 (24%)**	**8,760**	**6,658**	**2,102 (24%)**
Training Room & Manager's Office	**Occupancy Sensors**	**4,680**	**3,557**	**1,123 (24%)**	**4,680**	**3,557**	**1,123 (24%)**
Occupancy Sensor Weighted Average[32]		**8,167**	**6,208**	**1,960 (24%)**	**8,418**	**6,762**	**1,656 (20%)**

9.7.2 Evaluation Calculation Method

The evaluator calculated the savings using a similar approach to the applicant. TOU data was used to determine the operations schedules and effective full load hours for all metered groups. Data were drawn from the loggers and expanded to fit an 8,760-model based on trends in the data. The custom savings equations are presented below. For site cooling hours, the evaluator assumed cooling would only occur between April and October. For each hourly

[31] Front End, Perishables, and Aisles.
[32] Weighted by connected kW.

interval within that range of months in the 8760 model, if dry bulb temperature taken from local TMY3 data was greater than or equal to the setpoint of 55°F, then that hour was determined to be a cooling hour. Cooling hours that coincided with the lighting hours were used to determine total annual cooling savings. The cooling COP is assumed to be 2.9 for the packaged DX units, 2.7 for coolers, and 1.7 for freezers.

$Baseline\ Fixture\ kWh$	$= \frac{Quantity_B * Wattage_B}{1000} * Evaluated\ Operating\ Hours\ without\ controls$
$Proposed\ Fixture\ kWh$	$= \frac{Quantity_P * Wattage_P}{1000} * Evaluated\ Operating\ Hours\ without\ controls$
$Fixture\ kWh\ Savings$	$= Baseline\ Fixture\ kWh - Proposed\ Fixture\ kWh$
$Control\ kWh\ Savings$	$= Proposed\ Fixture\ kW * (Evaluated\ Operating\ Hours\ without\ controls - Evaluated\ EFL\ Operating\ Hours\ with\ controls)$

$HVAC\ Interactive\ Fixture\ Savings$	$= (pre\ conn\ kW - post\ conn\ kW) * Coincident\ Occupied\ Cooling\ Hours * \frac{0.8}{Cooling\ COP}$
$HVAC\ Interactive\ Control\ Savings$	$= (post\ conn\ kW * (pre\ coincident\ occupied\ cooling\ hours - post\ coincident\ cooling\ hours) * 0.8)/(Cooling\ COP)$
$Total\ kWh\ Savings$	$= Fixture\ kWh\ Savings + Control\ kWh\ Savings + HVAC\ Interactive\ Fixture\ Savings + HVAC\ Interactive\ Controls\ Savings$

All spreadsheets used to estimate evaluation savings will be made available to the PAs for review at their request.

10 Final Results

This section summarizes the evaluation results determined based on the analysis described above. The evaluated savings for the project were lower than the applicant reported savings mostly because of a drop in the EFL hour reduction between the baseline lights without controls and the installed fixtures with dimming controls. Table 5-113 summarizes the energy usage values observed in the tracking and evaluation calculations.

Table 5-113. Energy Savings Summary

Parameter	Tracking Value(s)	Evaluation Value(s)
Lighting fixture savings	144,973 kWh	162,233 kWh
Lighting control savings	85,019 kWh	37,690 kWh
Total	**229,992 kWh**	**199,923 kWh**

Table 5-114 and Table 5-115 below show the evaluation inputs and savings calculations for the lighting fixtures and controls, respectively. According to the tracking savings estimates for the sales area (front end, perishables, rear aisle, and aisle 1-10), the program replaced fixtures that operated for 8,760 hours annually but simply removed fixtures that operated for 4,680 hours per year. Since these fixtures were removed and could not be metered, the 4,680 annual hours assumed in the tracking savings for these removed fixtures was also assumed in the evaluation savings. There were other spaces (vestibule, security manager's office, and produce prep) where 4,680 annual hours was assumed in the tracking system and also assumed in the evaluation savings. These fixtures accounted for 0.4% of the project's savings and were not metered. Table 5-116 shows various levels and lighting hours of use for both tracking and evaluation analysis.

Table 5-114. Evaluation Fixture Inputs and kWh Savings

	A	B	C	D	E	F	G=A*B*E/1000	H=C*D*E/1000	I=G-H	J	K	L	M=F*J*K*0.8/L	N=I+M
Space Type	Baseline Quantity	Baseline Watts per Fixture	Installed Quantity	Installed Watts per Fixture	Annual Hours	Connected kW Savings	Baseline kWh	Installed kWh	kWh Fixture Savings	Percent of Space Cooled	Annual Cooling Hours	Cooling COP	Interactive Cooling Savings	Total kWh Fixture Savings
FRONT END (D)	40	112	37	86	8,760	1.298	39,245	27,874	11,370	100%	3,650	2.9	1,293	12,664
FRONT END (D&N)	40	112	0	0	4,680[33]	4.480	20,966	0	20,966	100%	2,044	2.9	2,499	23,466
PERISHABLES (D)	22	112	28	86	8,760	0.056	21,585	21,094	491	100%	3,650	2.9	56	546
PERISHABLES(D&N)	22	112	0	0	4,680	2.464	11,532	0	11,532	100%	2,044	2.9	1,375	12,906
REAR AISLE (D)	11	112	12	86	8,760	0.200	10,792	9,040	1,752	100%	3,650	2.9	199	1,951
REAR AISLE (D&N)	12	112	0	0	4,680	1.344	6,290	0	6,290	100%	2,044	2.9	750	7,040
AISLE 1 - 10 (D)	90	112	90	86	8,760	2.340	88,301	67,802	20,498	100%	3,650	2.9	2,331	22,829
AISLE 1 - 10 (D&N)	90	112	0	0	4,680	10.080	47,174	0	47,174	100%	2,044	2.9	5,624	52,798
CUSTOMER RESTROOMS (2)	2	88	2	39	8,760	0.098	1,542	683	858	100%	3,650	2.9	98	956
VESTIBULE	4	112	4	39	4,680	0.292	2,097	730	1,367	100%	2,044	2.9	163	1,529
SECURITY MANAGERS OFFICE	1	112	1	49	4,680	0.063	524	229	295	100%	2,044	2.9	35	330
PRODUCE PREP	9	13	9	28	4,680	-0.135	548	1,179	-632	100%	2,044	2.9	-75	-707
MEAT COOLER	8	13	4	28	8,760	-0.008	911	981	-70	100%	3,650	2.7	-9	-79
PRODUCE COOLER	4	13	4	28	8,760	-0.060	456	981	-526	100%	3,650	2.7	-65	-590
STOCKROOM	3	430	3	117	8,760	0.939	11,300	3,075	8,226	100%	3,650	2.9	935	9,161
STOCKROOM	3	430	9	117	8,760	0.237	11,300	9,224	2,076	100%	3,650	2.9	236	2,312
GROCERY FREEZER	9	13	6	28	8,760	-0.051	1,025	1,472	-447	100%	3,650	1.7	-89	-536
BREAKROOM HALL	2	112	2	49	8,760	0.126	1,962	858	1,104	100%	3,650	2.9	126	1,229
BREAKROOM	4	112	4	49	8,760	0.252	3,924	1,717	2,208	100%	3,650	2.9	251	2,459
EMPLOYEE RESTROOMS (2)	4	88	4	39	8,760	0.196	3,084	1,367	1,717	100%	3,650	2.9	195	1,912
TRAINING ROOM	1	112	1	49	4,680	0.063	524	229	295	100%	2,044	2.9	35	330
CASH OFFICE	2	112	2	49	3,997	0.126	895	392	504	100%	1,552	2.9	53	557
CASH OFFICE	1	60	1	25	3,997	0.035	240	100	140	100%	1,552	2.9	15	155
DEPT MANAGERS OFC	1	112	2	49	4,680	0.014	524	459	66	100%	2,044	2.9	8	73
FRONT CANOPY	10	227	10	54	5,168	1.730	11,731	2,791	8,941	0%	N/A	N/A	0	8,941
Total	**395**		**235**			**26.179**	**298,472**	**152,278**	**146,194**				**16,039**	**162,233**

[33] From Tracking analysis.

Table 5-115. Evaluation Controls Inputs and kWh Savings

	A	B	C	D=A*B/1000	E=C*D	F	G	H	I=D*F*G*0.8/H	J=E+I
Space Type	**Installed Quantity**	**Installed Watts per Fixture**	**Annual Hours Reduction**	**Connected kW**	**kWh Controls Savings**	**Percent of Space Cooled**	**Annual Cooling Hours Reduction**	**Cooling COP**	**Interactive Cooling Savings**	**Total kWh Controls Savings**
FRONT END (D)	37	86	2,193	3.18	6,978	100%	744	2.9	646	7,624
PERISHABLES (D)	28	86	2,193	2.41	5,280	100%	744	2.9	489	5,769
REAR AISLE (D)	12	86	2,193	1.03	2,263	100%	744	2.9	210	2,473
AISLE 1 - 10 (D)	90	86	2,193	7.74	16,973	100%	744	2.9	1,571	18,544
MEAT COOLER	4	28	216	0.11	24	100%	53	2.7	2	26
PRODUCE COOLER	4	28	216	0.11	24	100%	53	2.7	2	26
STOCKROOM	9	117	2,182	1.05	2,297	100%	870	2.9	250	2,547
GROCERY FREEZER	6	28	216	0.17	36	100%	53	1.7	4	41
BREAKROOM	4	49	2,102	0.20	412	100%	832	2.9	44	457
TRAINING ROOM	1	49	1,123	0.05	55	100%	453	2.9	6	61
DEPT MANAGERS OFC	2	49	1,123	0.10	110	100%	453	2.9	12	122
Total	**197**			**16.15**	**34,453**				**3,236**	**37,690**

D-Dimming Controls

Table 5-116: Dimming levels from both tracking and evaluated analysis

Dimmer Space Type		**Tracking**							**Evaluation**						
	Connected kW	**Power Level 1**	**Hrs Level 1**	**Power Level 2**	**Hrs Level 2**	**Power Level 3**	**Hrs Level 3**	**FLEH**	**Power Level 1**	**Hrs Level 1**	**Power Level 2**	**Hrs Level 2**	**Power Level 3**	**Hrs Level 3**	**FLEH**
Front End	3.2	52%	3,650	43%	1,095	18%	4,015	3,092	96%	5,475	45%	2,555	25%	730	6,567
Perishables	2.4	47%	3,650	42%	1,095	18%	4,015	2,898	96%	5,475	45%	2,555	25%	730	6,567
Rear Aisle	1.0	52%	3,650	43%	1,095	18%	4,015	3,092	96%	5,475	45%	2,555	25%	730	6,567
Aisle 1-10	7.7	52%	3,650	43%	1,095	18%	4,015	3,092	96%	5,475	45%	2,555	25%	730	6,567
Overall	**14.4**	**51%**	**3,650**	**43%**	**1,095**	**18%**	**4,015**	**3,059**	**96%**	**5,475**	**45%**	**2,555**	**25%**	**730**	**6,567**

10.1 Explanation of Differences

The evaluated savings for this lighting project are lower than the applicant reported savings primarily due to a decrease in the EFL hour reduction between the baseline fixtures without controls and the installed fixtures with dimming controls. The main factors impacting savings are shown in Table 5-117.

Table 5-117. Summary of Key Parameters for Controlled Fixtures

		Tracking		Evaluated	
Space Type	Control Type	Baseline Hours	Proposed Hours	Baseline Hours	Proposed Hours
Sales Floor[34]	Dimming	8,760	3,084	8,760	6,567
Meat Cooler	Occupancy Sensors	4,680	3,557	8,760	8,544
Produce Cooler	Occupancy Sensors	8,760	6,658	8,760	8,544
Grocery Freezer	Occupancy Sensors	8,760	6,658	8,760	8,544
Stockroom	Occupancy Sensors	8,760	6,658	8,760	6,578
Break Room	Occupancy Sensors	8,760	6,658	8,760	6,658
Training Room & Manager's Office	Occupancy Sensors	4,680	3,557	4,680	3,557
Occupancy Sensor Weighted Average[35]		**8,167**	**6,208**	**8,418**	**6,762**

Overall, the evaluated savings are 13% lower than the applicant-reported savings. Table 5-118 provides a summary of the differences between tracking and evaluated values.

Table 5-118. Summary of Deviations

End-Use	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
Lighting Fixtures	Operation	Annual Hours (weighted)	+0.5%	**Increased savings –** due to an increase in annual operating hours for fixtures.
Lighting Controls	Operation	Annual Hours (weighted)	-22.0%	**Decreased savings –** due to a lower impact on operational schedule due to dimming and occupancy sensor controls.
Lighting Fixture	Interactive	HVAC Interaction	+7.0%	**Increased savings** – due to the addition of HVAC interactive effects from lighting wattage reduction.
Lighting Controls	Interactive	HVAC Interaction	+1.4%	**Increased savings** – due to the addition of HVAC interactive effects from lighting wattage reduction.

10.1.1 Ancillary impacts

For lighting measures, electric HVAC interactive savings occur in retrofitting the T8 fluorescent fixtures to LEDs and adding controls. The tracking estimate did not include HVAC interactive effects. The areas where all fixture retrofits took place are served by a packaged DX (COP: 2.9), coolers (COP: 2.7), and freezers (COP: 1.7). Adding these effects accounts for an 8% increase in savings compared to the tracking values, which did not include HVAC interactive effects.

RICE18N002

Program	**RICE2018**
Application ID(s)	**7799073**
Project Type	**C&I Retrofit**
Program Year	**2018**

[34] Front End, Perishables, and Aisles. See Table 5-116

[35] Weighted by connected kW.

Evaluation Firm	**DMI**	
Evaluation Engineer	**Dan McKinley**	
Senior Engineer	**Jay Robbins**	

Evaluated Site Summary and Results

The project took place at a 40,000 ft2 light industrial manufacturing facility which produces sensors and circuit board products for medical and defence applications. Normal manufacturing hours are from 7:30 AM – 3:30 PM, with occasional use to 6:30 PM. The facility is served by 1 x primary variable speed 36kW Gardner Denver EGC air compressor and 1 x backup single stage, load unload, 30 hp Gardner Denver EBE air compressor, both supplying compressed air at 100 psi gauge to support manufacturing equipment loads. 1 x 120 gal air receiver, 1 x HPR150 Hankison air dryer, and 1 x permanent CDI flow meter are also present. The compressed air system is operational 24 hr/day, 7 days per week, serving relatively low, constant loads outside of normal manufacturing hours.

The energy savings measure was to identify and repair leaks in the compressed air system, so this is a retrofit measure. The leak repairs were performed in April 2018. The energy savings come from decreased compressed air flow and compressor demand.

The vendor report for this project identified the pre-measure facility average compressed air load as 51 standard ft3/min (scfm) with a leak load of 32 scfm. The report states that the leak load was reduced from 32 cfm to 17 cfm for a 15 cfm airflow savings and a final average compressed air load of 36 cfm. Despite this, the PA calculations used 32 and 17 cfm as the pre and post average airflows to calculate savings independently of the vendor.

Following the completion of this project in May 2018, the vendor measured the facility average compressed air load as 36 scfm. The reduction in average load, 15 scfm, was used to calculate an annual savings of 25,780 kWh per year.

The operation at this site was not impacted by COVID, although the metering period, which began prior to the declaration of the COVID-19 pandemic, was significantly extended owing to PA restrictions on site visits during the initial months of the pandemic. The evaluation conducted a full metering and verification approach because the operation of the installed equipment was not impacted by COVID and the site was comfortable with the evaluator conducting an in-person site visit and metering. The evaluation results are presented in Table 1-1.

Table 5-119. 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)
7799073	Compressed Air Leak Repair	Tracked	25,780	48%	3.07	3.07
		Evaluated - ops	28,676	57.5%	2.76	3.56
		Realization Rate	111%	120%	90%	116%
Totals		**Tracked**	**25,780**	**48%**	**3.07**	**3.07**
		Evaluated - ops	**28,676**	**57.5%**	**2.76**	**3.56**
		Realization Rate	**111%**	**120%**	**90%**	**116%**

Explanation of Deviations from Tracking

The evaluated savings are greater than the applicant-reported savings primarily due to the difference in leak reduction calculation, operating hours, and a difference in compressor performance. Further details regarding deviations from the tracked savings are presented in Section 3-4.

Recommendations for Program Designers & Implementers

The evaluation recommends that a greater amount of post-measure airflow trend data be collected when determining the reduction in airflow due to leak repairs. This evaluation is based upon the applicant data that includes ~43 hrs of post-repair trend data and short-term events may have a significant impact on savings.

Compressed air leak repairs have a 2-year measure life and the evaluation site visit was performed at the end of the measure life, 24 months after this measure was installed. Additionally, the site performed another compressed air leak repair in early 2020, between the evaluation metering period (March 2020) and the leak repair being evaluated (2018). The evaluator collected metered data regardless to verify site operation, but leak savings are entirely dependent on the implementor's pre/post airflow data.

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 a compressed air leak audit and repair. 73 leaks were detected and 80% were assumed to be repaired according to the applicant, from which the applicant attributed a 15 cfm constant compressed air load reduction based on pre/post airflow measurements.

Application Information and Applicant Savings Methodology

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

Applicant Description of Baseline

The applicant classified the energy savings measure as a retrofit, so the pre-installation operating conditions were used as a baseline. There are discrepancies for the measured airflow values in the applicant documentation. An average facility compressed air load of 32 scfm was used as the baseline by the PA in the savings calculations; however, this compressed air load does not correspond to the May 2018 TA study. The TA study report states that 32 scfm is the leak load, not the average load, and the average facility baseline compressed air load is 51 scfm.

The PA savings calculations correspond to the tracked savings; the applicant values are taken from the PA savings calculations over the vendor's TA study report when the two conflict. The PA has not provided evidence to support the compressor performance shown in Table 2-1, which disagrees with the manufacturer's datasheet included in the TA study which is reproduced in Table 2-3. The applicant has listed the operating pressure as 125 psig.

Table 5-120. Applicant Baseline Key Parameters

		BASELINE		
Measure	**Parameter**	**Value(s)**	**Source of Parameter Value**	**Note**
ECM 1	average airflow from pre-repair metering	32 scfm	Applicant Calculations	
	compressor performance	4.89 scfm/kW	Applicant Calculations	
	compressor operating pressure	125 psig	Applicant Report	

Applicant Description of Installed Equipment and Operation

The installed case is the compressed air system with repaired air leaks. The PA assumed that the primary compressor operated constantly to meet the facility compressed air load for 8,400 hr/year and the applicant did not provide supporting information for this value. The PA calculations, which show 8,400 hr/year, disagree with the applicant's TA study report which shows 8,760 hr/year.

The applicant calculations state the average airflow from post-repair metering as 17 scfm, which disagrees with the TA study which states that 17 scfm is the average post-repair leak load, and that the average airflow from post-repair metering is 36 scfm.

Table 5-121: Application Proposed Key Parameters

		PROPOSED		
Measure	**Parameter**	**Value(s)**	**Source of Parameter Value**	**Note**

ECM 1	primary compressor operating hours	8,400 hr	Applicant Calculations	
	compressor performance	4.89 scfm/kW	Applicant Calculations	
	average airflow from post-repair metering	17 scfm	Applicant Calculations	

2.2.2 Applicant Energy Savings Algorithm

The applicant determined savings by comparing the pre and post installation average compressed air loads. The difference in these loads, multiplied by compressor performance and annual operating hours, yield annual energy savings. Note that this algorithm is based on the PA's calculations who appears to have incorrectly entered the leak load values instead of average airflow.

$$S = (A_i - A_f) * \eta * t_a$$

where:

S = total measure savings, kWh/year

A_i = average airflow from leak pre-repair metering, 32 scfm

A_f = average airflow from leak post-repair metering, 17 cfm

η = compressor performance, 4.89 cfm/kW

t_a = 8,400 hr/year, annual compressor operational time

yielding a savings of 25,780 kWh per year.

The applicant has calculated the demand savings by assuming that the reduction in airflow is constant throughout the year, so demand savings, D, are:

$$D = (A_i - A_f) * \eta$$

The applicant has calculated percent saved on peak as (4,032 hr/yr) / (8,400 hr/yr), equal to 48%. The applicant does not provide supporting justification for 4,032 hr/yr.

The compressor performance shown in Table 2-3 is included in the applicant's report, but is inconsistent with the average performance value used in the savings analysis, 4.89 scfm/kW.

Table 5-122: Gardner-Denver VS170 Performance at 125 psig

Package Power	**flow**	**Max Airflow**	***flow (150*% flow)***	**P**	***performance***
%	scfm	%	*scfm*	kW	*scfm/kW*
100%	150	100%	*150*	35.9	*4.18*
90%	132	90%	*135*	32.5	*4.15*
80%	116	80%	*120*	29.6	*4.05*
70%	99	70%	*105*	26	*4.04*
60%	85	60%	*90*	22.8	*3.95*
50%	67	50%	*75*	19.8	*3.79*
40%	47	40%	*60*	16.4	*3.66*
30%	x	30%		x	
min.	45	min.	*45*	14.1	*3.19*
columns in italics have been added by the evaluator for clarity.					

2.2.3 Evaluation Assessment of Applicant Methodology

The applicant's methodology in calculating average load from the plots of pre-installation measured data in the TA study is unclear, and it is unclear why the applicant has used "leak loads" calculated in the TA study as average loads in the calculations. The difference between leak loads and average loads pre and post install are the same (15 scfm), so with the exception of the compressor performance value used this distinction does not appear to impact the savings. The applicant supplies no supporting information to justify a post-install leak load of 17 cfm which is also directly used as post-install airflow in the applicant calculations.

The engineering data sheet for the Gardner Denver VS170 EGC rotary screw compressor provided by the applicant in the TA study and partially reproduced in Table 2-3 appears to be a reasonable basis for estimating the installed primary compressor (Gardner Denver 330EGC753) performance; the "EGC" designation, full load operating pressures, and max current shown on the data sheet match the installed compressor nameplate. This data sheet is the manufacturer's data and is dated August 2002.

The evaluator was unable to find a data sheet which exactly matched the installed compressor as the Gardner Denver line of air compressors appears to have been re-numbered since the primary compressor was installed. Based on the similarities described between the compressor referred to in the applicant's data sheet and the primary compressor, the evaluator judges the use of this datasheet as adequate. This compressor does not appear in CAGI data.

The evaluator is unsure why this datasheet was not used in the applicant's savings calculations as the applicant selected a value of 4.89 scfm/kW which does not correspond to this table. As discussed in the next section, during the site visit the evaluator observed the compressed air system to be operating at 100 psig instead of 125 psig as reported by the applicant. Table 2-4 reproduces compressor performance at this pressure from the manufacturer's datasheet and although the applicant's performance value is closer to the values shown in this table, there is still a significant difference between the two values.

Table 5-123: Gardner-Denver VS170 Performance at 100 psig

Package Power	flow	Max Airflow	*flow (170*% flow)*	P	*performance*
%	scfm	%	*scfm*	kW	*scfm/kW*
100%	170	100%	*170*	35.9	*4.74*
90%	152	90%	*153*	32.5	*4.71*
80%	136	80%	*136*	28.4	*4.79*
70%	117	70%	*119*	25.1	*4.74*
60%	98	60%	*102*	21.7	*4.70*
50%	81	50%	*85*	18.3	*4.64*
40%	60	40%	*68*	15.6	*4.36*
30%	x	30%		x	
min.	43	min.	*45*	10.1	*4.46*
columns in italics have been added by the evaluator for clarity.					

The operating hours used by the applicant, 8,400 hr/yr, are not supported with documentation. These operating hours are likely intended to reflect down-time in the primary compressor during which either the backup compressor is operating or the site does not require a compressed air supply.

2.3 Site Visit

The evaluator conducted a site visit on March 10, 2020 to inventory compressed air system equipment including compressors, receivers, dryers, and meters. The evaluator ascertained details on compressor control strategies, modulation, and how the primary and backup compressor interact. The evaluator installed a current logger on the primary compressor and a motor run-time meter on the backup compressor to determine overall system performance, annual operating time, and observe demand load profiles. A current meter was installed on the primary compressor rather than a power meter owing to space limitations in the disconnect box and a lack of voltage points. Given the stated run-time of the backup compressor (1 hour per week) and site visit time constraints, a run-time meter was deemed adequate for the backup compressor. No meter was installed on the air dryer due to its small size of 1.1kW.

The meters remained installed for 7 months owning to restrictions in site visits caused by the COVID-19 pandemic. The evaluator attempted to access trend data from the permanent CDI flow meter but the site contact was unable to provide access via USB at the time of visit. The site contact was not able to provide access at the meter retrieval visit on October 27, 2020 and was subsequently unable to provide airflow data despite follow-up contact.

A site walk through with an ultrasonic leak detector was performed with the site contact during the March 2020 site visit in order to verify that leak repairs were performed according to the vendor provided schedule. This was accomplished by randomly selecting approximately 20 leak locations, 6 of which could be identified on the vendor provided schedule, which included 73 total leak repairs. The site contact advised if found leaks were new, but it was unclear when leaks had been repaired due to a more recent 2020 compressed air audit. 3 locations had no leaks, while 2 had slow leaks and 1 had a fast leak. Of compressed air connections which were tested but could not be identified on the vendor leak repair schedule, the vast majority had no or slow leaks. Because the measure life was expired at the time of the site visit and a subsequent leak repair had been performed by the applicant, this leak repair verification was not used to adjust measure savings. Following the site visit, the evaluator requested and received pre and post measure airflow data from the vendor, and this data was used to determine the evaluated leak reduction.

2.3.2 Summary of Site Visit Findings

The site visit was conducted with the facilities site lead. The site contact indicated that compressed air leak audits have been conducted at set intervals for several years. Following the 2018 measure evaluated in this report, a compressed air audit and repair had been conducted shortly before the March 2020 site visit.

- Quantity Confirmation: The evaluator confirmed that 1 variable speed lead compressor and 1 constant speed backup compressor were present on site, however the variable speed compressor model number observed did not correspond to the performance specifications used by the applicant. As discussed in Section 2.2.2, the evaluator deems the applicant's performance specifications based on manufacturer's data to be sufficient. The evaluator was not able to confirm the total quantity of leak repairs made due to the expired measure life and subsequent leak repair.

- Technology Confirmation: The evaluator observed a compressed air demand digital readout on the lead compressor showing a variation in load, indicating that the compressor was modulating to meet the demand. The evaluator confirmed that the backup compressor was single-speed.

Table 5-124. Measure Verification

Measure Name	Verification Method	Verification Result
Compressed Air Leak Detection, Tagging, and Repair	Sample repaired leaks to determine if leaks have been repaired or are still present.	Of 6 leaks which had been repaired according to the applicant's invoice, 3 had no leaks, 2 had slow leaks, and 1 had a fast leak. However, because the site contact indicated that a different compressed air leak repair occurred between measure implementation and the evaluation site visit, these results are inconclusive.

Compressed Air Leak Detection, Tagging, and Repair	Meter primary compressor power consumption in order to confirm applicant's post-repair compressor power.	The evaluator logged current consumption of the compressor and confirmed that the applicant's reported post-repair power consumption is reasonable. However, because an additional leak repair occurred between evaluation and measure implementation these results are inconclusive.
Compressed Air Leak Detection, Tagging, and Repair	Download airflow trend data from permanently installed airflow meter to confirm applicant's post-repair airflow.	The site contact was unable to provide access to trends from the airflow meter.
Compressed Air Leak Detection, Tagging, and Repair	Review pre- and post- measure airflow data collected by the applicant to determine if the reported airflow savings are accurate.	The vendor was able to provide pre and post measure airflow trends, however the post-measure airflow trends contain only 43 hours of trends.

2.4 Evaluation Methods and Findings

This section describes the evaluator methods and findings.

2.4.1 Evaluation Description of Baseline

The evaluator agrees with the applicant's classification of this measure as a retrofit, so the pre-installation operating conditions are the baseline. The underlying equipment is unlikely to fail during the short two-year leak repair measure life. In the unlikely event that the compressors were to fail during the measure life, it is expected that another VFD compressor would be installed and that the performance improvement would be minimal.

2.4.2 Evaluation Calculation Method

The evaluator calculates energy savings using a similar methodology to the applicant; however, the evaluator's approach accounts for different average airflow savings during occupied and unoccupied periods. Additionally, the evaluator calculates air compressor efficiencies for the pre and post install conditions separately to more accurately capture actual operation.

The evaluator obtained pre/post airflow directly from the implementer as it was not included in the applicant documentation. This data was reviewed to clarify the leak reduction discrepancies within the applicant documentation. The raw data was also used to analyze the time of week variation in airflow.

The evaluator did not use the metered current data collected between the first and second site visit to calculate airflow because it was collected after the two-year measure life had expired and after a different, more recent, compressed air leak inventory and repair had been conducted. This current data was only used to verify annual hours of operation.

The evaluation methodology is as follows:

1. Bin applicant provided pre and post measure airflow into a 24 x 7 matrix in order to observe variations in airflow by time of day (0-23) and day of week (1-7). This matrix is shown in Figure 2-1.
2. Average airflow bins for both the pre and post data into occupied (production) and unoccupied (non-production) average airflows. The evaluator describes the baseline as 50.6 cfm during occupied periods and 45.2 cfm during unoccupied periods. The evaluator judges that the analysis can be adequately completed by rounding the occupancy hours stated by the site contact to whole hours increments which of 07:00 AM to 4:00 PM.
3. Interpolate compressor performance in Table 2-4 (100 psi compressor performance, from manufacturer's datasheet) to determine the performance which corresponds to each average airflow. Where the average airflow is less than the

compressor minimum airflow listed in this table, this analysis assumes that the compressor cycles on and off to meet the airflow load at the minimum performance value.

4. Calculate the compressor electrical power consumption according to $P = A / \eta$ where A is the average airflow and η is the corresponding compressor performance in cfm/kW.

5. Based on feedback from the site contact, the site has compressed air loads 8,760 hr/year, with the backup compressor serving these loads whenever the primary compressor is unavailable. After reviewing the current meter data collected on the site visit, the evaluator has determined that site had compressed air loads throughout the metering period and that the backup compressor operated for ~1.3 hours/week on average. Leak reductions will reduce airflow loads on both the primary and backup compressors. The evaluator assumes that the backup compressor operates at the same efficiency as the primary compressor, and therefore for analysis purposes 8,760 hours/year of compressed air load on the primary compressor can used to calculate savings.

6. Calculate the energy savings according to $E = (P_{pre} – P_{post}) * t$ where P_{pre} and P_{post} are the pre and post compressor operating power and t is the operating hours for either the occupied or unoccupied state. As discussed in section 2.4.3 occupied hours are defined as 07:00 AM to 4:00 PM Monday thru Friday. Occupied hours are calculated as 9 hours/day * 5 days/week * 52 weeks/year = 2,340 hours/year. Unoccupied hours are calculated as 8,760 – 2,340 = 6,420 hours/year.

7. The percentage of energy savings on peak is calculated by first calculating the % on peak for the occupied and unoccupied periods separately. The occupied period is entirely within the on-peak period, so has a value of 100% on-peak. The unoccupied period has 7 hours within the on-peak period (4:00 PM to 11:00 PM), so the unoccupied % on peak is calculated as 7 / (24 – 9) = 47%, where 9 is the number of hours on-peak and 24 is the number of hours per day. The overall % on peak is the sum of the product of the energy savings and % on-peak for the occupied and unoccupied cases.

8. The summer demand reduction corresponds to 1:00 PM to 5:00 PM, and therefore 3 of 4 hours of this period fall into the occupied time range. Summer demand reduction is calculated according $D_{summer} = (P_{pre} – P_{post})_{occupied} * (3/4) + (P_{pre} – P_{post})_{unoccupied} * (1/4)$.

9. The winter demand reduction corresponds to 5:00 PM to 7:00 PM and therefore it falls entirely within the unoccupied period of operation. Therefore, the winter demand reduction is calculated according to $D_{winter} = (P_{pre} – P_{post})_{unoccupied}$

The evaluation calculation methodology, completed with applicant pre and and post measure airflow data, is summarized in Table 2-5.

Figure 2-42. Compressor Load Variation

pre-measure airflow (cfm)								post-measure airflow (cfm)							
	Day of Week (1= Monday)								Day of Week (1= Monday)						
Hour	1	2	3	4	5	6	7	Hour	1	2	3	4	5	6	7
0	45.3	44.7	45.3	43.7	43.5	45.3	45.5	0	N/A	28.8	30.8	N/A	N/A	N/A	N/A
1	45.3	44.3	45.2	43.6	44.2	45.6	45.5	1	N/A	28.8	28.9	N/A	N/A	N/A	N/A
2	46.1	43.7	45.8	43.8	43.6	45.6	46.1	2	N/A	29.3	28.7	N/A	N/A	N/A	N/A
3	45.5	43.9	45.6	43.6	44.4	46.1	45.7	3	N/A	30.6	28.7	N/A	N/A	N/A	N/A
4	45.8	44.1	46.6	43.7	44.1	46.0	45.5	4	N/A	29.8	28.9	N/A	N/A	N/A	N/A
5	45.1	44.5	45.4	44.8	44.3	45.6	45.8	5	N/A	29.1	29.8	N/A	N/A	N/A	N/A
6	45.2	44.3	46.5	44.7	44.8	45.7	45.5	6	N/A	28.8	30.2	N/A	N/A	N/A	N/A
7	47.9	49.3	48.8	50.3	48.7	45.6	45.8	**7**	N/A	35.0	32.7	N/A	N/A	N/A	N/A
8	49.2	52.3	50.0	53.3	50.7	46.3	45.9	**8**	N/A	36.2	35.3	N/A	N/A	N/A	N/A
9	47.5	52.0	49.3	51.0	50.6	46.8	45.8	**9**	N/A	40.3	N/A	N/A	N/A	N/A	N/A
10	47.2	53.9	49.5	52.3	51.7	45.9	45.2	**10**	40.9	49.9	N/A	N/A	N/A	N/A	N/A
11	48.2	53.4	51.2	51.8	52.9	46.2	46.0	**11**	35.7	45.7	N/A	N/A	N/A	N/A	N/A
12	46.9	52.3	51.5	50.1	51.8	45.7	46.5	**12**	38.7	43.1	N/A	N/A	N/A	N/A	N/A
13	48.2	54.5	51.0	50.8	55.5	45.7	46.0	**13**	43.0	39.5	N/A	N/A	N/A	N/A	N/A
14	48.4	52.1	52.1	51.4	53.5	45.7	45.9	**14**	41.9	39.4	N/A	N/A	N/A	N/A	N/A
15	46.4	50.0	50.7	49.7	49.5	45.7	45.5	**15**	40.6	37.0	N/A	N/A	N/A	N/A	N/A
16	45.3	48.0	46.1	47.4	48.7	45.6	45.8	16	32.2	32.3	N/A	N/A	N/A	N/A	N/A
17	44.2	47.3	44.7	45.5	46.4	45.9	45.3	17	29.8	29.0	N/A	N/A	N/A	N/A	N/A
18	44.4	45.9	43.6	44.1	45.5	45.1	45.4	18	29.7	30.6	N/A	N/A	N/A	N/A	N/A
19	44.3	44.9	44.3	43.9	44.7	45.4	45.6	19	30.1	32.5	N/A	N/A	N/A	N/A	N/A
20	44.3	45.5	43.9	43.7	45.3	45.7	44.8	20	30.1	30.6	N/A	N/A	N/A	N/A	N/A
21	44.1	46.2	44.0	44.2	45.3	45.7	45.2	21	30.1	29.0	N/A	N/A	N/A	N/A	N/A
22	43.8	45.6	43.9	43.3	45.4	45.6	45.0	22	29.1	29.3	N/A	N/A	N/A	N/A	N/A
23	43.9	46.4	44.1	44.0	44.6	45.6	45.4	23	30.2	32.7	N/A	N/A	N/A	N/A	N/A

Table 5-125. Summary of Evaluation Calculation Methodology

		pre-measure			post-measure				savings					
case	period	airflow (cfm)	eff. (cfm/kW)	P (kW)	airflow (cfm)	eff. (cfm/kW)	P (kW)	annual hours	P (kW)	E (kWh)	airflow (cfm)	% on peak	summer (kW)	winter (kW)
evaluated	occupied	50.6	4.29	11.81	39.7	4.26	9.32	2,340	2.49	5,822	11.0	100%		
	unoccupied	45.2	4.27	10.59	29.9	4.26	7.03	6,420	3.56	22,855	15.3	47%		
	total							8,760		28,676		57%	2.76	3.56

3 Final Results

This section summarizes the evaluation results determined in the analysis above. This section includes a summary table of savings by major end-use and application. Compressor performance, pressure, leak reduction, and operating hours are among the key parameters for this project.

Table 5-126. Summary of Key Parameters

	BASELINE		PROPOSED / INSTALLED	
Parameter	**Tracking**	**Evaluation**	**Tracking**	**Evaluation**
	Value(s)	**Value(s)**	**Value(s)**	**Value(s)**
compressor performance	4.89 scfm/kW	occupied: 4.29 scfm/kW unoccupied: 4.27 scfm/kW	4.89 scfm/kW	occupied: 4.26 scfm/kW unoccupied: 4.26 scfm/kW
compressor operating pressure	125 psig	100 psig	125 psig	100 psig
primary compressor operating hours	8,400	8,760	8,400	8,760
average leak reduction	0 scfm	0 scfm	15.0 scfm	occupied: 11.0 scfm unoccupied: 15.3 scfm

3.1 Explanation of Differences

As shown in Table 3-1, the key drivers between the applicant and evaluation savings estimates are due to the difference in compressor performance used and the difference in operation hours used. The compressor performance differs because the applicant did not appear to use the cutsheet included in the TA study to estimate performance; additionally, the performance differs because the applicant did not determine the appropriate performance for different compressor operating points. The operational hours differ because the applicant assumed fewer operational hours than were actually present; no source is provided for the applicant's value.

Table 3-2 provides a summary of the differences between tracking and evaluated values.

Table 5-127. Summary of Deviations

Measure	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
App ID 7799073	Technology	Efficiency	16.1%	Increased savings by using efficiencies from manufacturer datasheets.
	Operational	Hours	3.7%	Increased savings by accounting for additional operating hours
	Methodology	Average Leak Reduction	-8.6%	Decreased savings during occupied periods by accounting for variations in compressed air demand throughout the day.
	Final RR			**111%**

RICE18N039

Report Date: 06/17/2021

Application ID(s)	8020501
Project Type	New construction
Program Year	2018
Evaluation Firm	DNV
Evaluation Engineer	George Sorin IOAN
Senior Engineer	Long Vu

Evaluated Site Summary and Results

The project consisted of replacing a failed 7.5-ton rooftop (RTU) HVAC unit with an energy efficient 7.5-ton unit at a retail store. The measure saves energy because the installed RTU is more efficient than the baseline. The store hours are between 9:00 AM to 9:00 PM from Monday to Saturday and between 10:00 AM to 8:00 PM on Sunday.

The applicant classified the measure as a new construction with an industry standard practice (ISP) baseline. The applicant referenced Table C403.2.3(1) from IECC 2012 to define the ISP. IECC 2012 has different minimum efficiency requirements for units equipped with electric heat and units equipped with gas-fired furnaces. The applicant defined the baseline efficiency as the average of cooling efficiency values associated with those two types of units. The applicant calculated the project impacts using a spreadsheet calculator.

The site contact indicated that, during the metering period, the store operation was not impacted by the current pandemic and the evaluators conducted metering and verification to evaluate the measure. The results of the evaluation include updates on both non-operational and operational parameters associated with the evaluated measure.

Based on the on-site findings and the review of the project documentation, the evaluator classified the project as a lost opportunity with an ISP baseline. Because the evaluated project was installed in December 2017 when IECC 2012 was in force, the evaluators used the same ISP reference as the applicant and updated the ISP from 11.3 IEER (used by the applicant) to 11.2 IEER (requirement for air-cooled RTUs, equipped with gas-fired furnaces, with cooling capacities between 65,000 Btuh and 125,000 Btuh). The evaluator estimated the project impacts based on temperature data recorded by the EMS between May 10,2021 and June 10, 2021 corroborated with the current draw of the RTU that was metered between February 25, 2021 and June 6, 2021. The evaluator calculated the project savings using a temperature-based spreadsheet calculator like the calculator used by the applicant. The evaluated savings were smaller than the reported tracking value primarily because the installed unit's evaluated operating hours in cooling mode were smaller than the applicant value and because the evaluated baseline efficiency is greater than the applicant value used in the tracking savings calculations. The evaluation results are presented in Table 1-1.

Table 5-128. 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)
8020501	Install one 7.5-ton RTU	Tracked	1,700	46%	0.61	0.00
		Evaluated	1,231	65%	0.68	0.00
		Realization rate	**72%**	**141%**	**112%**	**100%**

Explanation of Deviations from Tracking

The evaluated savings are less than the reported savings primarily because the evaluated operating hours are smaller than the hours used by the applicant. Further details regarding deviations from the tracked savings are presented in Section 3-1.

Recommendations for Program Designers & Implementers

There are no recommendations currently.

Customer Alert

There were no customer alerts.

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 was installed at a retail facility and consisted of installing one 7.5-ton RTU equipped with gas-fired heating that provides cooling and heating to the facility.

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.

Applicant Description of Baseline

According the project files, the applicant classified the project as a new construction with an ISP baseline. The applicant used Table C403.2.3(1) from IECC 2012 as ISP. For air-cooled RTUs with cooling capacities between 65,000 Btuh and 125,000 Btuh, the code has separate cooling efficiency requirements for units equipped with electric resistance for heating and units equipped with gas-fired furnaces. The applicant calculated the measure impacts using an average of the two cooling efficiency values required by IECC 2012. The applicant Table 5-129 presents the applicant's baseline key input parameters.

Table 5-129. Applicant baseline key parameters

Parameter	Value(s)	Source of Parameter Value
RTU capacity	7.5 ton	Applicant savings calculations
RTU quantity	1	Applicant savings calculations
RTU integrated energy efficiency ratio (IEER)	$11.3 = \frac{11.4 + 11.2}{2}$	Applicant savings calculations
RTU energy efficiency ratio (EER)	$11.1 = \frac{11.2 + 11}{2}$	Applicant savings calculations
RTU annual equivalent full load hours	1,178 hours	Applicant savings calculations

Applicant Description of Installed Equipment and Operation

The installed unit is more efficient than the baseline and provides the same cooling energy as the baseline. Table 5-130 presents the applicant's proposed key input parameters.

Table 5-130: Applicant proposed key parameters

Parameter	Value(s)	Source of Parameter Value
RTU capacity	7.5 ton	Installed unit nameplate
RTU quantity	1	Applicant savings calculations
RTU rated efficiency	12 EER/13.8 IEER	Installed unit nameplate
RTU annual equivalent full load hours	1,178 hours	Applicant savings calculations

Applicant Energy Savings Algorithm

The applicant calculated the impacts due to the measure installation using a deemed savings calculator that accounts for the rooftop size, efficiency, and proposed operating hours.

To predict the operating hours, the applicant used a temperature-based profile generated using TMY3 weather. Table 5-131 presents the profile the applicant used to calculate the operating hours during which the unit operates in cooling mode.

Table 5-131. Cooling operating profile developed by the applicant

OA Dry-bulb Range (°F)		Total Hours	% Cool Load
Min	Max		
95	100	3	100%
90	95	40	100%

85	90	67	90%
80	85	268	80%
75	80	330	70%
70	75	309	60%
65	70	383	50%
60	65	388	40%
55	60	324	30%

Based on the profile presented in Table 5-131 above, the equivalent full-load hours (EFLH) of the unit when operates in cooling mode is 1,178 hours per year.

To calculate the project impacts, the applicant used the EFLH, the unit capacity and the installed and baseline efficiencies in the following formula:

$$Savings = 12 \times Capacity \times \left(\frac{1}{Eff_{installed}} - \frac{1}{Eff_{baseline}}\right) \times EFLH$$

where,

$Savings$	– first year project savings (1,178 kWh/year)
12	- constant used to convert cooling efficiency $\left(\frac{kW}{Ton} = \frac{12}{IEER}\right)$
$Capacity$	- installed unit rated capacity (7.5 ton)
$Eff_{installed}$	- installed unit integrated energy efficiency ratio (IEER) (13.8)
$Eff_{baseline}$	- baseline unit integrated energy efficiency ratio (IEER) (11.3)
$EFLH$	- equivalent full-load hours the unit operates in cooling mode (1,178 hours/year)

More details associated with the applicant savings calculations are provided in the project files.

Evaluation Assessment of Applicant Methodology

The applicant calculated the project impacts using a calculator that uses the unit capacity and efficiency of the installed and baseline units and an operating profile. The applicant did not indicate how the operating profile was generated. The project was installed in December 2017 when IECC 2012 was in force. Table C403.2.3(1) of IECC 2012 shows that an air-cooled 7.5 ton single package units installed after June 1, 2011 should have a 11.2 IEER. This value is slightly different than the baseline IEER used by the applicant.

On-Site Inspection and Metering

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

Summary of On-site Findings

The evaluator conducted a site visit on February 25, 2021. During the site visit, the evaluator verified the installation of the measure and installed metering equipment on the evaluated unit. The evaluator gathered the following information:

1. Inspected the evaluated unit. Photo 2-1 below shows the nameplate of the unit.

Photo 2-1. Evaluated 7.5 ton RTU

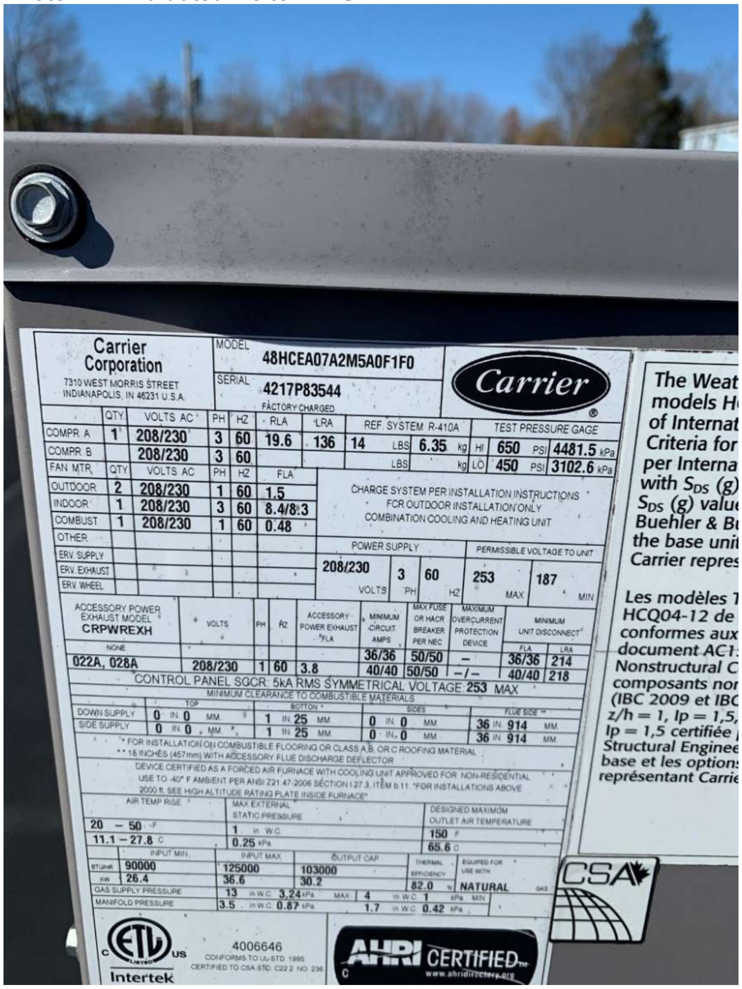


Table 2-4 provides a summary of the measure verification method.

Table 2-132. Measure Verification

Measure Name	Verification Method	Verification Result
Install one 7.5-ton RTU	Visual inspection of the unit.	The unit has been installed and operates as intended.

2. The evaluators also interviewed the energy manager in charge of the operation of mechanical equipment installed at the facility and gathered details on the operation of the HVAC at the site. According to the energy manager, the HVAC is controlled remotely from a central location and the RTUs are programmed to automatically switch between cooling and heating operating modes. The site operation has not been impacted by the pandemic and the controlling setpoints have not been changed since the new RTU has been installed.

3. The energy manager provided EMS data recorded between 05/10/2021 and 06/10/2021.

Measured and Logged Data

During the site visit, the evaluator deployed one current transformer (CT) with a logger on the control panel of the evaluated RTU. The metering period was from February 25, 2021 through June 2, 2021. Table 2-5 presents the logger deployment details.

Table 2-5. Evaluation Data Collection – Installed Equipment

Parameter	M&V Equipment Brand and Model	Metering Start/Stop Dates	Metering Interval

Electric current (amperage)	1 x HOBO logger w/current transformer probe	02/25/2021 – 06/02/2021	5 minutes
Supply air temperature (SAT)	EMS	05/10/2021 – 06/10/2021	15 minutes
Space temperature (ST)	EMS	05/10/2021 – 06/10/2021	15 minutes

Figures 2-5 and 2-6 shows the graphical summary of the metered and EMS data.

Figure 2-5. RTU metered amperes during the metering period (02/25/2021 – 06/02/2021)

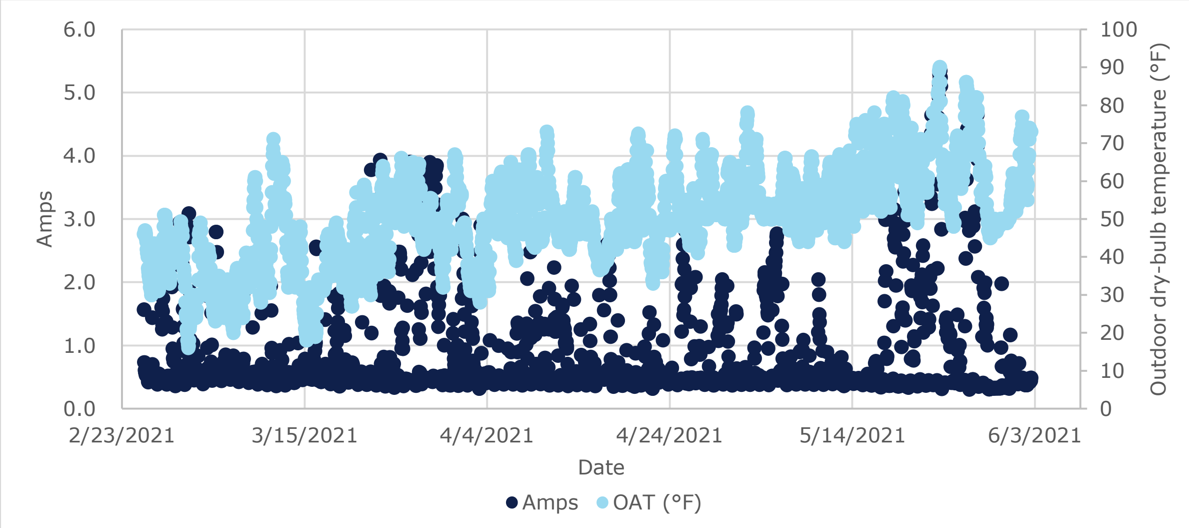
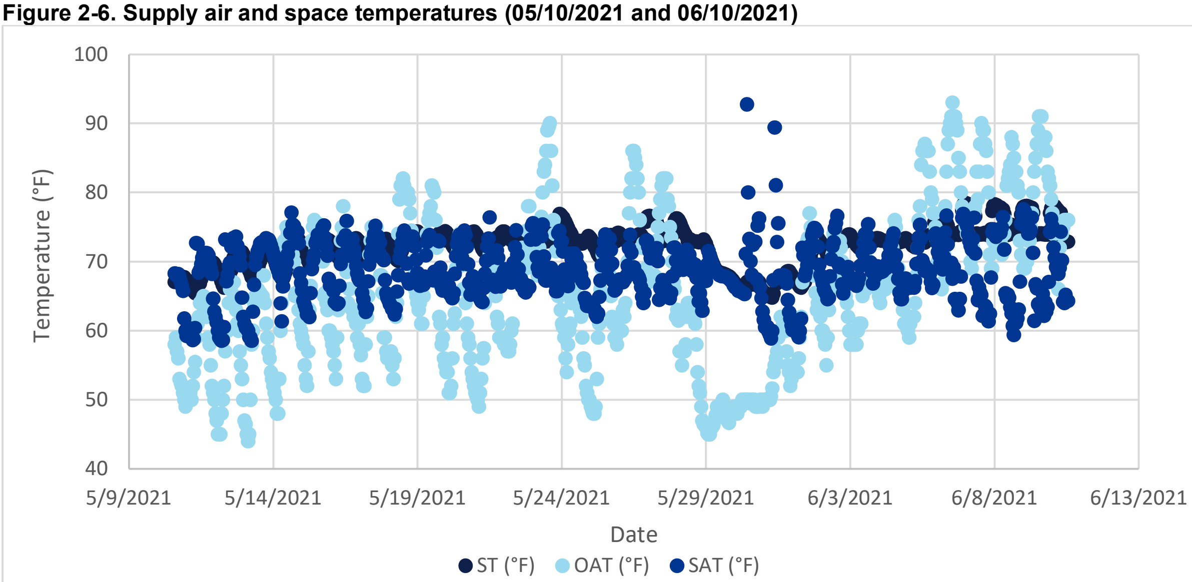


Figure 2-6. Supply air and space temperatures (05/10/2021 and 06/10/2021)



The evaluator processed the metered current draw to determine if the RTU is controlled based on a schedule. Table 2-6 below shows the average hourly current draw of the unit during each day of the week over the metering period.

Table 5-6. RTU hourly current draw during each day of the week

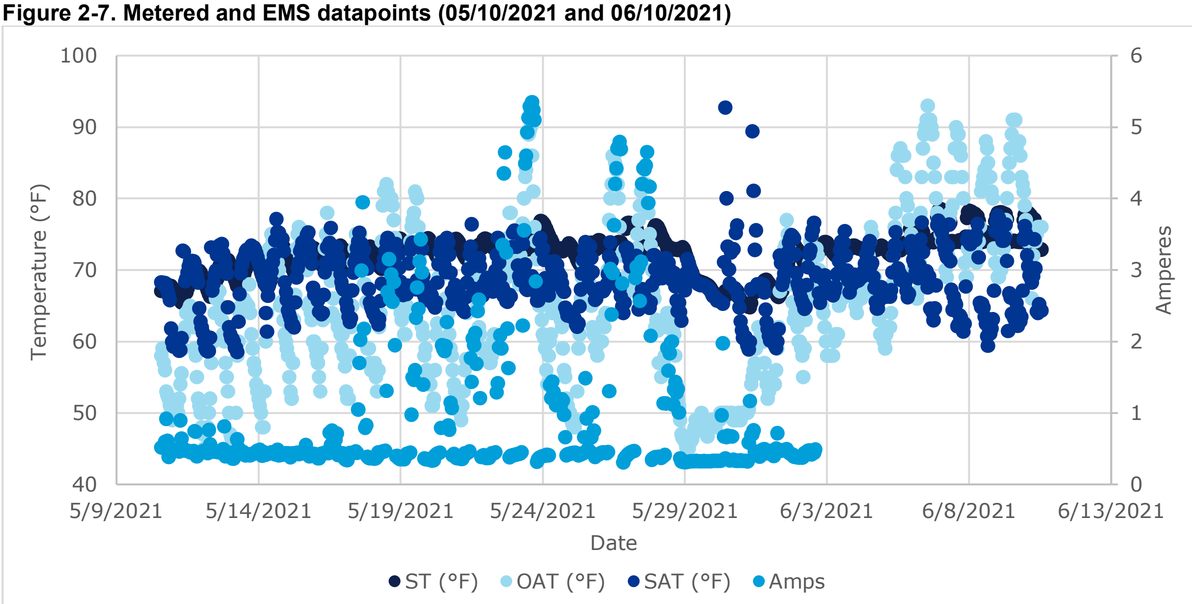
Amperes Weekday	Hour 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1.1	1.5	1.4	1.3	1.3	1.2	1.2	1.2	1.3	1.2	1.3	0.9	0.4	0.4	0.4	0.5	0.5
2	0.5	0.5	0.6	0.5	0.5	0.5	1.1	1.6	1.2	1.1	1.1	1.0	1.0	0.9	0.9	0.9	1.0	0.9	1.0	0.8	0.4	0.4	0.5	0.5
3	0.5	0.5	0.5	0.5	0.5	0.8	1.3	1.5	1.2	1.0	0.9	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.7	0.4	0.4	0.4	0.4
4	0.5	0.5	0.5	0.5	0.5	0.5	1.0	1.0	0.8	0.9	0.8	0.9	0.9	1.0	1.1	1.2	1.2	1.3	1.4	0.9	0.4	0.4	0.4	0.4
5	0.5	0.5	0.5	0.5	0.5	0.5	1.3	1.6	1.3	1.3	1.1	1.2	1.3	1.2	1.1	1.1	1.0	1.2	1.3	0.9	0.4	0.4	0.5	0.5
6	0.5	0.5	0.5	0.5	0.5	0.5	1.1	1.5	1.3	1.3	1.1	1.1	1.1	1.1	1.0	1.0	1.1	1.1	1.2	0.9	0.4	0.4	0.5	0.5
7	0.5	0.5	0.5	0.5	0.5	0.5	1.2	1.4	1.0	0.9	0.9	0.9	0.8	0.7	0.8	0.9	1.0	0.9	1.0	0.8	0.5	0.4	0.4	0.5

The data presented in Table 2-6 above shows the unit operates according to two schedules:

- Occupied (06:00 to 19:00 from Mon to Sat and 07:00 to 18:00 on Sun)
- Unoccupied (20:00 to 05:00 from Mon to Sat and 19:00 to 06:00 on Sun)

The data from Figures 2-5 and 2-6, for the period between 05/10/2021 and 06/10/2021, is presented in Figure 2-7 below.

Figure 2-7. Metered and EMS datapoints (05/10/2021 and 06/10/2021)



The evaluator processed the data presented in Figure 2-7 above to determine when the RTU was operating in cooling mode. More details on the approach used to determine the operation of the RTU in cooling mode are presented in Section 2.4.2.

Evaluation Methods and Findings

This section describes the evaluator methods and findings.

Evaluation Description of Baseline

The evaluator reviewed the project files and interviewed the site contact to gather information on the baseline. Based on the information provided in the project files and by the site contact, the evaluator determined this measure is a lost opportunity with an ISP baseline. Because the evaluated project was installed in December 2017 when IECC 2012 was in force, the evaluators used the same ISP reference as the applicant and updated the cooling efficiency from 11.3 IEER (used by the applicant) to 11.2 IEER (air-cooled RTU equipped with a gas-fired furnace). Table 2-7 presents the evaluator's baseline key input parameters.

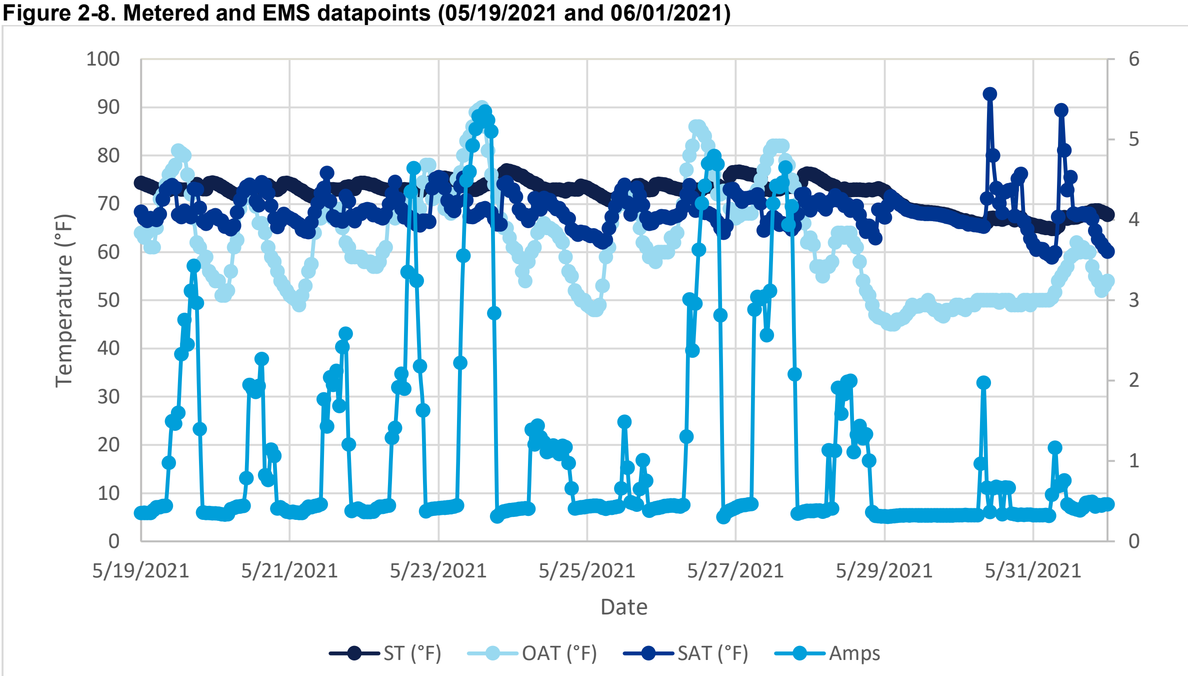
Table 5-7. Evaluator baseline key parameters

Parameter	Value(s)	Source of Parameter Value
RTU capacity	7.5 ton	Nameplate
RTU quantity	1	Site inspection
RTU rated efficiency	11.0 EER/11.2 IEER	IECC 2012 Table C403.2.3(1)
RTU annual equivalent full load hours	813 hours	EMS data (corroborated with metered data)
Cooling space temperature setpoints	Occupied (06:00 to 19:00 from Mon to Sat and 07:00 to 18:00 on Sun): 73°F Unoccupied (20:00 to 05:00 from Mon to Sat and 19:00 to 06:00 on Sun): 80°F	Provided by the energy manager responsible for the site HVAC and corroborated with the metered amps (Table 2-6 above).

Evaluation Calculation Method

The evaluator reviewed the metered data and determined the evaluated RTU's operation is a function of outdoor conditions. The evaluator reviewed the metered data to determine when the RTU enters the cooling mode. Figure 2-8 shows a sample of the metered data.

Figure 2-8. Metered and EMS datapoints (05/19/2021 and 06/01/2021)



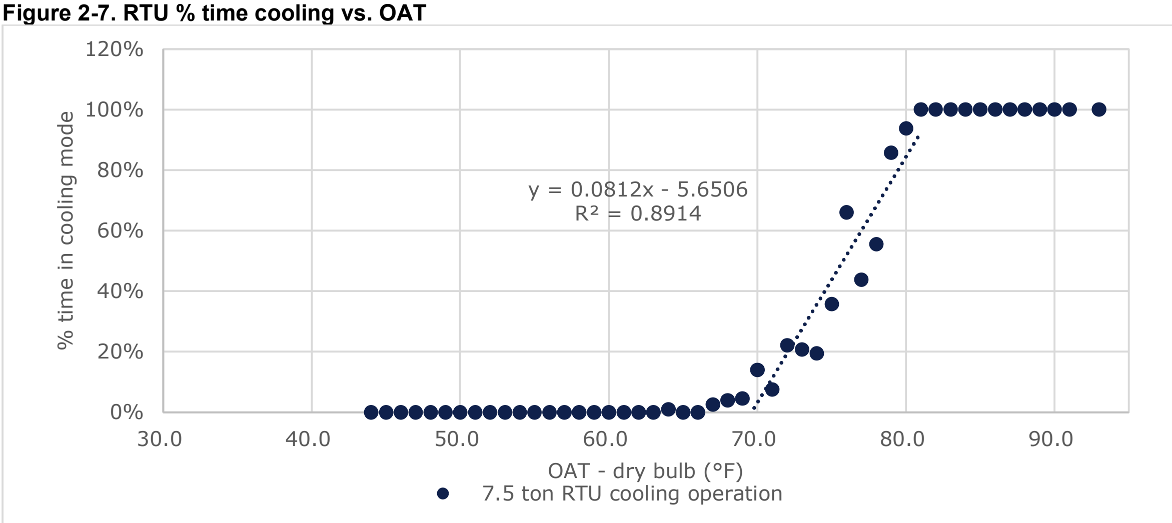
In Figure 2-8 above, the evaluator attempted to isolate periods during which the RTU was cooling and not heating or bringing 100% outdoor air (free-cooling mode). To determine if the RTU operates in cooling mode, the evaluator compared the supply air temperature (SAT), space temperature (ST), and outdoor air dry-bulb temperature (OAT) as follows:

- if OAT-SAT>4°F and SAT<ST, the unit is cooling

For instances during which the two conditions above were met, the evaluator reviewed the current draw values and determined that all metered current draw values were smaller than the unit's rated current draw for operation in cooling mode (approximately 30 Amps). The evaluators determined the metered current draw does not include the operation of the entire unit and used that data only to verify the RTU operating schedule as presented in Table 2-6 above.

Using the temperature values logged by the EMS (recorded every 5 minutes), the evaluator determined if the RTU operated in cooling mode (assigned a value of 1 if the SAT met the two conditions presented in the paragraph above) and then averaged the values over each hour between 05/10/2021 and 06/10/2021. Figure 2-7 shows the % time the RTU was cooling as a function of OAT.

Figure 2-7. RTU % time cooling vs. OAT



The evaluator used the curve presented in Figure 2-7 above and the TMY3 weather data (dry-bulb) recorded in Providence, RI to calculate the % time cooling during each hour of the year. To calculate the % time cooling, the evaluator used the following approach:

- if the OAT is below 70°F, the RTU does not operate in cooling mode (0% time cooling during that hour)
- if the OAT is between 70°F and 80°F, the RTU operates in cooling mode based on the following formula: $\%\,time\ ON = 0.0812 \times TMY3\ OAT\ (dry - bulb)(°\mathrm{F}) - 5.6506$
- if the OAT is greater than 80°F, the RTU operates continuously in cooling mode (100% time cooling during that hour)

To calculate the impacts of the evaluated measure, the applicant used the following formula (similar to the formula used by the applicant):

$$Savings = 12 \times Capacity \times \left(\frac{1}{Eff_{installed}} - \frac{1}{Eff_{baseline}}\right) \times \sum_{i=1}^{8760} \%TimeCooling$$

where,

$Savings$	– first year project savings
12	- constant that converts cooling energy into electric energy
$Capacity$	- installed unit rated capacity (7.5 ton)
$Eff_{installed}$	- installed unit integrated energy efficiency ratio (IEER) (13.8 kW/ton)
$Eff_{baseline}$	- baseline unit integrated energy efficiency ratio (IEER) (11.2 kW/ton)
$\%TimeCooling$	- % time the unit operates in cooling mode for each hour of the year (hourly values add to 813 annual equivalent full-load hours in cooling mode)

The first year savings due to the installation of the evaluated measure is 1,231 kWh.

Final Results

The project consisted of replacing a failed 7.5-ton rooftop (RTU) HVAC unit with an energy efficient 7.5 ton unit at a retail store. The measure saves energy because the installed RTU is more efficient than the baseline. The evaluator calculated the savings using a similar methodology with the one used by the applicant. The evaluated savings are less than the reported values. The parameters impacted the analysis are summarized in Table 3-1.

Table 5-133. Summary of Key Parameters

Parameter	BASELINE Tracking Value(s)	BASELINE Evaluation Value(s)	PROPOSED / INSTALLED Tracking Value(s)	PROPOSED / INSTALLED Evaluation Value(s)
RTU capacity (ton)	7.5	7.5	7.5	7.5
RTU quantity	1	1	1	1
RTU efficiency (IEER)	11.3	11.2	13.8	13.8
RTU cooling operation OAT threshold	above 55°F	above 69°F	above 55°F	above 69°F
RTU annual equivalent full load hours	1,178	813	1,178	813

Explanation of Differences

The evaluated savings are smaller than the reported value primarily because evaluated EFLH is smaller than the applicant value and because the evaluated baseline efficiency is greater than the applicant value. Table 3-2 provides a summary of the difference between the tracking and the evaluated values.

Table 5-134. Summary of Deviations

Measure	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
8020501	Operational	Operating hours	-31%	**Decreased savings** – The evaluated operating hours in cooling mode are less than the values used by the applicant in the savings calculations. This is mainly due to the fact the RTU starts cooling when the OAT is above 69°F, while the applicant predicted the RTU starts cooling when the OAT is above 55°F.
8020501	Baseline	Baseline cooling efficiency	+3%	**Increased savings** – The evaluated baseline was defined using 2012 IECC (11.2 IEER) and was slightly less efficient than the baseline used to calculate the tracking savings (11.3 IEER).
Final RR				**RR% = 72%**

Ancillary impacts

The installed RTU is equipped with one 125 MBtuh furnace with an 82% rated thermal efficiency. The ISP is defined by 2012 IECC which requires furnaces have a thermal efficiency of at least 80%. According to the applicant the RTU operates in heating mode approximately 760 hours per year. The gas impacts associated with the installation of this measure can be calculated using the following formula:

$$Savings\ (therms) = \frac{760\ hours}{1\ year} \times 125\ MBtuh \times \left(\frac{82\%}{80\%} - 1\right) \times \frac{1\ therm}{100\ MBtu} = 23.75\text{ therms}$$

RICE18N040

Report Date: 6/14/21

Application ID(s)	7614310	
Project Type	C&I Initial Purchase & End of Useful Life	
Program Year	2018	
Evaluation Firm	DNV	
Evaluation Type	Full M&V	

Evaluation Engineer	Shravan Iyer	
Senior Engineer	Chad Telarico	

Evaluated Site Summary and Results

This site is a 25,592 ft^2 grocery store, and the projects installed at the site includes the following refrigeration measures:

- **Evaporator fan motor replacement**- The measure involves replacing shaded pole motors with ECM motors on the evaporator fans on (134) refrigerated display cases and (73) walk-in coolers and freezers.
- **Door Heater Controls-** The measure involves installing anti-sweat (ASH) door heater controls on (97) refrigerated freezer and cooler doors.

This site was categorized as an essential service and was allowed to operate as usual during the COVID-19 pandemic in 2020. There were no significant changes that were made to the operation of the store during this period that would alter its energy use in a way that would make the pre and post pandemic operations inconsistent. Additionally, since the site is a grocery store the refrigeration loads at the site remain fairly constant throughout the year and there is no seasonality observed in the operation of the refrigerated cases and walk-in coolers and freezers. Therefore, the evauluators evaluated the measures installed at this site using a full M&V approach.

The measures save energy in the following manner:

- **Evaporator fan motor replacement**- Electronically commutated (ECM) motors are more efficient than shaded pole motors in their operation and have lower wattage, thereby drawing lower power during the course of their operation.
- **Door Heater Controls-** The ASH controllers work by comparing the glass door temperature to the store dew-point temperature. By definition, as the store dew-point temperature increases, there is more moisture in the store. By maintaining the glass door temperature just above the dew-point temperature, condensation is prevented from forming on the glass. There is more moisture in the air outdoors in warmer weather, which correlates to higher moisture levels indoors. The ASH controllers, therefore, run the ASHs more often in the warmer weather than the cooler weather

The evaluation results are presented in Table 1-1.

Table 5-135. 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)
7614310	Refrigeration Measures	Tracked	204,654	46%	23.36	23.36
		Evaluated - ops	108,394	48%	12.55	12.37
		Realization Rate	53%	104%	54%	53%
Totals		**Tracked**	**204,654**	**46%**	**23.36**	**23.36**
		Evaluated - ops	**108,394**	**48%**	**12.55**	**12.37**
		Realization Rate	**53%**	**104%**	**54%**	**53%**

Explanation of Deviations from Tracking

The evaluated savings are lower than the applicant-reported savings because of the non-operational EC motors observed onsite and some of the freezer doors that had the ASH controls running at maximum capacity in the post case. Further details regarding deviations from the tracked savings are presented in Section 3-4.

Recommendations for Program Designers & Implementers

There are no recommendations currently.

Customer Alert

There were no customer alerts.

Evaluated Measures

The measures installed at this site include:

Evaporator fan motor replacement- The measure involves replacing shaded pole motors with ECM motors on the evaporator fans of refrigerated display cases and walk-in coolers and freezers.

Door Heater Controls- The measure involves installing anti-sweat (ASH) door heater controls on the freezer and cooler doors.

Application Information and Applicant Savings Methodology

The site installed anti-sweat heat controls on the refrigerated cooler and freezer cases to prevent the glass doors from fogging up during days with high humidity, i.e., when the indoor relative humidity was higher than usual. The site also installed ECM motors on their display cases and walk-ins to reduce the energy consumption of the cases. The following table lists the breakdown of the applicant savings:

Table 5-136. Applicant Savings breakdown

Measure Component	Applicant Electric Savings (kWh)
Evaporator fan motor replacement	129,032
Door heater controls	75,622
Total	**204,654**

Applicant Description of Baseline

The applicant classified the ASH measure as a retrofit measure. The pre-existing condition was assumed to be the baseline, which consisted of no ASH controllers and the door heaters running 8,760 hours annually. The ECM motor measure was also classified as a retrofit because the pre-existing condition consisted of shaded pole motors that were operational.

Table 5-2. Applicant baseline key parameters

		BASELINE		
Measure	**Parameter**	**Value(s)**	**Source of Parameter Value**	**Note**
Refrigeration Measures	Pre-existing motors	Shaded Pole	Applicant documentation	
Refrigeration Measures	Pre-Exisiting Door heater controls	No ASH Controls	Applicant documentation	

Applicant Description of Installed Equipment and Operation

The applicant baseline for the two refrigeration measures installed at the site is described below:

Evaporator fan motor replacement- The applicant installed ECM motors on the refrigerated cases and walk-in coolers and freezers at the store to reduce energy use and increase the efficiency of operation of the evaporator fan motors. The motors installed as part of the project are listed below in Table 2-1-1 and Table 2-1-2:

Display Cases:

Table 2-1-1. Description of Installed motors on Display Cases

Index #	Reach-in location	Installed Motor Type	Installed Motor Count
1	34 Door Freezer	ECM	38
2	Next to Door 24	ECM	2
3	4 Section	ECM	14
4	5 Section Meat	ECM	17

5	Bacon and Pickles	ECM	8
6	Sushi	ECM	2
7	Free standing cooler	ECM	5
8	Free standing freezer	ECM	6
9	4 Section Produce cooler	ECM	20
10	Cakes	ECM	5
11	4 Section	ECM	17
Total			**134**

Walk-ins:

Table 2-1-2. Description of Installed motors on Walk-ins

Index #	Reach-in location	Installed Motor Type	Installed Motor Count
1	Cooler and Freezers	ECM	50
2	Kitchen Prep	ECM	23
Total			73

Door Heater Controls- The applicant installed anti-sweat controls on refrigerated cases in the store. The list of doors installed with anti-sweat controls is listed in the table below in Table 2-1-3:

Table 2-1-3. Description of Refrigerated Cases with ASH controls

Index #	Door Type	Reach-in location	Proposed #of doors installed with ASH	Proposed Lin Ft.
1	MT	Dairy Cooler	24	60
2	MT	5 Door Cooler	9	24
3	LT	23 Door Reach in	24	60
4	LT	Ice Freezer	15	37.5
5	LT	Food Freezer	2	5
6	LT	2 3 door Freezer	6	15
7	MT	24 FS4	2	6
8	LT	3-5 Door Freezer	15	37.5
			97	245

Table 5-1-4: Application proposed key parameters

			PROPOSED	
Measure	**Parameter**	**Value(s)**	**Source of Parameter Value**	**Note**
Refrigeration Measures	Post case motors	ECM Motors	Applicant documentation	
Refrigeration Measures	Post Case door heater controls	ASH controllers installed	Applicant documentation	

Applicant Energy Savings Algorithm

The evaluation team received an eQUEST Refrigeration model, supplemental files (informational spreadsheets) explaining the model output represented, and re-creating individual measure savings. The following describes the individual files received and how they were used to replicate the applicant savings.

- eQUEST Refrigeration model claimed to have been created using eQUEST 3.61 Refrigeration version. The model represents the baseline conditions
- Five (5).SIM files. These are simulation summary files that contain the annual energy usage of each simulation. Each SIM file represents a different run/measure. The five SIM files represent:
    - Baseline
    - ASH controls for low-temperature (LT) cases/doors
    - ASH controls for medium-temperature (MT) cases/doors
    - EC motors for cases
    - EC motors for walk-ins

  - "Efficient case." All measures combined, i.e., includes interactive effects
- Four (4) .csv files were containing DOE2 keyword and keyword values. The .csv's represent changes that, when applied to the baseline model, can be used to re-create individual measure-level models and their energy usage. When baseline model energy usage is compared to the individual measure model usage, individual measure savings is calculated. The four files represent:
  - ASH controls for low-temperature (LT) cases/doors
  - ASH controls for medium-temperature (MT) cases/doors
  - EC motors for cases
  - EC motors for walk-ins
- "Summary and instructions" spreadsheet that explains how the model's baseline energy usage was compared to the different runs (individual measure runs and the "efficient cause," i.e., all measures combined run). The spreadsheet contains energy usage outputs from the.SIM files and breaks down how the applicant calculated individual measure energy savings from the model outputs and the actual installed quantities of ASH controls and EC motors (because the actual quantity installed differed from the modeled quantity).

Discrepancies and Notes:
The evaluation team used the received files and documentation to attempt to re-create the applicant savings. It was generally successful, but there are some discrepancies and notes to consider:

- The individual measure model runs were re-created. The "efficient case" (all measures combined) model run was not re-created due to time constraints. The measure's DOE2 keywords needed to be manually inputted into the baseline model text file. For re-creation and M&V planning purposes, only individual measure runs were compared to the applicant's runs. This means that interactive effects were not re-created or compared. The applicant claimed interactive effects to have less than 1% change from individual measure savings to combined savings.
- The model runs were simulated using two versions of eQUEST Refrigeration – v. 3.61b (the same version as what was reported by the applicant) and v. 3.65.7175 (the most recent version). Both produced discrepancies when compared to the applicant runs.
  - The v.3.65 runs had negligible discrepancies (<1% difference) for all but one run – the ECM walk-ins run. There was a 42% difference between the applicant's savings estimate and the re-created savings estimate. The total (sum of the savings for all four-measure runs) discrepancy was 6%.
  - The v.3.61 runs had large discrepancies (~43%) for all but one measure run. The total discrepancy was 19%.
- The evaluation team accepts the results of re-creating the applicant savings using the received files.

The following sub-sections describe the specific DOE2 (eQUEST model) keyword adjustments made to the baseline model to simulate the measure's effect on equipment and building energy usage.

Evaporator fan motor replacements

The evaporator fan motor replacement measure was broken into two separate simulations – one simulation-modified DOE2R keyword for refrigerated cases and one simulation-modified DOE2R keyword for refrigerated walk-ins. Each simulation modified values of the baseline model keywords that represent the refrigerated fixture fan power. The following tables describe the DOE2R keywords and keyword value adjustments that estimate measure savings. The explanation for the DOE2R keywords is provided below the tables in this section.

Refrigerated cases:

Component Name (all REFG-FIXTURE)	DOE2R Keyword on "REFG-FIXTURE"	Baseline Value (kW)	Proposed value (kW)	LINE-UP-LENGTH (Lin.Ft)	NUMBER-OF-DOORS
C2074134607A6	FAN-KW/LEN	0.025	0.001008	48	N/A

C2474134607A6	FAN-KW/LEN	0.03	0.002879	4	N/A
C2574134607A6	FAN-KW/DOOR	0.06	0.01822514	N/A	5
C2974134607A6	FAN-KW/LEN	0.03	0.00359849	16	N/A
C2A74134607A6	FAN-KW/DOOR	0.06	0.01822514	N/A	6
C2B74134607A6	FAN-KW/DOOR	0.06	0.01439395	N/A	24
C2C74134607A6	FAN-KW/DOOR	0.06	0.01822514	N/A	24
C2D74134607A6	FAN-KW/LEN	0.02	0.00195712	6	N/A
C2E74134607A6	FAN-KW/LEN	0.02	0.0018298	6	N/A
C2F74134607A6	FAN-KW/LEN	0.015	0.0018298	8	N/A
C3074134607A6	FAN-KW/LEN	0.0136	0.0018298	44	N/A
C3174134607A6	FAN-KW/LEN	0.0245	0.00359849	44	N/A
C3274134607A6	FAN-KW/LEN	0.025	0.00359849	12	N/A
C3374134607A6	FAN-KW/LEN	0.027	0.00359849	40	N/A
C3474134607A6	FAN-KW/LEN	0.027	0.00126667	40	N/A
C3574134607A6	FAN-KW/LEN	0.03	0.00359849	6	N/A
C3674134607A6	FAN-KW/DOOR	0.06	0.01822514	N/A	2
C3774134607A6	FAN-KW/DOOR	0.06	0.01822514	N/A	15
C3874134607A6	FAN-KW/LEN	0.03	0.00359849	6	N/A
C3974134607A6	FAN-KW/LEN	0.03	0.00359849	4	N/A
C3A74134607A6	FAN-KW/DOOR	0.06	0.01822514	N/A	15

Refrigerated walk-ins:

Component Name (all REFG-FIXTURE)	“SUPPLY-KW/FLOW” Baseline Value	“SUPPLY-KW/FLOW” Proposed value	SUPPLY-FLOW (CFM)
W-6274134607A6_SYSTEM	0.000367	0.000091	733.239
W-6374134607A6_SYSTEM	0.000367	0.000091	521.209
W-6474134607A6_SYSTEM	0.000367	0.000091	662.4
W-6574134607A6_SYSTEM	0.000367	0.000091	768.636
W-6674134607A6_SYSTEM	0.000367	0.000091	792.459
W-6774134607A6_SYSTEM	0.000367	0.000091	402.414
W-6874134607A6_SYSTEM	0.000367	0.000091	1216.3
W-6974134607A6_SYSTEM	0.000367	0.000091	2100.49
W-6A74134607A6_SYSTEM	0.000367	0.000091	895.266

W-6B74134607A6_SYSTEM	0.000367	0.000091	672.824
W-6C74134607A6_SYSTEM	0.000367	0.000091	399.189
W-6D74134607A6_SYSTEM	0.000367	0.000091	535.595
W-6E74134607A6_SYSTEM	0.000367	0.000091	604.454
W-6F74134607A6_SYSTEM	0.000367	0.000091	1466.88
W-7074134607A6_SYSTEM	0.000367	0.000091	702.176
W-7174134607A6_SYSTEM	0.000367	0.000091	839.295
W-7274134607A6_SYSTEM	0.000367	0.000091	2056.05
W-7374134607A6_SYSTEM	0.000367	0.000091	687.277
W-7474134607A6_SYSTEM	0.000367	0.000091	334.642

Door heater controls:

The door heater controls measure was broken into two separate simulations – one simulation modified DOE2R keywords for LT fixtures, and one simulation modified DOE2R keywords for MT fixtures. Each simulation modified values of the baseline model keywords that represent the refrigerated fixtures' heater controls and humidity set points. The following tables describe the DOE2R keywords and keyword value adjustments that estimate measure savings:

ASH controls for low-temperature cases:

Component Name (all REFG-FIXTURE)	Baseline Value for "MIN-HUMIDITY"	Proposed value for "MIN-HUMIDITY"	Baseline Value for "MAX-HUMIDITY"	Proposed value for "MAX-HUMIDITY"	Baseline Value for "HEATER-CTRL"	Proposed value for " HEATER-CTRL "
C2A74134607A6	N/A	34	N/A	73	FIXED	RELATIVE-HUMIDITY
C2C74134607A6	N/A	34	N/A	73	FIXED	RELATIVE-HUMIDITY
C3674134607A6	N/A	34	N/A	73	FIXED	RELATIVE-HUMIDITY
C3774134607A6	N/A	34	N/A	73	FIXED	RELATIVE-HUMIDITY
C3A74134607A6	N/A	34	N/A	73	FIXED	RELATIVE-HUMIDITY

ASH controls for medium-temperature fixtures:

Component Name (all REFG-FIXTURE)	Baseline Value for "MIN-HUMIDITY"	Proposed value for "MIN-HUMIDITY"	Baseline Value for "MAX-HUMIDITY"	Proposed value for "MAX-HUMIDITY"	Baseline Value for "HEATER-CTRL"	Proposed value for " HEATER-CTRL "

C2B74134607A6	N/A	34	N/A	73	FIXED	RELATIVE-HUMIDITY

Explanation of DOE2R keywords:

- FAN-KW/LEN: Defines that fan power (kW) per unit length of refrigeration fixture. FAN-KW/LEN is multiplied by LINE-UP-LENGTH to calculate the total fan kW for the fixture.
- FAN-KW/DOOR: Defines that fan power (kW) per door of a refrigeration fixture. FAN-KW/DOOR is multiplied by NUMBER-OF-DOORS to calculate the total fan kW for the fixture.
- SUPPLY-KW/FLOW: Defines the fan power (kW) per cfm of fan flow. SUPPLY-KW/FLOW is multiplied by SUPPLY-FLOW to calculate the total fan kW for the fixture.
- SUPPLY-FLOW: Defines the design flow rate (cfm) of the walk-in evaporator fixture.
- LINE-UP-LENGTH: Defines the length (in feet) of the line-up for refrigerated cases.
- NUMBER-OF-DOORS: Defines the number of doors of the line-up for refrigerated cases.
- HEATER-CTRL: Defines the type of anti-condensate control for refrigeration fixtures. A value of "FIXED" means that the heater is always on. A value of "RELATIVE-HUMIDITY" means that the heater is controlled based on the relative humidity of the adjacent space, i.e., outside the fixture door.
- MIN-HUMIDITY: Specifies the adjacent zone relative humidity at which the heater is off.
- MAX-HUMIDITY: Specifies the adjacent zone at which the heater is turned on at full output.

The applicant provided hard-entered simulation outputs, outputs for the baseline case, efficient case (all measures combined), LT ASH controls, MT ASH controls, ECM cases, and ECM walk-ins. Measure interactivity is found by finding the savings from all measures modeled simultaneously (the efficient case) and dividing this by the sum of the individually modeled savings. This factor is then applied to the individually modeled savings to find the interactive savings of each individual measure.

For the ECMs, the actual number of installed motors was different from the recommended and modeled motors. The modeled savings were adjusted to represent the actual number of installed motors.

The savings values for both ECM motor replacement and the ASH controls are summarized in the table below:

Table 2-1-4 Applicant Savings Estimate

Simulation Run	DOE-2R modeled kWh	Modeled Savings (kWh)	Measure interactivity ("All measures" savings/sum of individual ECM savings	Interactive Savings (Individual ECM savings x measure interactivity %)	Tracking savings
Baseline	1,759,698	-	99.1%		
All Measures	1,503,926	255,772			
LT ACH controls	1,691,210	68,488		67,882	67,882

MT ASH controls	1,751,891	7,807		7,738	7,738
Case ECMs	1,616,622	143,076		141,811	93,150[36]
Walk-in ECMs	1,721,015	38,683		38,683	35,883[37]
Total savings (kWh)					**204,654**

The total project kWh savings is 204,654 kWh and was found to match the tracking value.

Evaluation Assessment of Applicant Methodology

The evaluators agree with the applicant's savings calculation methodology, wherein the applicant used eQUEST to model the savings for the ECM motors and the ASH controls. The evaluation finds this method reasonable.

Site Inspection

A site visit was performed on 2/17/2021 to verify the new ECM motors and the anti-sweat controls installed on the refrigerated cases, walk-in coolers and freezers, and install metering equipment to capture trend data (voltage, amperage and power factor) on the ASH controls and the evaporator fans. The initial discussions with the site contact over the phone prior to the site visit revealed that the ECM motors that were initially installed at the site had caused problems, and they all had to be removed, and new ECM motors had to be installed. During the site visit, the evaluators first confirmed the counts of the refrigerated doors and cases throughout the store.

The evaluators also verified the evaporator fans below the refrigerated cases at the store. The fans were found to be operational, but the evaluators also observed several evaporator fans were sometimes frozen along with the refrigerant lines that ran across the fans beneath the cases. The following figure shows one such fan that was observed onsite to be frozen and not working at the time of the site visit:

Fig.1- Sample evaporator fan found frozen onsite

The evaluators verified a sample of 30 evaporator fans (on 5 door refrigerated cases) throughout the store, and it was found that 5 fan motors on display cases out of the 30 fans sampled were frozen and were not working at all the time of the site visit. The evaluators then installed HOBO Amp loggers on two anti-sweat controllers (2002825 and 2003876) and one ElitePRO kW logger (XC1307123) that metered a set of five evaporator fans. The evaluators tested another

[36] Only 134 of the 204 modelled case ECMs were actually installed. Therefore, 141,811 x (134/204) = 93,150

[37] Only 73 of the 78 modelled walk-in ECMs were actually installed. Therefore, 38,683 x (73/78) = 35,883

refrigerated case with five fans and conducted spot measurements to verify the amperage of each evaporator fan. On metering, a set of five fans, the amperage logged was 0.85 Amps, and after shutting off one fan, the remaining four were measured, and the amperage logged was 0.68. Thus, the amperage of one fan motor was estimated to be 0.17 Amps. The evaluators also installed temperature sensors to meter indoor air temperature and relative humidity. The following table shows a summary of the metering equipment installed at the site:

Table 2.2.1- Table showing meters installed at the site

Index #	Logger ID	Logger Type	Parameter Measured	Metering Interval
1	2002825	Current Logger	Amps	8 Weeks
2	2003876	Current Logger	Amps	8 Weeks
3	XC1307123	Power Logger	Power	8 Weeks
4	10387502	HOBO T/RH Logger	T/RH- Indoor	8 Weeks
5	10387504	HOBO T/RH Logger	T/RH- Indoor	8 Weeks
6	2406218	HOBO T/RH Logger	T/RH- OAT	8 Weeks
7	2002767	HOBO T/RH Logger	T/RH- OAT	8 Weeks

Summary of Onsite Findings

The evaluators made the following observations on site:

- It was found that five of the thirty evaporator fan motors sampled were frozen and were not working during the site visit.
- The ASH were found to be installed and operational.

Table 5-137. Measure Verification

Measure Name	Verification Method	Verification Result
Refrigeration Measures	Verify the operation of the evaporator fans by visual inspection	Five out of 30 fans inspected were found to be non-operational
Refrigeration Measures	Verify the installation of the ASH controller	Verified

Evaluation Methods and Findings

This section describes the evaluator methods and findings.

Evaluation Description of Baseline

The evaluator reviewed the project files and interviewed the site contact to gather information on the baseline for measure ASH and ECM measures. The evaluators agree with the applicant that the measures are categorized as retrofit measures, and the pre-existing condition is the baseline.

Evaluation Calculation Method

The evaluators used the approach outlined in the M&V plan earlier to estimate the savings for both measures installed at the site, which is estimating the savings using a spreadsheet-based analysis instead of an eQUEST model as was used in the applicant documentation. The primary reason for doing so is, in this case the evaluators were unable to calibrate the model using the metered data that we obtained onsite, because the data was not reflective of actual site operations, but this data could be better used with the spreadsheet approach that was used for evaluating the measures at this site, which would make it simpler to apply the site level findings.

Evaporator fan motor replacements

The evaluators used metered data obtained from the ElitePRO kW logger to determine the post-case watts consumed by the ECM motors, which was estimated to be 11.6 watts per motor. The following table shows a sample of the metered data from the logger:

Table 2-4. Sample Data from ElitePRO kW Logger

Date	End Time	Power 1 Avg. Volt L1 Phase	Power 1 Avg. Amp L1 Phase	Power 1 Avg. kW L1 Phase	Power 1 Avg. kVA L1 Phase	Power 1 Avg. PF L1 Phase
2/17/2021	13:50:00	110.181	0.85	0.058	0.093	1
2/17/2021	13:55:00	110.89	0.84	0.058	0.093	1
2/17/2021	14:00:00	110.273	0.84	0.058	0.092	1
2/17/2021	14:05:00	111.035	0.84	0.058	0.094	1
2/17/2021	14:10:00	110.104	0.84	0.057	0.092	1
2/17/2021	14:15:00	111.207	0.84	0.058	0.093	1
2/17/2021	14:20:00	110.152	0.85	0.058	0.093	1
2/17/2021	14:25:00	111.644	0.84	0.058	0.093	1
2/17/2021	14:30:00	109.989	0.84	0.057	0.092	1
2/17/2021	14:35:00	111.162	0.84	0.058	0.093	1
2/17/2021	14:40:00	110.372	0.83	0.057	0.092	1
2/17/2021	14:45:00	111.084	0.83	0.057	0.092	1
2/17/2021	14:50:00	110.458	0.84	0.058	0.092	1

The post case watts of the ECM motors were determined as shown below:

Average kW from metered data (For five fans) = 0.0581 kW

kW/fan motor= 0.0581 kW/5

kW/fan motor= 0.0116

Therefore, watts/fan= 11.6 watts

To estimate the base case watts consumed, i.e., the watts consumed by the shaded pole motors that existed previously, the evaluators used data obtained from a similar study conducted by researchers at the University of Missouri and the Oak Ridge National Laboratory, wherein metered data was used to compare the efficiencies of various evaporator fan motors such as ECMs, PMS and shaded pole motors in identical refrigerated display cases at a grocery store[38]. Using the study results mentioned above, the evaluators were able to model the pre-case watts of the shaded pole motors to

[38]Becker, Bryan. R, Fricke, Brian. A, *High Efficiency Evaporator Fan Motors for Commercial Refrigeration Applications*, 16th International Refrigeration and Air Conditioning Conference at Purdue, July 2016.

be 29 watts. In the post case, the evaluators observed that in the refrigerated cases, five motors out of the thirty evaporator fan motors that the evaluators inspected were found to be frozen and did not work at the time of the site visit. The evaluators are not aware of the kind of preventive maintenance activity that goes on at the site and is unsure when these fans would be fixed. It was determined that the motors operated for 8,760 hours in both the pre and post-case. Interactive effects were accounted for in the pre and post-case using equations from the Rhode Island TRM[39]. Therefore, the evaluators estimated the savings for this measure using the following methodology described below:

Hours of Operation= 8,760 Hours
Number of Motors in the pre-case (refrigerated cases + Walk-ins)[40]= 207
Number of Motors Operational (Pre-Case) = 185
Number of Motors Operational (Post Case)[41] = 185
Base Case Watts (Shaded Pole motor)[42] = 29 watts/motor
Post Case Watts/Motor= 11.6 watts/motor

Interactive Effects (Per Motor- Base Case) = (1 + (Refrig Eff x (3413 Btu/hr/kW)/ (12000 Btu/hr/kW))
Interactive Effects (Per Motor- Base Case) = (1 + (1.6 kW/Ton x (3413 Btu/hr./kW/12,000 Btu/hr./kW))

Total Base Case kW= Base Case Watts/1000 x Interactive Effects x Number of Motors Operational (Pre-Case)

Total Base Case kW= 7.806 kW

Total Post Case kW= Post Case Watts/1000 x Interactive Effects x Number of Motors Operational (Pre-Case)
Total Post Case kW= 3.122 kW

Total Base Case kWh= Total Base Case kW x 8,760 Hrs/year
Total Base Case kWh= 7.806 kW x 8,760 Hrs/year
Total Base Case kWh= 68,384 kWh

Total Post Case kWh= Total Post Case kW x 8,760 Hrs/year
Total Post Case kWh= 3.122 kW x 8,760 Hrs/year
Total Post Case kWh= 27,354 kWh

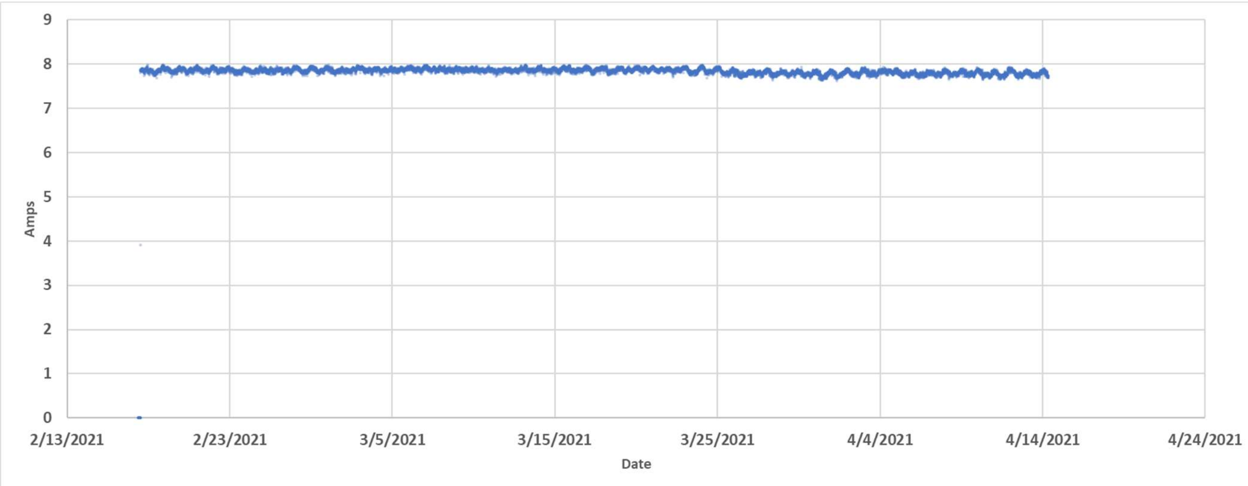
Savings (kWh)= Total Base Case kWh - Total Post Case kWh
Savings (kWh)= 68,384 kWh - 27,354 kWh
Savings (kWh)= 41,031 kWh

Door heater controls

The evaluators examined the metered data and observed that one of the loggers installed on the ASH controller (metering three five-door freezers) had failed to record any data due to some malfunction. The other current logger installed showed that the controller was operational throughout the metering period, as shown in the figure below:

Fig.1- Raw Amp data showing the operation of ASH controller

[39]Interactive Effects= (1 + Refrig Eff x (Btu/hr./kW)/(Btu/hr./ton). Where, Refrigeration Efficiency= 1.6 kW/Ton, 3413 Btu/hr./kW, 12,000 btu/hr./kW (Conversion factors).
[40] 134 motors in display cases, 73 in walk-ins
[41]From site visit. 5 motors out of 30 display case were found to be frozen and not working. Extrapolating that to 134 motors, we get 112 motors. We are assuming all 73 motors in Walk-ins were operational
[42] See footnote 3



As we can observe from the above data, the anti-sweat heat controls installed on three five-door freezers appear to be operating at a constant load throughout the metering period. Though this data might reflect the operation of the controller on the given set of doors, the evaluators do not believe this data to be reflective of the typical operation of the ASH controls at the store.

Because the evaluators could install only two meters at the site, and one did not provide any meaningful data and the other did not seem representative of the measure on all doors, the evaluators used the results of a similar project in Connecticut last year to calculate the savings for this measure. The methodology described below to calculate the savings in the absence of good metered data.

The evaluators used the following steps to calculate the energy savings for this measure. The primary variables used in the savings estimate are the number of doors controlled[43], voltage, amps, power factor, and operating hours. Spot measurements recorded the voltage and amps. The pre case hours was assumed to be 8,760 hours, and the post case hours was estimated based on the results of a similar project installed in Connecticut, wherein the “percent ON” time of the doors was estimated based on the results of a study involving multiple grocery stores in multiple cities in Connecticut. The power factor is unity because the anti-sweat heater is a purely resistive load. In addition to these measured variables, the evaluators referred to secondary sources to quantify the interactive savings associated with reduced heat load on the refrigeration system caused by fewer operating hours. The evaluator referred to the CT PSD for the ACOP values for the freezer and cooler cases and an SDGE workpaper for the 35% factor representing the heat from the door heaters that end up as cooling load within the cases. For peak kW savings, the evaluator used the COP values from the CT PSD rather than the ACOP values, where the “A” stands for average. Therefore:

Freezer kWh Savings = 47 freezer doors x
120 volts x
1.57[44] amps per door x
1.0 power factor x
(8760 baseline hours – 5,502 proposed hours) x
1 kW / 1,000 Watts x
(1 + 35% of load from heater that ends up as load on case[45] / 2.03 ACOP[46])

= 33,741 kWh

Cooler kWh Savings = 35 cooler doors x

[43] 97 refrigerated doors; 35 cooler doors and 62 freezer doors

[44] Spot measurement of the case. 7.83 Amps/5 = 1.57 Amps

[45] From SDG&E workpaper https://www.sdge.com/sites/default/files/WPSDGENRRN0009%2520Rev%25200%2520Anti-Sweat%2520Heat%2520%2528ASH%2529%2520Controls%2520_0.doc

[46] From CT PSD

120 volts x
1.57 amps per door x
1.0 power factor x
(8,760 baseline hours – 4,237 proposed hours) x
(1 + 35% of the load from a heater that ends up as load on case[45]/ 2.69 ACOP[46])

=33,623 kWh

The metered data shown in Fig.1 shows those cases where the controller runs throughout in the post case. Those doors have zero savings, i.e., the 15 doors that were metered.

Total Savings = 33,741 + 33,623 = 67,364 kWh

Therefore, total project savings= Evaporator fan motor savings + ASH controller savings

Therefore, total project savings= 41,031 kWh + 67,364 kWh

Total Savings= 108,394 kWh

Final Results

The following table summarizes the key parameters that were used in the estimation of savings and compares them with the tracking and post case:

Table 5-138. Summary of Key Parameters

	BASELINE		PROPOSED / INSTALLED	
Parameter	**Tracking Value(s)**	**Evaluation Value(s)**	**Tracking Value(s)**	**Evaluation Value(s)**
Number of motors (found to be operational)	207	185	207	185
Doors with Operational ASH	97	82	97	82
Motor Watts (Pre-Case)	60	60	29	29
Motor Watts (Post Case)	18.22	18.22	11.2	11.2

Explanation of Differences

The evaluation found the total project savings to be 108,394 kWh which is lower than the tracking savings. The primary reasons are the non-operational motors that were observed onsite and the freezer doors that had the ASH controls running at maximum capacity in the post case. Additionally, the difference in the pre and post-motor watts between the tracking and evaluation estimates resulted in a significant change. The other major reason is the change in the savings calculation methodology wherein the applicant savings was calculated using an eQUEST model, whereas the evaluators used a spreadsheet-based savings calculation approach. Table 3-2 provides a summary of the differences between tracking and evaluated values.

Table 5-139. Summary of Deviations

Measure	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
7614310	Quantity	Non-operational Fans	-34%	**Decreased savings – 69,207**
7614310	Technology	The difference in motor Wattage improvement between tracking and evaluation	-9%	Decreased savings – 18,795
7614310	Operation	ASH operation in post case	-4%	Decreased savings – 8,258 kWh
Final RR				**53%**

Ancillary impacts

There are no ancillary impacts.

RICE18N048

Report Date: 05/17/2021

Application ID(s)	6686101	
Project Type	Retrofit	
Program Year	2018	
Evaluation Firm	DNV	
Evaluation Engineer	George Sorin IOAN	
Senior Engineer	Long Vu	

Evaluated Site Summary and Results

The project was installed at an industrial facility and included the repair of 121 air leaks in the compressed air distribution system. The measure saves energy because it reduces the load on the main air compressors by 85 cfm. The impacted compressed air plant consists of two load/unload 350-hp air compressors that operate in a primary-backup configuration (only one 350-hp air compressor operates at any given time) and three load/unload 150-hp air compressors that provide supplemental compressed air when load is greater than the capacity of the 350-hp air compressor. The facility and the compressed air system operate for 8,400 hours per year.

The applicant classified the measure as a retrofit with pre-existing conditions as the single baseline.

The operation of the facility and of the compressed air plant was not impacted by the current pandemic and the evaluators conducted metering and verification to evaluate the measure. The results of the evaluation include updates on both non-operational and operational parameters associated with the evaluated measure.

Based on the on-site findings and the review of the project documentation, the evaluator classified the project as a retrofit with the pre-existing conditions as the single baseline. The evaluator calculated the project savings using the same methodology as the applicant's with updated input parameters. The evaluated savings were smaller than the reported tracking value primarily because tracking savings included an administrative error and because the impacted air compressors were more efficient than the applicant predicted. The evaluation results are presented in Table 1-1.

Table 5-140. 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)
6686101	Repair compressed air leaks	Tracked	156,660	48%	13.99	13.99
		Evaluated	139,962	48%	15.97	15.97
		Realization rate	**89.3%**	**100%**	**114%**	**114%**

Explanation of Deviations from Tracking

The evaluated savings are less than the reported savings primarily because the tracking savings included an administrative error and because the impacted air compressors are more efficient than the applicant predicted. Further details regarding deviations from the tracked savings are presented in Section 3-1.

Recommendations for Program Designers & Implementers

There are no recommendations currently.

Customer Alert

There were no customer alerts.

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 was installed at a manufacturing facility and consisted of repairing 121 compressed air leaks in the compressed air distribution system that serves the facility. The measure reduced the compressed air load by 85 cfm.

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.

Applicant Description of Baseline

According the project files, the applicant classified the project as a retrofit with the pre-existing conditions as the single baseline. The pre-existing conditions were the compressed air plant equipped with two 350-hp air compressors that operate in a primary-backup configuration (only one 350-hp air compressor operates at any given time) and three 150-hp air compressors that provide supplemental compressed air when load is greater than the capacity of the 350-hp air compressor. The facility and the compressed air system operate for 8,400 hours per year. The compressed air distribution system had 121 air leaks. Table 5-129 presents the applicant's baseline key input parameters.

Table 5-141. Applicant baseline key parameters

Parameter	Value(s)	Source of Parameter Value
Compressed air plant efficiency	4.99 cfm/kW	Applicant savings calculations
Compressed air leaks to be repaired	121	Post-installation inspection
Leak load (associated with 121 fixed leaks)	121.75 cfm	Provided by National Grid's technical representative
Compressed air plant operating hours	8,400 hours/year	Applicant savings calculations

Applicant Description of Installed Equipment and Operation

According to the invoice issued by the compressed air contractor, 121 air leaks have been repaired at the facility. The applicant's installed case assumed that all repaired air leaks resulted in a reduction of compressed air load from 121.75 cfm to 36.75 cfm (70% leak load reduction) for a total of 85 cfm. The compressed air plant efficiency, operating pressure, hours of operations, used for the installed case matched the values of the baseline. Table 5-130 presents the applicant's proposed key input parameters.

Table 5-142: Applicant proposed key parameters

Parameter	Value(s)	Source of Parameter Value
Compressed air plant efficiency	4.99 cfm/kW	Applicant savings calculations
Compressed air leaks repaired	121	Contractor invoice
Leak load (associated with 121 fixed leaks)	36.75 cfm	Provided by National Grid's technical representative (assumes 30% of the load will still be present after the leaks are fixed)
Compressed air plant operating hours	8,400 hours/year	Applicant savings calculations

Applicant Energy Savings Algorithm

A compressed air vendor conducted an audit of the compressed air system and determined the following:

- the compressed air plant operates continuously to support the process at the facility

- the compressed air plant is equipped with five units: two 350 hp and three 150 hp air compressors

- one of the two 350 hp air compressors operates at any given time to serve the baseload (these two units are manually switched)

- the 150 hp compressors turns on to supply the peak load required by the process

- the average compressed air flow supplied by the plant was 2,392 cfm and the system had 282 leaks.

The vendor estimated a load associated with each of the 282 leaks for a total of 287 cfm (12% of the total compressed air load). The savings associated with the incentivized are calculated based on the leak load estimates provided in the study report that summarized the audit. The project savings were calculated using the following formula:

$$savings = \frac{(air_b - air_p)}{eff} \times hours$$

where:

$savings$	= applicant savings, 142,665 kWh
eff	= efficiency of the compressed air system, 4.99 cfm/kW
air_{base}	= baseline leak load, 121.75 cfm
air_p	= proposed leak load, 36.75 cfm
$hours$	= operating hours of the compressed air system, 8,400 hours

According to the National Grid's representative, the project savings were initially overestimated by 10% (156,660 kWh/year) and entered in the tracking system. The tracked savings have not been updated based on the most up to date savings calculations developed by the applicant. Additional details on the applicant algorithm could be found in the project files.

Evaluation Assessment of Applicant Methodology

The applicant calculated the project savings using a one-line calculation that accounted for the pre-existing and proposed compressed air load values, operating hours, and compressed air plant efficiency. A compressed air audit is the source of values used in the calculations. The audit results are based on metered data that provides details on the compressed air plant operating hours and provides supporting information for calculating the plant efficiency (cfm/kW). The audit also provided an inventory of air leaks and their associated compressed-air load. The documentation did not indicate how the cfm leakage was calculated for each leak. The leak load presented in the audit report represented 12% of the compressed air plant-load and is reasonable for facilities that have a well-maintained system.

On-Site Inspection and Metering

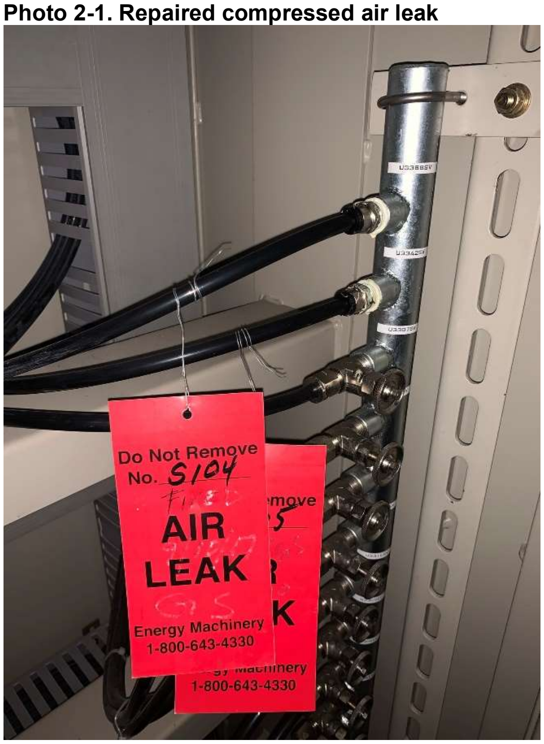
This section provides details on the tasks performed during the site visit and the gathered data.

Summary of On-site Findings

The evaluator conducted a site visit on March 8, 2021. During the site visit, the evaluator interviewed the facility manager and verified the installation of the measure. The evaluator gathered the following information:

4. Inspected a sample of 20 compressed air leaks that have been fixed as part of the evaluated project. Photo 2-1 below shows an example of a compressed air leak fixed.

Photo 2-1. Repaired compressed air leak



5. The site contact verified that the facility's compressed air demand has not changed since the implementation of the project.

6. The site contact indicated the process requires compressed air year-round.

7. Five air compressors supply compressed air and operate as presented in Table 2-3 below:

Table 2-143. Measure Verification

Air Compressor	Rated hp	Design	Operation
AC1	150	Rotary screw	Trim
AC2	150	Rotary screw	Trim
AC3	150	Rotary screw	Trim
AC4	350	Rotary screw	Baseload (manually turned off when AC5 is manually turned on); 125 psi supply air pressure
AC5	350	Rotary screw	Baseload (manually turned off when AC4 is manually turned on); 125 psi supply air pressure

According to the site contact, either AC4 or AC5 units operate continuously and one out of three 150 hp units operates approximately 7 hours every day.

Table 2-4 provides a summary of the measure verification method.

Table 2-144. Measure Verification

Measure Name	Verification Method	Verification Result
Repair compressed air leaks	Visual inspection of the repaired compressed air leaks.	All inspected repaired leaks have been repaired.

Based on the information provided in the compressed audit report conducted before the project was installed, the evaluators concluded the load reduction associated with the repaired leaks is reasonable.

Measured and Logged Data

During the site visit, the evaluator deployed current transformer (CT) with loggers on all five air compressors impacted by the incentivized measure. The metering period was from March 8, 2021 through May 5, 2021. The logger installed on

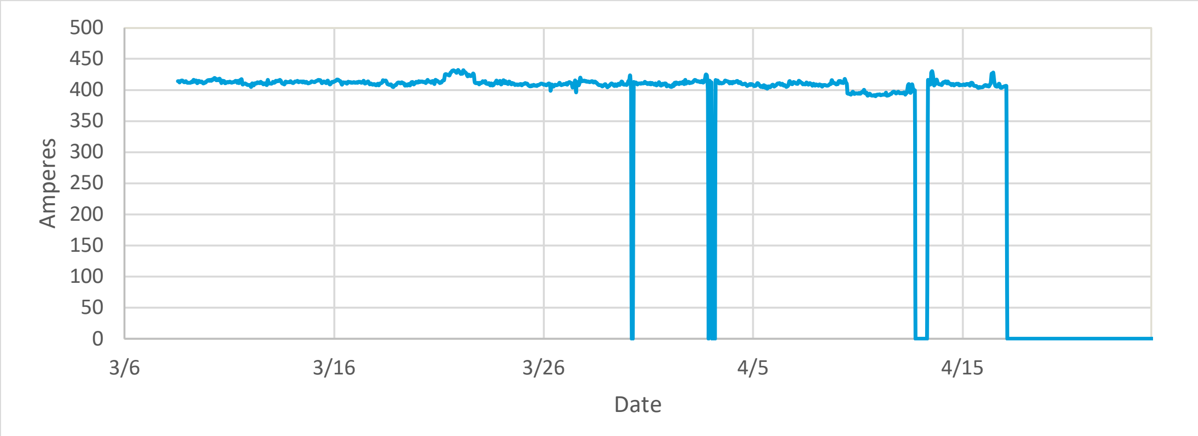
AC5 was faulty and did not record any data. AC5, though, was running during the second site visit. Table 2-5 presents the logger deployment details.

Table 2-5. Evaluation Data Collection – Installed Equipment

Parameter	M&V Equipment Brand and Model	Metering Start/Stop Dates	Metering Interval
Electric current (amperage)	5 x HOBO logger w/current transformer probes	03/08/2021 – 05/05/2021	5 seconds

Figure 2-5 show the graphical summary of AC4 metered data.

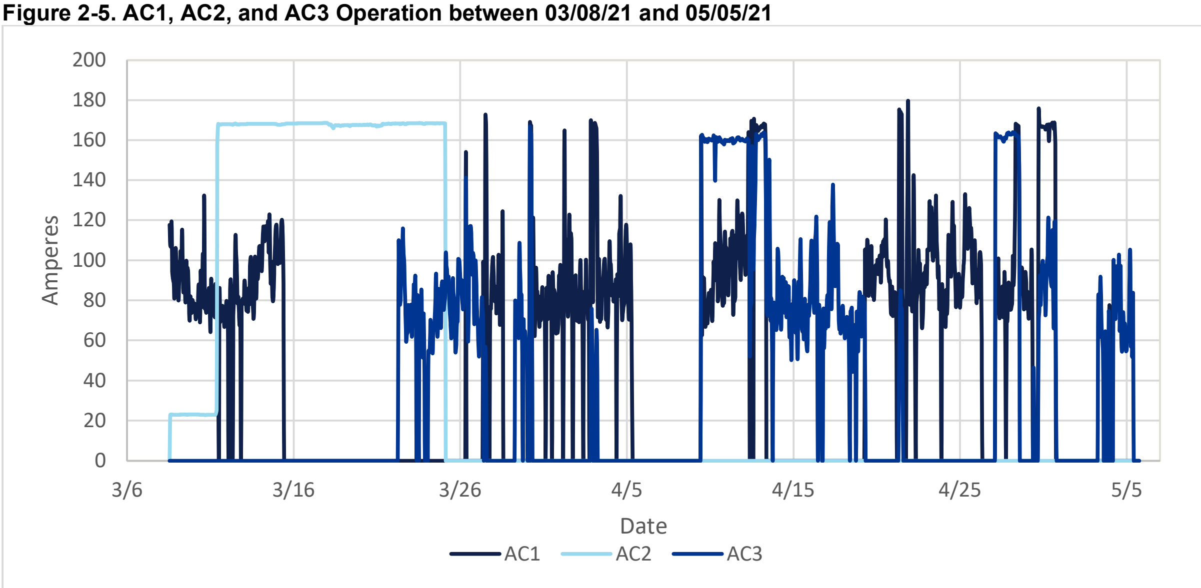
Figure 2-5. AC4 Operation between 03/08/21 and 4/17/21



Metered data presented in Figure 2-5 above shows AC4 was used to supply the baseload between March 8, 2021 and April 8, 2021 and operated at full load for the majority of the time that the unit was on. According to the site contact, on April 8, 2021, AC4 was turned off and AC5 was turned on to supply the compressed air baseload. The metered data and information provided by the site contact corroborates with the information provided by the compressed air study conducted in 2015 that indicates at any given time either AC4 or AC5 operates continuously.

Figure 2-5 presents the metered data for trim air compressors (AC1, AC2, and AC3).

Figure 2-5. AC1, AC2, and AC3 Operation between 03/08/21 and 05/05/21



Trim air-compressors operated in average 33% of the time during the metering period. In average, each trim air compressor operated 7.92 hours per day. The trim compressors metered hours of operation are 13% higher than the number of hours (approximately 7 hours per day) the site contact indicated the trim compressors operate.

Because the compressed air plant had to meet the compressed air load due to air-leaks before meeting any other loads for the facility's operation, the compressed air load due to air-leaks were supplied by the baseload air compressors (AC4 or AC5). The evaluator determined the measure impacted the baseload air compressors and calculated the measure impacts using their efficiency. The manufacturer of AC4 and AC5 does not provide an efficiency (cfm/kW) for those units. Table 2-6 presents the performance data provided by the manufacturer.

Table 2-6. AC4 and AC5 Performance Data

Parameter	Value(s)
Motor nameplate (hp)	350
Rated airflow (cfm)	1,550
Maximum rated pressure (psi)	150
Shaft input power (bhp)	379
Shaft input power unloaded (bhp)	60
Specific power consumption (bhp/100 cfm)	24.95

The evaluator calculated the baseload compressors efficiency using the following formula:

$$eff = 1.08 \times \frac{1}{\frac{bhp}{100 \times cfm} \times \frac{0.746}{Motor_{eff}}} = 1.08 \times \frac{1}{\frac{24.95}{100} \times \frac{0.746}{0.917}} = 5.32\ cfm/kW$$

where:

eff = air compressor efficiency (cfm/kW)

1.08 = increase in efficiency due to supply pressure decrease from (150 psi rated to 125 psi operating; 1% efficiency increase for each 2% decrease in supply pressure)

$\frac{bhp}{cfm}$ = specific power consumption (24.95 bhp/100cfm)

0.746 = conversion from hp to kW

$Motor_{eff}$ = 350 hp TEFC NEMA standard motor efficiency (91.7%)

Evaluation Methods and Findings

This section describes the evaluator methods and findings.

Evaluation Description of Baseline

The evaluator reviewed the project files and interviewed the site contact to gather information on the baseline. Based on the information provided in the project files and by the site contact, the evaluator determined this measure is an add-on with a single baseline. The baseline is the preexisting compressed air system with 121 leaks that contributed with 85 cfm to the compressed air load. Table 2-6 presents the evaluator's baseline key input parameters.

Table 5-6. Evaluator baseline key parameters

Parameter	Value(s)	Source of Parameter Value
Compressed air plant efficiency	5.32 cfm/kW	Calculated
Compressed air leaks to be repaired	121	Post-installation inspection
Leak load (associated with 121 fixed leaks)	121.75 cfm	Provided by National Grid's technical representative
Compressed air plant operating hours	8,760 hours/year	Metered data corroborated with information provided by the site contact

Evaluation Calculation Method

The evaluator used the metered data to determine which air compressors are impacted by the evaluated measure and how many hours they operate. The evaluator used the same leak load reduction (from 121.75 cfm to 36.75 cfm) as the applicant and evaluated compressed air efficiency calculated in Section 2.3.2 above. The evaluator calculated the project savings using the following formula:

$$savings = \frac{(air_b - air_p)}{eff} \times hours$$

where:

$savings$	= evaluated savings
eff	= efficiency of the compressed air system, 5.32 cfm/kW
air_b	= baseline leak load, 121.75 cfm
air_p	= proposed compressed air load, 36.75 cfm
$hours$	= operating hours of the compressed air system, 8,760 hours

The evaluated measure savings is 139,962 kWh per year.

Final Results

The project was installed at an industrial facility and included the repair of 121 air leaks in the compressed air distribution system. The measure saves energy because it reduces the load on the main air compressors. The evaluator calculated the savings using a similar methodology with the one used by the applicant. The evaluated savings are less than the reported values. The parameters impacted the analysis are summarized in Table 3-1.

Table 5-145. Summary of Key Parameters

	BASELINE		PROPOSED / INSTALLED	
Parameter	**Tracking Value(s)**	**Evaluation Value(s)**	**Tracking Value(s)**	**Evaluation Value(s)**
Repaired air leaks	N/A	121	N/A	121
Reduced compressed air load (cfm)	N/A	85	N/A	85
Impacted air-compressors efficiency (cfm/kW)	4.99	4.99	5.32	5.32
Impacted air-compressors operating hours (hours/year)	8,400	8,400	8,760	8,760
Savings adjustment factor	9.44%		0%	

N/A = Not applicable

Explanation of Differences

The evaluated savings are smaller than the reported value primarily because evaluated efficiency value of the impacted air compressors is greater than the applicant value and because the evaluators did not use a factor to adjust the savings. Table 3-2 provides a summary of the difference between the tracking and the evaluated values.

Table 5-146. Summary of Deviations

Measure	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
6686101	Administrative	Tracking error	-9.4%	**Decreased savings** – The tracking savings have not been updated based on the most up-to-date savings calculations. The final revision of ex-ante savings calculations resulted in less savings than initially predicted.
6686101	Technology	Efficiency	-3.3%	**Decreased savings** – The evaluated efficiency of the impacted air compressors is greater than the value used by the applicant in the savings calculations.
6686101	Operational	Operating hours	+2.0%	**Increased savings** – The evaluated operating hours of the impacted air compressors are greater than the values used by the applicant in the savings calculations.
Final RR				**RR% = 89.3%**

Ancillary impacts

There are no ancillary impacts associated with the evaluated measure.

RICE18N053

Report Date: 4/25/2021

Program	Custom Electric	
Application ID(s)	6500330	
Project Type	C&I Initial Purchase & End of Useful Life	
Program Year	2018	
Evaluation Firm	DNV	DNV
Evaluation Engineer	Shravan Iyer	
Senior Engineer	Steve Carlson	

11 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. to 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. 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 all the time (24x7), and the 200HP compressor serves as a backup to meet load requirements. 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 energy savings measure installed at the facility involves:

EEM-1: Fixing air leaks in the compressed air system- A total of (126) air leaks were identified during the compressed air-leak audit that was performed at the site, and the identified leaks were tagged, out of which 80% of the leaks were fixed, reducing the leak load from 225 cfm to 90 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 compressor doesn't have to draw as much power to maintain the required cfm and pressure levels by fixing the air leaks because the line losses would be minimal. The measure was categorized as a retrofit measure.

The evaluation found the measure savings to be 211,703 kWh annually, which is higher than the tracking savings listed in the applicant documentation. The evaluation results are presented in Table 1-1.

Table 5-147. 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)
6500330	Fixing Compressed Air Leaks	Tracked	180,699	56%	25.09	25.09
		Evaluated - ops	211,703	47.7%	23.96	24.28
		Realization Rate	117%	85%	95.5%	96.8%
Totals		Tracked	180,699	56%	25.09	25.09
		Evaluated - ops	211,703	47.7%	23.96	24.28
		Realization Rate	**117%**	**85%**	**95.5%**	**96.8%**

11.1 Explanation of Deviations from Tracking

The evaluated savings are higher 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. Further details regarding deviations from the tracked savings are presented in Section 3-4.

11.2 Recommendations for Program Designers & Implementers

There are no recommendations currently.

11.3 Customer Alert

There were no customer alerts.

12 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.

12.1 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 (126) air leaks were tagged, out of which 80% of the leaks were fixed, reducing the leak load from 225 cfm to 90 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 would generate the demand, energy, and peak savings for the project based on the user-provided inputs.

12.2 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 and a full load operating pressure of 125 psig and (1) 150 HP two-stage rotary screw compressor with a rated capacity of 763 acfm and a full load operating pressure of 125 psig. 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.

The following table shows the key inputs used in the applicant savings calculation methodology:

Table 5-148. 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	100 (80% of 126 leaks tagged)	Applicant Documentation	

12.2.1 Applicant Description of Installed Equipment and Operation

The facility proposed to fix the compressed air leaks that were observed throughout the facility. The facility 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 facility was able to identify and tag (126) air leaks, out of which 80% or about (100) leaks were fixed. This reduced the leak load from 225 cfm prior to fixing the air leaks to 90 cfm after fixing the air leaks. The following table lists the key inputs in the installed case:

Table 5-2: Application proposed key parameters

Measure	Parameter	PROPOSED 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	100 (80% of 126 leaks tagged)	Applicant Documentation	

12.2.2 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 below:

Average flow from pre-repair metering[47] *= 225 cfm*
Average flow from post-repair metering[48]*= 90 cfm*
System efficiency= 5.38 cfm/kW
Annual operating hours= 7,200 hours

Average flow saved= pre-repair cfm – post-repair cfm
Average flow saved= 225 cfm – 90 cfm
Average flow saved= 135 cfm

Average Power saved= Average Flow saved/System Efficiency
Average Power saved= 135 cfm/5.38 cfm/kW
Average Power saved= 25.093 kW

Annual Energy Saved= 25.093 kW x 7,200 hours
Annual Energy Saved= 180,699 kWh

Therefore, the tracking savings for this project was found to be 180,699 kWh, and the summer and winter seasonal demand was found to be 25.09[49] kW.

From the above savings calculation, we can observe that the variables that have the greatest impact on the savings are the operational hours of the compressors and the flow savings.

12.2.3 Evaluation Assessment of Applicant Methodology

The evaluators agree with the applicant savings methodology. The evaluators agree with the methodology used to identify the compressed air leaks in the facility using an ultrasonic leak detector to determine the pre-repair cfm consumed in the facility. The post-repair cfm was measured similarly, and the pre and post-repair cfm values were used as inputs in the savings calculator spreadsheet. The evaluator finds this methodology reasonable.

12.3 Site Inspection

A site visit was performed on 2/23/2021 to verify the compressed air leaks fixed as part of the project and install ElitePRO power loggers to capture trend 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

[47] From project files
[48] From project files
[49] 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

that the facility runs the 150HP compressor 24x7, and the 200HP compressor serves as a backup to meet load requirements. But the facility usually requires both compressors to run to maintain plant pressure.

The evaluators physically verified a sample of the leaks that were tagged and fixed as part of the project as claimed in the applicant documentation. The leaks were found to have red tags that showed that they were identified during the leak survey. 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) 150 HP two-stage rotary screw compressor with a rated capacity of 763 acfm and a full load operating pressure of 125 psig and (1) 200HP two-stage variable speed, rotary screw compressor with a rated capacity of 918 acfm and a full load operating pressure of 125 psig. The 150HP compressor was identified as the primary, and the 200HP compressor served as backup. 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 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 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. The major compressed air loads at the facility include pneumatically controlled production equipment, automated conveyors, and other miscellaneous equipment.

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 at 1-minute intervals by logging voltage, amperage, and power factor. Installing the loggers on both compressors would help understand the operating profiles of both compressors.

12.3.1 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 115 psig.
- 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 backup compressor kicks in when the 150HP primary compressor is fully loaded.

The following table shows the summary of the verification methods used to verify the installation of the project and the corresponding evaluation findings:

Table 5-149. Measure Verification

Measure Name	Verification Method	Verification Result
Fixing Compressed Air Leaks	Verify the nameplate of the compressor 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 via. physical inspection	The compressed air leaks that were fixed were found to be tagged during the facility walk-through

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

12.4 Evaluation Methods and Findings

This section describes the evaluator methods and findings.

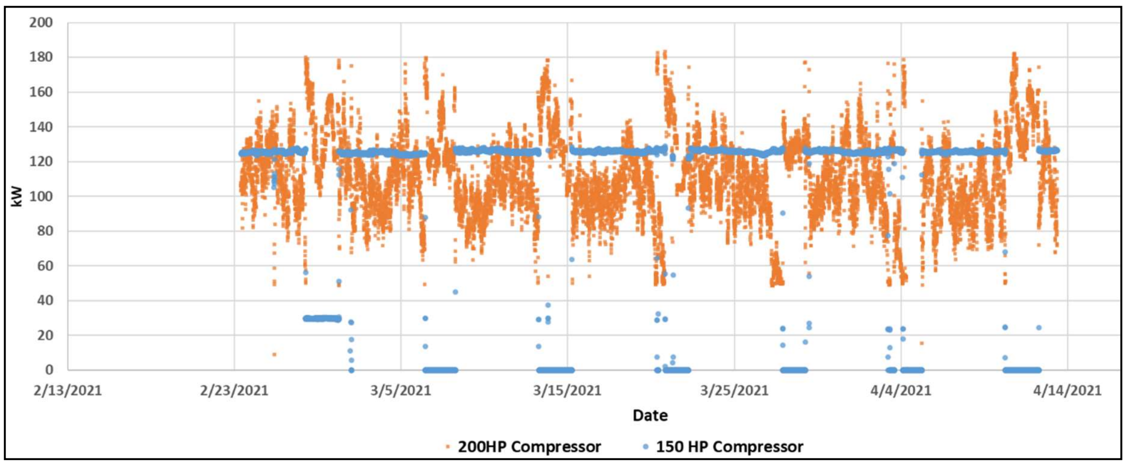
12.4.1 Evaluation Description of Baseline

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 verified a sample of the leaks that were fixed to see if it matches the number of leaks claimed in the tracking documentation and found that the claimed leaks were fixed. The evaluator determined this measure is a retrofit with a single baseline, and the baseline is the pre-existing condition.

12.4.2 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 February 23rd and April 14th, 2021, for four weeks. During this period, the operating profile of the loggers from the metered data was observed to be as shown below:

Fig.1- Metered Data for 150HP and 200HP compressors



From the above figure, we can observe 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. 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 both compressors where the average hourly kW draw was modeled over a typical week during the metering period as shown below:

Fig.2- Average Hourly kW draw of 150 HP Compressor (from metered data)

150 HP Compressor- Average Hourly kW draw							
Hour/Day	Sun	Mon	Tue	Wed	Thu	Fri	Sat
0	22.24	4.23	124.50	125.90	125.76	125.16	125.51
1	22.20	4.23	113.00	125.72	125.79	125.24	125.54
2	25.98	4.24	126.03	125.91	125.51	125.15	125.39
3	15.29	4.23	126.06	125.90	125.32	125.11	125.38
4	4.26	4.22	125.86	125.95	125.58	125.17	125.43
5	4.24	4.21	126.15	125.98	125.37	125.33	125.65
6	4.24	5.51	126.13	125.69	125.53	125.13	116.64
7	7.67	105.96	126.26	125.82	125.70	125.25	84.55
8	18.06	125.32	126.18	126.01	125.68	125.30	73.45
9	4.36	125.42	126.15	125.87	125.68	125.13	50.88
10	4.27	125.79	125.83	126.12	124.21	125.03	40.51
11	4.27	125.87	125.63	126.05	125.54	125.19	48.28
12	4.28	122.66	125.61	125.88	125.39	125.16	40.37
13	4.27	125.75	125.59	125.88	125.33	125.18	40.29
14	4.27	125.59	125.44	125.75	125.23	125.06	40.31
15	4.27	125.77	125.30	125.86	125.31	125.19	52.25
16	4.26	125.77	125.45	125.74	125.27	125.29	58.37
17	4.26	125.80	125.60	125.78	125.42	125.50	58.38
18	4.27	125.82	125.64	125.86	125.39	125.57	58.46
19	4.27	125.80	125.73	125.84	125.43	125.57	58.55
20	4.26	125.75	125.85	125.88	125.29	125.34	59.53
21	4.27	125.98	126.02	125.88	125.37	125.32	40.87
22	4.25	125.76	125.95	125.90	125.50	125.42	38.88
23	4.25	125.71	125.86	125.80	125.26	125.26	22.69

Fig.3- Average Hourly kW draw of 200 HP Compressor (from metered data)

200 HP Compressor- Average Hourly kW draw							
Hour/Day	Sun	Mon	Tue	Wed	Thu	Fri	Sat
0	125.32	104.94	94.74	98.71	103.01	110.16	99.36
1	119.21	106.96	103.56	96.91	97.21	109.39	96.02
2	114.39	107.89	90.58	99.04	101.13	110.19	93.48
3	125.90	106.94	92.09	100.79	101.25	108.65	94.73
4	134.63	107.42	93.66	95.91	99.15	105.34	94.87
5	134.20	117.03	100.04	95.16	107.53	97.43	90.52
6	130.50	135.53	95.02	97.81	102.67	95.83	75.93
7	117.58	102.46	99.01	103.55	108.25	111.46	91.62
8	105.22	98.72	94.54	105.34	113.14	114.25	100.37
9	118.04	102.05	98.15	108.03	105.08	110.54	116.09
10	113.70	109.67	103.31	104.31	91.28	111.88	126.79
11	114.02	110.55	108.42	110.13	116.50	108.37	119.19
12	116.99	109.70	106.64	113.44	122.20	104.94	127.36
13	117.16	109.66	109.43	110.05	120.16	104.49	125.76
14	113.85	113.63	111.60	117.08	126.04	111.64	124.56
15	112.01	106.68	110.97	100.72	115.09	105.26	118.58
16	112.81	114.23	111.53	102.16	118.47	109.81	114.22
17	115.71	111.53	106.64	106.30	112.64	112.65	113.32
18	115.06	115.92	114.13	112.68	114.34	112.82	110.35
19	112.60	109.71	109.44	109.91	112.85	103.67	110.99
20	113.16	114.61	112.11	114.10	117.92	108.63	111.48
21	113.54	112.26	111.05	110.52	117.69	107.34	125.74
22	111.39	109.77	111.36	107.57	116.97	111.04	128.79
23	103.64	95.02	94.85	100.39	110.72	102.36	125.28

The above heat maps help understand the operating profiles of the two compressors. From **Fig.2,** We observe that the 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 metering period. From **Fig.3,** we observe that the 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 sees increased levels of operating kW 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.

Based on the data shown in the above heat maps, the evaluators modeled the savings using an 8760-analysis profile. The metered kW data was aggregated into 168-hour week profiles as shown in the above heat maps, averaged by the hour of the day and weekday to represent the typical kW demand of the air compressor. This data was extrapolated to a year (using an 8,760 spreadsheet) to model the post-case annual kWh consumption of the compressors. The baseline compressor kW was modeled using metered data obtained from the loggers, which was converted to cfm using compressor CAGI sheet data. The leak load was added to the post case cfm to estimate the base-case cfm, which was again converted to kW to estimate the baseline kWh consumption. The evaluators did this by adding the cfm to the baseloaded compressor until the 200HP compressor kicked-in. The compressor efficiency i.e. the cfm/kW for the baseloaded compressor was determined using compressor CAGI sheet data. The difference between this calculated baseline kW and the estimated kW from metered data in the 8,760 sheet is the annual kWh energy savings which amounted to 211,703 kWh. The measure resulted in total demand savings of 24.16 kW.

13 Final Results

The following table summarizes the key parameters that were used in the estimation of savings and compares them with the tracking and post case:

Table 5-150. Summary of Key Parameters

Parameter	BASELINE Tracking Value(s)	BASELINE Evaluation Value(s)	PROPOSED / INSTALLED Tracking Value(s)	PROPOSED / INSTALLED Evaluation Value(s)
Compressor HP	150	150	150	150
Compressor HP	200	200	200	200
Operating Hours	7,200	8,760	8,760	8,760
Compressor Efficiencies (cfm/kW)	5.38	5.38	5.4	5.4

13.1 Explanation of Differences

The evaluation savings were found to be 211,703 kWh which is higher than the tracking savings. The increase in savings is due to the increased operating hours of the compressors compared to what was claimed in the applicant documentation. Table 3-2 provides a summary of the differences between tracking and evaluated values.

13.1.1 Ancillary impacts

There are no ancillary impacts.

RICE18N059

Report Date: 4/26/21

Application ID(s)	8469852 8507515
Project Type	C&I Initial Purchase & End of Useful Life
Program Year	2018
Evaluation Firm	DNV
Evaluation Approach	Full M&V
Evaluation Engineer	Joe St. John
Senior Engineer	Olav Hegland

Evaluated Site Summary and Results

The project was implemented at an industrial manufacturing facility and consisted of two retrofit measures, compressed air leak repair, and duct-sealing of three RTUs.

Measure-1 Compressed Air Leak Repair (8507515):The leak repair measure consisted of 70.2 cfm worth of compressed air leak repairs. The initial proposal was provided by one vendor who audited the facility, identified 72 air leaks, and identified 216 CFM of leak repairs. A CFM meter was installed to observe compressed air demand before and after the leaks had been addressed. The meter showed that 70.2 CFM worth of savings had been achieved from the effort. Savings for these air leaks were determined by applying the CFM reduction to the plant kW/CFM value of 0.2038 kW/CFM, and 8,400 annual operating hours. The plant consists of three air compressors total, but only one compressor operated during the period when pre and post CFM data was collected. The total tracking savings for this measure are 120,168 kWh.

Measure-2 RTU Duct Sealing (8469852): The tracking documentation indicates that the duct sealing measure consisted of adding duct sealing to three rooftop units (20, 55, and 40 tons), allowing the duct leakage rate to be reduced from 15% of design flow to 3% of the design flow, allowing the RTUs to deliver 34,157 CFM instead of 38,815 CFM. Fan savings account for 89% of the claimed savings for this measure, while cooling savings account for 11% of the claimed savings for this measure.

For the compressed air measure, the pre and post data used for the analysis was collected before the COVID pandemic happened, so there was no COVID impact on the analysis for this measure. For the RTU duct sealing measure, the customer indicated that COVID had no impact on the operation of the RTUs. For this reason, a full M&V approach was used to analyze the data collected from this site during the evaluation monitoring phase, which occurred during the COVID pandemic.

The evaluation results are presented in Table 1-1.

Table 5-151. 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)
8507515	Compressed Air Leak Repair	Tracked	120,168	48.0%	0.00	0.00
		Evaluated - ops	119,815	4.0%	13.68	13.68
		Realization Rate	99.7%	8.4%	N.A.	N.A.
8469852	RTU Duct Sealing	Tracked	46,802	63.0%	9.50	6.50
		Evaluated - ops	36,880	4.5%	5.24	3.29
		Realization Rate	78.8%	7.2%	55.1%	50.7%
Totals		**Tracked**	**166,970**	**52%**	**9.50**	**6.50**
		Evaluated - ops	**156,695**	**4%**	**18.92**	**16.97**
		Realization Rate	**93.8%**	**7.9%**	**199%**	**260%**

Explanation of Deviations from Tracking

The evaluated savings are very similar to the applicant-reported savings for the compressed air leak repair measure. New, more efficient VFD compressors were installed at the facility in June of 2020, but these compressors were installed after the 2-year measure life for this measure had elapsed. The evaluated savings are less than the applicant-reported savings for the RTU duct sealing measure primarily due to the evaluation finding that in the post-case, RTU-13, the 20-ton unit, was found not to have any flow control mechanism like RTU-14 and RTU-15, meaning that RTU-13 is a constant volume unit. Since this is a constant volume unit, fans were running at or near 100% full flow regardless of the leakage. Further details regarding deviations from the tracked savings are presented in Section 3-4.

Recommendations for Program Designers & Implementers

There are no recommendations currently.

Customer Alert

There were no customer alerts. The customer requested a copy of the site report.

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 two retrofit measures: compressed air leak repair and duct-sealing of three RTUs.

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.

Applicant Description of Baseline and Proposed Key Parameters

This section describes the baseline equipment, system, assumptions, and/or control sequence as described by the applicant.

Compressed air leak repair

The measure was classified as a retrofit measure where pre-installation operating conditions were used as a baseline. The baseline consisted of the metered compressed air demand, where the operating compressor has an efficiency of 0.2038 kW/CFM. Annual compressor operating hours were assumed to be 8,400.

Key parameters used in the tracking calculations for the compressed air leak repair measure are shown in Table 5-152.

Table 5-152. Key parameters for compressed air leak repair measure

Variable	Tracking Value
Flow reduction from fixing leaks (CFM)	70.2
Annual operating hours	8,400
kW/CFM	0.204
kWh Savings	120,168

RTU duct sealing

The measure was classified as a retrofit measure where pre-installation operating conditions were used as a baseline.

Key parameters used in the tracking calculations for the RTU duct sealing measure are shown in Table 5-153 and Table 5-154. Table 5-153 shows the key variables for the fan savings portion of the measure, which makes up 89% of the claimed savings for this measure, and Table 5-154 shows the key variables for the cooling savings portion of the measure, which comprises 11% of the claimed savings for the measure. Table 5-153 shows that the tracking calculations assume that the units had VFDs to control the flow, but the evaluator found that RTU-14 and RTU-15 were controlled with inlet guide vanes, and no VFDs, and that RTU-13 is a constant volume unit, with no flow control mechanism.

Table 5-153. Key parameters for fan savings portion of RTU duct sealing measure

Variable	RTU-13	RTU-14	RTU-15

Design Flow (CFM)	6,500	21,905	10,410
Baseline Leak Rate	15%	15%	15%
Post Leak Rate	3%	3%	3%
Normal operating flow % of design flow	100%	100%	100%
Pre leakage rate (CFM)	975	3,286	1,562
Post leakage rate (CFM)	195	657	312
Flow to zone (CFM)	5,525	18,619	8,849
Baseline total flow	6,500	21,905	10,410
Post total flow	5,720	19,276	9,161
Baseline flow %	100%	100%	100%
Post flow %	88%	88%	88%
Design Brake Horsepower (HP)	2.5	22.7	6.8
Motor efficiency	87%	92%	90%
Baseline VFD efficiency	100%	100%	100%
Post VFD efficiency	95%	95%	95%
kW to HP conversion factor	1.0	1.0	1.0
Affinity Exponent	2.0	2.0	2.0
Motor baseline kW	2.9	24.8	7.6
Motor post kW	2.4	20.2	6.2
Annual Hours	6,426	6,426	6,426
Baseline fan kWh	18,572	159,073	48,967
Post fan kWh	15,139	129,670	39,916
Fan energy savings	3,433	29,403	9,051

Table 5-154. Key parameters for cooling portion of RTU duct sealing measure

Variable	RTU-13	RTU-13	RTU-14
Baseline Total Average CFM (CFM)	6,500	21,905	10,410
Baseline Average OA CFM (CFM)	500	4,000	3,925
OA CFM Percent	8%	18%	38%
Baseline Leak Rate	15%		
Post Leak Rate	3%		
Post Total Average CFM	5,720	19,276	9,161
Post Average Outdoor OA CFM	440	3,520	3,454
Air density (lb/ft3)	0.075		
Supply air enthalpy (Btu/lb)	23.0		
Weighted average ∆ enthalpy (Btu/lb)	7.81	7.81	7.81
Hours	1,659	1,659	1,659

Baseline Btu	29,164,412	233,315,296	228,940,634
Post Btu	25,664,683	205,317,461	201,467,758
COP	3.5	3.5	3.5
BTU to kWh conversion factor	3,412	3,412	3,412
Baseline kWh	2,430	19,443	19,078
Post kWh	2,139	17,110	16,789
Cooling energy savings (kWh)	292	2,333	2,289

Applicant Energy Savings Algorithm

Compressed air leak repair

The applicant calculated the savings using a spreadsheet tool. The difference in compressed air demand from pre- and post-implementation metering, compressor efficiency, and annual operating hours were used to determine electrical savings. The applicant calculated the savings using the following formula:

$$Total\ Savings = \Delta Demand_{Compressed\ Air} \times \eta_{compressor} \times Hours_{Annual}$$

where,

$Total\ Savings$ = measure savings (kWh/year)

$\Delta Demand_{Compressed\ Air}$ = difference in pre/post compressed air demand (70.2 cfm)

$\eta_{Compressor}$ = Compressor efficiency (0.2038 kW/cfm)

$Hours_{Annual}$ = 8,400 annual operating hours

Total project savings result in 120,168 kWh from the repair in air leak repairs.

RTU duct sealing

The applicant calculated the savings using a spreadsheet tool, one tab calculates fan savings, and one tab calculates cooling savings.

Fan savings algorithms:

$$Fan\ savings = Baseline\ Fan\ Energy - Post\ Fan\ Energy$$

$$Baseline\ Fan\ Energy^{50} = \frac{Design\ Brake\ Horsepower}{Motor\ Efficiency} \times Annual\ Hours$$

$$Post\ Fan\ Energy = \frac{Design\ Brake\ Horsepower}{Motor\ Efficiency \times VFD\ Efficiency} \times Annual\ Hours \times \left(\frac{Post\ Flow}{Design\ Flow}\right)^{Affinity\ Exponent}$$

$$Post\ Total\ Flow = Baseline\ Total\ Design\ CFM\ \times ((1 - Baseline\ Leak\ Rate) + Post\ Leak\ Rate)$$

Table 5-153 shows the key input variables used for the fan savings for this measure.

Cooling savings algorithms:

$$Cooling\ savings = Baseline\ Cooling\ Energy - Post\ Cooling\ Energy$$

[50] The tracking calculations erroneously did not consider the 0.746 kW/HP conversion factor to convert from BHP to brake kW.

$$Baseline\ Cooling\ Energy = \frac{Baseline\ Design\ OA\ CFM\ \times Air\ Density\ \times 60\frac{min}{hr}}{3{,}412\ Btu/kWh \times 3.50\ COP} \times \sum_{Bin\ Temp=67.5}^{Bin\ Temp=97.5} Hours\ at\ 5°\ BinTemp\ \times (Outdoor\ Air\ Enthalpy\ at\ 5°\ Bin\ Temp - Supply\ Air\ Enthalpy)$$

$$Post\ Cooling\ Energy = \frac{Post\ OA\ CFM\ \times Air\ Density\ \times 60\frac{min}{hr}}{3{,}412\ Btu/kWh \times 3.50\ COP} \times \sum_{Bin\ Temp=67.5}^{Bin\ Temp=97.5} Hours\ at\ 5°\ BinTemp\ \times (Outdoor\ Air\ Enthalpy\ at\ 5°\ Bin\ Temp - Supply\ Air\ Enthalpy)$$

$$Post\ OA\ CFM = Baseline\ \%\ Outdoor\ Air\ \times Post\ Total\ Flow$$

$$Baseline\ \%\ Outdoor\ Air = \frac{Baseline\ Design\ OA\ CFM}{Baseline\ Total\ Design\ CFM}$$

$$Post\ Total\ Flow = Baseline\ Total\ Design\ CFM\ \times ((1 - Baseline\ Leak\ Rate) + Post\ Leak\ Rate)$$

Table 5-154 shows the key variables for the cooling savings portion of the measure

Evaluation Assessment of Applicant Methodology

The evaluator generally agrees with the overall approach used in the tracking energy savings estimation methodology for both measures. There are several deviations, noted below:

Compressed air leak repair

The evaluators updated the parameters in the algorithm based on evaluation findings, but the algorithm itself is sound.

RTU duct sealing

The tracking methodology incorrectly did not use the 0.746 kW per HP conversion factor in the fan savings portion of this measure. See Table 5-153. The evaluator will use the conversion factor. Additionally, the tracking methodology would be appropriate if all the RTUs had VFDs, but the evaluator found that none of the RTUs had VFDs. The evaluator found that RTU-13 is a constant volume unit and that RTU-14 and RTU-15 are variable air volume units, with inlet guide vanes, not VFDs, used to control the airflow volume. Instead of a VFD efficiency losses, and a VFD affinity law factor, the evaluator analysis uses default % flow vs. % power curves for fans controlled with inlet guide vanes.

Site Visit Findings

The initial site visit occurred on 2/25/21. A return site visit occurred on 4/22/21 to retrieve the loggers. This section describes the findings from the site visit.

Compressed air leak repair

The planned and completed site visit activities for the compressed air leak repair measure are shown in

Table 5-155.

Table 5-155. Site visit task list and results for compressed air leak repair measure

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. These units were installed 2.5 years after this measure was installed. The measure life for compressed air leak repairs is 2 years, so the installation of these new, more efficient compressors had no impact on the savings for this project.
Observe cfm demand meters	CFM demand meter showed 609 CFM, but the contact person stated this was only for a portion (around half maybe) of the facility demand, and he stated that he did not fully trust this meter. The tracking documentation showed that the CFM ranged from around 280 CFM (unoccupied, post), to 700 CFM (occupied pre and post).
Inventory equipment nameplates and determine from the site contact the control type of each compressor (VFD, load/unload, modulation, modulation w/ blowdown, etc.) **Determine the quantity and size of any storage tanks**	Both of the new units are VFD units. There are two large storage tanks (model number collected), but this info is not necessary for VFD systems. The old units had been removed.
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. However, this data was not used, because these compressors were installed 2.5 years after the measure was installed, and the measure EUL is only 2 years.
Obtain trend data for compressed air demand	No trend data were available.
Perform a walkthrough with an ultrasonic detector to test for air leaks	This was not possible. Site contact stated that they had not done any compressed air leak projects since this original project was done, which he was not involved with. He did not know where the compressed air leak repairs took place.
Site interview	Interview completed. See responses below.

Site interview questions and responses for compressed air leak repair measure:

Have there been compressed air audits performed since this application?

No

How often do you test for compressed air leaks?

Not regularly.

What is the typical plant cfm demand?

Meter on one of two pipes currently shows 672 CFM. Maybe multiply by 2?

Are there any seasonal variations in the system? How has COVID-19 affected your operation?

Other than around Christmas and during the summer, the load is similar. Only the machine shop uses compressed air.

Have any modifications been made to the system since installation? Any new CFM users added? If so, how much has CFM increased since the project was completed in December of 2017?

We purchased two new VFD compressors in June of 2020, which provide air to the entire facility, replacing the old compressors. We also significantly reduced compressed air demand by installing ~65 Prevose quick connects, which reduce CFM demand big time. It also increases safety.

What other changes to the system may have occurred since this project was completed?

We put in another trunk line parallel to the existing trunk line to increase pressure at the end of the plant.

Have any CFM uses been added or removed since the project has been completed? If so, how much CFM would you estimate?

No

What type of control do the base-load compressors have? Load/unload, modulation, etc.? (Original audit states that the (2) Gardner Denvers use inlet modulation with variable displacement, while the (1) Palatek used VSD). Is this still correct?

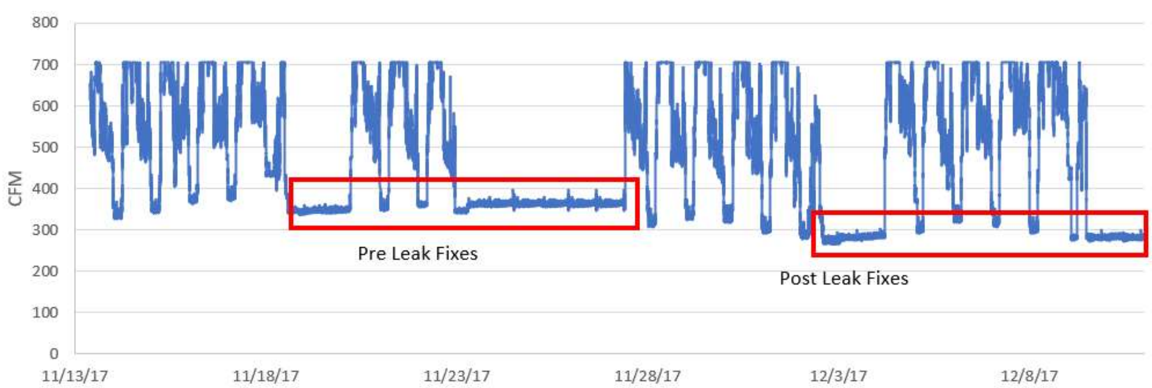
The two machines that were recently installed (June of 2020), which provide all the compressed air for the plant, are both VFD machines. Only one operates at a time, while the other serves as a backup.

Did the system have any downtime? Is there reduced CFM demand on holidays or during shutdown periods? How many days per year does this occur?

Shutdowns occur on Christmas day, Easter day. Thanksgiving. Typically, five holidays downtime per year. The compressors sometimes run on Sundays.

Figure 5-43 shows the pre and post CFM measurements that were collected by the vendor between 11/13/17 and 12/11/17. The data was collected at 1-minute intervals. The vendor examined this data (boxed in red) and estimated that the reduction in CFM demand was 70.2 CFM. This is the data that was used in the tracking calculations, as well as the evaluator calculations.

Figure 5-43. Pre and post CFM measurements collected by the vendor



RTU duct sealing

The planned and completed site visit activities for the RTU duct sealing measure are shown in Table 5-156.

Table 5-156. Site visit task list and results for RTU duct sealing measure

Task	Result
Inventory equipment nameplates and determine control type supply fans	Collected nameplate photos on RTU 13, 14, and 15. RTU-14 and RTU-15 were found to be variable air volume units, with inlet guide vanes used to control flow. RTU-13 was found to be a constant volume unit. Since RTU-13 is a constant volume unit that was found to run at full capacity for the entire post-case evaluation monitoring period, no savings are associated with RTU-13.
Install kW meter on at least (1) RTU supply fan, but kW and/or Amp loggers on up to all (3) RTUs if time allows.	Installed kW loggers on the supply fan motors of RTU 14 and 15. Installed Amp logger on the supply fan motor of RTU 13.
Take spot measurements of face velocity at the coils or air filters using pitot tube or hot-wire-anemometer, and measure area to compute CFM. Note inlet guide vane position if possible, and instantaneous kW value.	Took spot airspeed measurements for RTU 14 and RTU 15 using hot-wire anemometer and taking dimensions of the main filter bank. Did this after kW loggers were installed. Could not determine the position of inlet guide vanes. After examination of the data, it did not appear valid so it was not used to determine flow.
Site interview	Completed site interview questions. See responses below.

What is the typical daily, weekly, and annual operation schedule for these (3) RTUs? How has COVID-19 impacted their operation, if at all?

Goes into an unoccupied mode during weekends and evenings. COVID has not impacted the schedule.

Have any updates to the fans or RTUs been made since the project? For example, have VFDs been installed, or any significant work been performed?

No. Adding a new 17.5-ton unit soon.

Do you have any additional documentation from the vendor who performed this duct-sealing which provides any baseline or post-case CFM leakage rate measurements?

No

How are these RTU supply fans controlled? Do they have inlet guide vanes, or does a VFD control them?

The respondent said they have no VFDs. They run straight out. However, the model number indicates that RTU 14 and 15 are VAV units, with inlet guide vanes to control the flow. The post data showe that RTU-13 ran at 99.7% flow in the post-case, RTU-14 ran at 64% in the post-case, and RTU 15 ran at 92% in the post case. The tracking documentation showed that all of the units ran at 88% flow in the post-case. The contact person said that these units all run straight out since they are undersized (load has been added since the units were originally installed 20 years ago).

Did the RTU supply fans operate at a constant airflow rate in the baseline, or did their flow rate change dynamically based on feedback from the VAV boxes downstream?

See response above.

Are there any RTUs similar to any of these RTUs that did not have duct-sealing performed to potentially install kW loggers to capture the baseline operation? RTU-4 is a fan that is rated at 20 tons and provides 6,750 CFM of supply air.

This is similar to RTU 13, which is also 20 tons and provides 6,500 CFM of supply air. Did RTU-4 also get duct-sealing installed? It looks like RTU-4 is a constant volume unit, while RTU-13 is a variable air volume unit. Is that correct?

Unknown. (Contact person did not know)

Do you have any trend data on this equipment in the BAS, such as CFM, IGV percent, etc.?

Contact person does not know how to set up trends on their BAS

Figure 5-44 shows the amp measurements collected on RTU-13 during the evaluation monitoring period. The data was collected at 5-minute intervals from 2/24/21 to 4/22/21. The data shows that the unit was running at full load for 99.7% of the time. Examining the nameplate model number and cross-referencing the specification sheets showed that this unit is a constant volume unit. Since this unit runs at full flow during the post-case (i.e., it does not cycle on and off), no savings can be attributed to this measure since the baseline usage could not be higher than 100%.

Figure 5-44. RTU-13 Supply Fan Amp Measurements

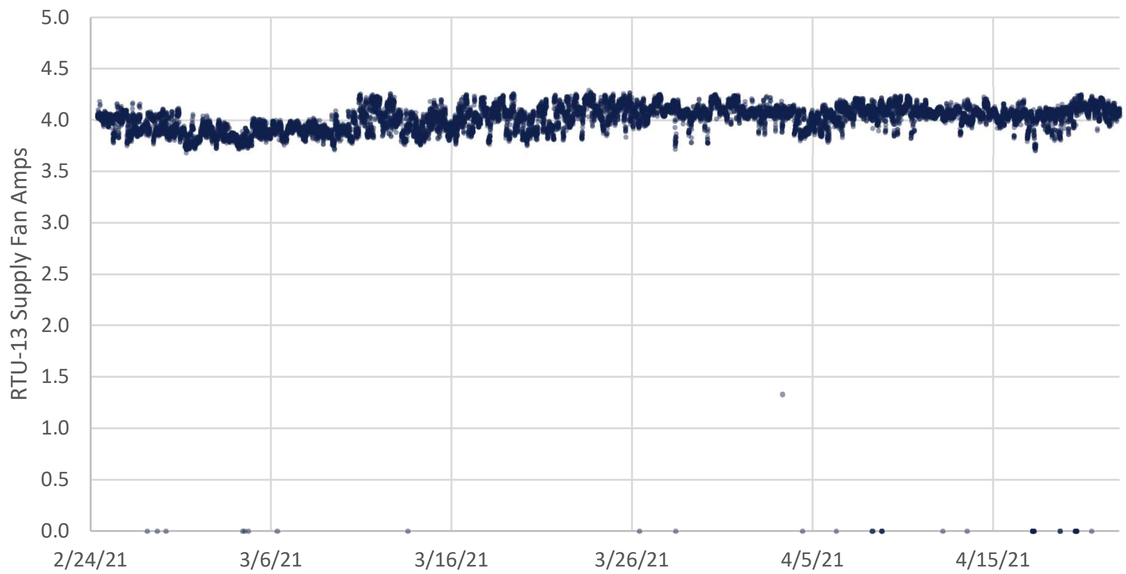


Figure 5-45 shows the kW measurements collected on RTU-14 during the evaluation monitoring period. The data was collected at 5-minute intervals from 2/24/21 to 4/22/21. This kW data was converted to airflow data using a %flow vs. %kW part load curve for forward curve fans with inlet guide vanes. The post-case flow data and the post-case kW data were used to update the key parameters in the savings algorithms.

Figure 5-45. RTU-14 Supply Fan kW Measurements

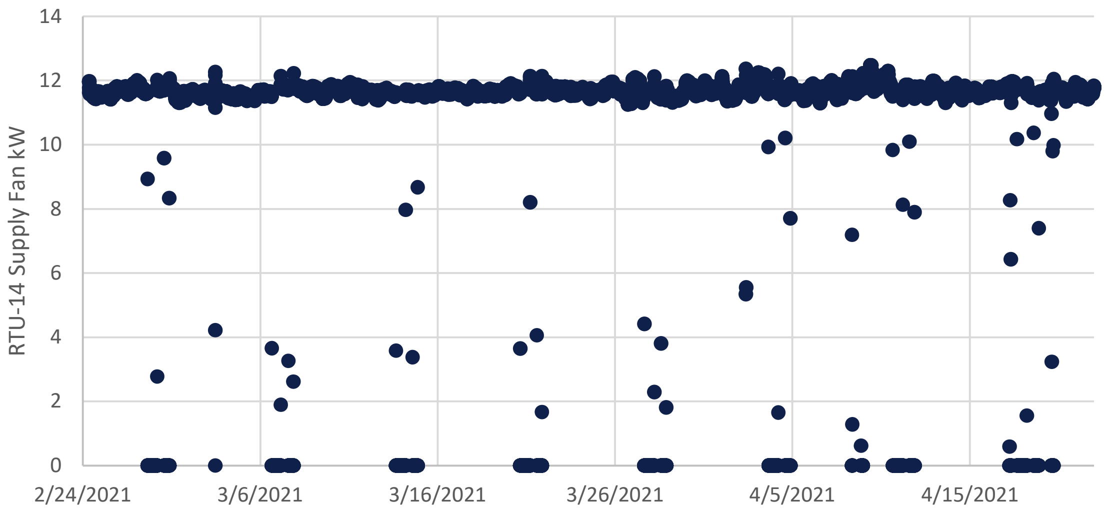
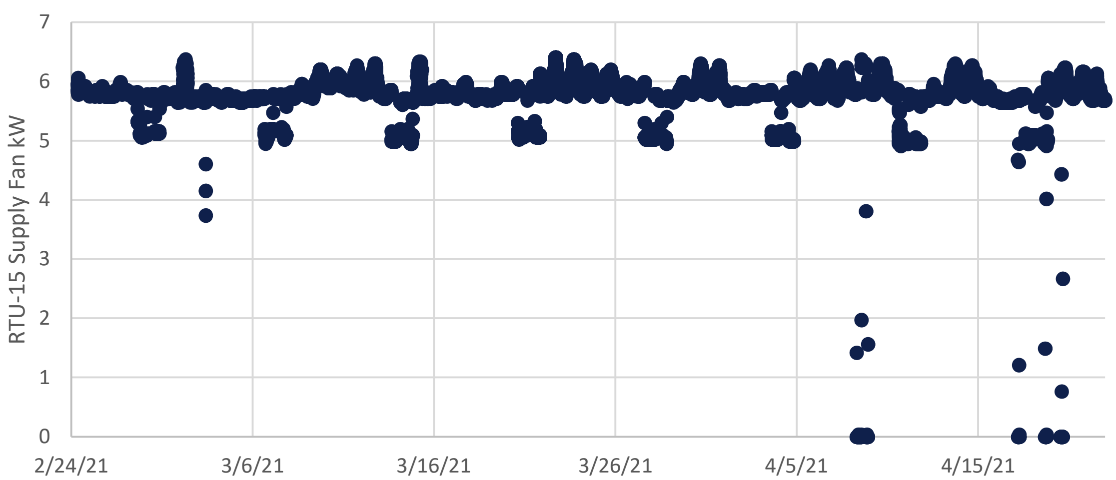


Figure 5-46 shows the kW measurements collected on RTU-15 during the evaluation monitoring period. The data was collected at 5-minute intervals from 2/24/21 to 4/22/21. This kW data was converted to airflow data using a %flow vs. %kW part load curve for forward curve fans with inlet guide vanes. The post-case flow data and the post-case kW data were used to update the key parameters in the savings algorithms.

Figure 5-46. RTU-15 Supply Fan kW Measurements



Evaluation Methods and Findings

This section describes the evaluator methods and findings.

Evaluation Description of Baseline

Compressed air leak repair

The evaluator reviewed the project files and interviewed the site contact to gather information on the baseline. The evaluator classified this measure as a retrofit add on where the baseline consists of the pre-existing operating conditions

RTU duct sealing

The evaluator reviewed the project files and interviewed the site contact to gather information on the baseline. The evaluator classified this measure as a retrofit add-on where the baseline consists of the pre-existing operating conditions.

Evaluation Calculation Method

This section describes the calculation steps used by the evaluator to estimate the savings from this measure.

Compressed air leak repair

The evaluator examined the pre and post CFM measurement data collected by the vendor shown in Figure 5-43, and updated the CFM reduction from 70.2 CFM to 67.1 CFM. The evaluator used a more rigorous approach in classifying the "shut down" periods, highlighted in the red boxes in Figure 5-43, compared with the vendor methodology.

The kW data collected on the new compressors showed that the compressors operated 8,760 hours per year, rather than 8,400 hours/year as assumed in the tracking calculations. Since the new compressors were installed 2.5 years after the measure was installed, and the measure has an EUL of only 2 years, the evaluators did not update the kW/CFM value in the tracking calculations.

$$Total\ Savings = \Delta Demand_{Compressed\ Air} \times \eta_{compressor} \times Hours_{Annual}$$

where,

$Total\ Savings$ = measure savings (kWh/year)

$\Delta Demand_{Compressed\ Air}$ = difference in pre/post compressed air demand (67.1 cfm)

$\eta_{Compressor}$ = Compressor efficiency (0.2038 kW/cfm)

$Hours_{Annual}$ = 8,760 annual operating hours

Total project savings result in 119,815 kWh from the repair in air leak repairs.

RTU duct sealing

For RTU-13, which was found to be a constant volume unit that was operating at 100% flow for the entire evaluation monitoring period, the evaluator assigned 0 savings. This is because if the post-case fan is operating at 100%, the baseline could not have been running at more than 100%, so there could be no difference between baseline and post-case.

For RTU-14 and RTU-15, which were found to be variable air volume units, with forward curved fans and inlet guide vanes to control/modulate airflow, the evaluator-collected post-case measured kW data was used to estimate post-case airflow data, using the available %flow vs. %kW curve for forward curved fans with inlet guide vanes.

For RTU-14 and RTU-15, the post-case measured supply fan kW data was extrapolated to a full year in an 8760 spreadsheet, based on day of week, and hour of day variables. The baseline supply fan kW data was assumed to operate at 100%.

The fan savings for RTU-14 and RTU-15 were calculated for each hour of the 8,760 file.

The cooling savings for RTU-14 and RTU-15 were estimated by adjusting the CFM reduction values assumed in the tracking estimates to the observed/calculated post-case CFM values.

Final Results

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

Compressed air leak repair

Table 5-157 shows the differences in the key parameters used in the tracking analysis and the evaluator analysis for the compressed air leak repair measure. The evaluator used a more rigorous approach for estimating the flow reduction from fixing leaks, based on the pre and post CFM data collected by the vendor. The evaluator found that the compressors operate for 8,760 hours per year, they never shut off entirely, but they do operate at lower capacities, with different kW/cfm values, during evenings and weekends. The largest adjustment to this measure was due to the fact that since this project was completed, the old compressors were replaced with two new VFD compressors, which have a lower kW/CFM value. This is the main driver for the lower realization rate for this measure.

Table 5-157. Summary of key parameters used in tracking and evaluator methodology for compressed air leak repair measure

Variable	Tracking	Evaluation
Flow reduction from fixing leaks (CFM)	70.2	67.1
Annual operating hours	8,400	8,760
kW/CFM	0.204	0.168
kWh Savings	120,168	98,495

RTU duct sealing

Fan savings

Table 5-158 shows the differences in the key parameters used in the tracking analysis and the evaluator analysis for the fan savings portion of the RTU duct sealing measure. Some of the main drivers behind the differences in fan savings between the tracking methodology and the evaluator methodology include:

Finding that RTU-13 results in no savings since it was running at 100% flow in the post-case and is a constant volume unit

The evaluator use of a 0.746 kW/HP conversion factor

Evaluator finding that supply fans run 8,760 hours/year, rather than 6,426 hours per year

Differences in baseline and post-case kW values

Table 5-158. Summary of key parameters used in tracking and evaluator methodology for RTU duct sealing measure – fan savings

Variable	Tracking			Evaluator		
	RTU-13	RTU-14	RTU-15	RTU-13	RTU-14	RTU-15
Design Flow (CFM)	6,500	21,905	10,410	6,500	21,905	10,410
Baseline Leak Rate	15%	15%	15%	3%	14%	10%
Post Leak Rate	3%	3%	3%	3%	3%	3%
Normal operating flow % of design flow	100%	100%	100%	100%	100%	100%
Pre leakage rate (CFM)	975	3,286	1,562	195	3,020	1,087
Post leakage rate (CFM)	195	657	312	195	657	312
Flow to zone (CFM)	5,525	18,619	8,849	6,305	18,885	9,323
Baseline total flow	6,500	21,905	10,410	6,481	16,289	10,339
Post total flow	5,720	19,276	9,161	6,481	13,926	9,564
Baseline flow %	100%	100%	100%	99.7%	74%	99%
Post flow %	88%	88%	88%	99.7%	64%	92%
Design Brake Horsepower (HP)	2.5	22.7	6.8	2.5	22.7	6.8
Motor efficiency	87%	92%	90%	87%	92%	90%
Baseline VFD efficiency	100%	100%	100%	N/A - no VFDs on any units. RTU-13 is constant speed, RTU-14 and RTU-15 have inlet guide vanes.		
Post VFD efficiency	95%	95%	95%			
kW to HP conversion factor	1.0	1.0	1.0	0.746	0.746	0.746
Affinity Exponent	2.0	2.0	2.0	NA	NA	NA
Motor baseline kW	2.9	24.8	7.6	2.4	13.3	6.3
Motor post kW	2.4	20.2	6.2	2.4	10.2	5.7
Annual Hours	6,426	6,426	6,426	8,760	8,760	8,760
Baseline fan kWh	18,572	159,073	48,967	21,289	116,837	55,542
Post fan kWh	15,139	129,670	39,916	21,289	89,501	49,816
Fan energy savings (kWh)	3,433	29,403	9,051	0	27,335	5,726
Total fan energy savings (kWh)	41,888			33,061		

Cooling savings

Table 5-159 shows the differences in the key parameters used in the tracking analysis and the evaluator analysis for the cooling savings portion of the RTU duct sealing measure. The cooling portion of the savings of the duct-sealing measure only makes up 11% of the claimed savings for the duct-sealing measure altogether. Both the tracking savings and evaluator savings assumed that cooling savings occur when the outdoor air temperature is above 65° F. Differences in operating hours may be due to different weather data being used. The tracking calculations used binned weather data, the evaluator used a TMY3 file from the nearest weather station. The primary differences between the tracking and evaluator methodology are due to:

Finding that RTU-13 results in no savings since it was running at 100% flow in the post-case and is a constant volume unit

The measured post-case supply fan kW data-informed differences in baseline and post case OA CFM values.

Table 5-159. Summary of key parameters used in tracking and evaluator methodology for RTU duct sealing measure – cooling savings

Variable	Tracking			Evaluator		
	RTU-13	RTU-13	RTU-14	RTU-13	RTU-13	RTU-14
Baseline Total Average CFM (CFM)	6,500	21,905	10,410	6,481	16,289	10,339
Baseline Average OA CFM (CFM)	500	4,000	3,925	499	2,975	3,898
OA CFM Percent	8%	18%	38%	8%	18%	38%
Baseline Leak Rate	15%			3%	14%	10%
Post Leak Rate	3%			3%	3%	3%
Post Total Average CFM	5,720	19,276	9,161	6,481	13,926	9,564
Post Average Outdoor OA CFM	440	3,520	3,454	499	2,543	3,606
Air density (lb/ft3)	0.075			0.075		
Supply air enthalpy (Btu/lb)	23.0			23.0		
Weighted average ∆Enthalpy	7.81	7.81	7.81	7.81	7.81	7.81
Hours	1,659	1,659	1,659	1,801	1,801	1,801
Baseline Btu	29,164,412	233,315,296	228,940,634	31,561,071	188,315,323	246,787,664
Post Btu	25,664,683	205,317,461	201,467,758	31,561,071	160,993,445	228,285,911
COP	3.5	3.5	3.5	3.5	3.5	3.5
BTU to kWh conversion factor	3,412	3,412	3,412	3,412	3,412	3,412
Baseline kWh	2,430	19,443	19,078	2,630	15,693	20,566
Post kWh	2,139	17,110	16,789	2,630	13,416	19,024
Cooling energy savings (kWh)	292	2,333	2,289	0	2,277	1,542
Total cooling energy savings (kWh)	4,914			3,819		

Explanation of Differences

This section describes the key drivers behind the difference in the application and evaluation estimates. 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 5-160. Summary of Deviations

Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
Baseline	N/A	0	N/A
Applicant calculation methodology	N/A	0	N/A
Tracking and admin	N/A	0	N/A
Technology	N/A	0	N/A
Quantity	N/A	0	N/A
Operational	Multiple – see Table 5-158 and Table 5-159	-18.9%	**Decreased savings**
HVAC interactive	N/A	0	N/A
Final RR			**81.1%**

RICE18N084

Report Date: 05/25/2021

Application ID(s)	7651168	
Project Type	New construction	
Program Year	2018	
Evaluation Firm	DNV	
Evaluation Engineer	Long Vu	
Senior Engineer	George Sorin IOAN	

Evaluated Site Summary and Results

The project was installed at a supermarket equipped with three compressor racks serving low temperature (LT), medium temperature (MT), and coffin case applications. The energy efficiency measures were tracked as a single application and include the following sub-measures (tracking savings included for reference):

1. Installing night cover on 96 linear feet of vertical open cases – 146 kWh/yr
2. Installing refrigeration heat reclaim for use in the HVAC system – 146 kWh/yr
3. Installing two destratification fans – 1,423 kWh/yr
4. Installing 64 linear feet of coffin cases with an R-290 system and case lids – 22,349 kWh/yr
5. Installed CO_2-based LT system cascading into R-407A-based MT system – 22,403 kWh/yr

Sub-measures 4 and 5 collectively account for 96% of the tracking savings. These sub-measures save energy by achieving higher refrigeration efficiency compared to the respective baseline systems. During the site visit, the evaluators were only able to verify the installation of the first three sub-measures, but were not able to install metering equipment or obtain EMS data about the operation of those three impacted measures. As a result, the evaluators used the savings output from the applicant savings analysis as the evaluated savings for the first three sub-measures. Because there was an error when the implementation vendor submitted the project documentation, the tracking savings (which should be the same values as the output of the applicant savings analysis) are different from the savings included in the applicant analysis. Additional details about this difference are included in Table 3-1.

In addition, the metering equipment that the evaluators installed on the coffin cases in sub-measure 4 only captured the lighting load of the installed system. As the result, the evaluators calculated the savings for this sub-measure using the on-site findings along with the information included in the specification cutsheet of the as-built cases.

The evaluators calculated the savings for sub-measure 5 using the on-site findings and metered data.

The applicant classified the measure as a new construction with an ISP baseline. The applicant ISP referenced IECC 2012.

The evaluators classified this measure as a lost opportunity with an ISP, with IECC 2012 as the applicable ISP. The evaluators agreed with the applicant's baseline descriptions

The evaluators interviewed the facility manager and learned that the facility's operation was not impacted by the pandemic and the impacted equipment operation metering period (March through May, 2021) is representative. Based on information provided by the site contact, the evaluators conducted the evaluation for this site using a standard M&V method.

The evaluator calculated the project savings using the same methodology as the applicant's with updated input parameters. The applicant calculated the project savings using eQuest Refrigeration v3.65. The evaluators reviewed the applicant's eQuest model input files and found the modelling methodology reasonable. The evaluators calculated the project impacts using the same methodology with updated input parameters based on on-site findings and metered data. The evaluated savings were greater than the reported tracking value primarily because the as-built coffin cases have lower annual energy consumption than the applicant predicted value, which indicate that the as-built coffin cases have higher performance than predicted by the applicant. The evaluation results are presented in Table 1-1.

Table 5-161. 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)
7651168	Custom refrigeration	Tracked	46,467	58%	3.89	5.23
		Evaluated	51,035	75%	3.16	4,82
		Realization rate	110%	129%	81%	92%

Explanation of Deviations from Tracking

The evaluated savings are 10% higher than the reported savings primarily because the as-built coffin cases have a higher performance than predicted by the applicant. Further details regarding deviations from the tracked savings are presented in Section 3-1.

Recommendations for Program Designers & Implementers

There are no recommendations at this site.

Customer Alert

There are no customer alerts at this site.

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 was installed at a grocery store as part of a major renovation project and consisted of installing five sub-measures:

1 Night cover on 96 linear feet of vertical open cases

2 Refrigeration heat rejection to HVAC system for heat reclaim

3 Two destratification fans

4 Sixty-four linear feet of coffin cases with R-290 system and case lids

5 CO_2-based LT system cascading into R-407A-based MT system

5.1 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.

Applicant Description of Baseline

The applicant classified the project as a new construction with an ISP baseline. The applicant used 2012 IECC to define the baseline. The applicant baseline condition consisted of the following:

1. Ninety-six linear feet of vertical open cases with no night cover
2. HVAC system does not utilize refrigeration heat rejection for heat claim
3. No destratification fans
4. Sixty-four linear feet of coffin cases utilize R-22 refrigerant and have no case lids
5. LT system utilizes R-407A refrigerant and a separate air-cooled condenser

The applicant modelled the baseline using eQuest Refrigeration v3.65. The applicant's baseline characterization is reasonable. Table 5-129 presents the applicant's baseline key input parameters.

Table 5-162. Applicant baseline key parameters

Sub-measure	Parameter	Value(s)	Source of Parameter Value
1	Air infiltration load	1.209 Btu/h-ft at all time	Model input
1	Vertical cases length	96 ft	Model input
2	Refrigeration heat reclaim	No	Model input
3	Heating setpoint	68°F from 6 a.m. through 11 p.m. 60°F from 11 p.m. through 6 a.m.	Model input
3	Destratification fan hours	0	Model input
4	Refrigerant	R-22	Model input
4	Coffin case lid	No	Project documentation
4	Surface conduction	225.2 Btu/h-ft	Model input
4	Air infiltration load	163.1 Btu/h-ft	Model input
4	Operating temperature	-8°F	Model input
4	Case display perimeter	64 ft	Model input
4	Coffin case operating hours	8,760 hours	Model input
4	Coffin case average demand	6.4 kW	Calculated value from model input
5	Refrigerant	R-407A	Model input
5	Saturated condensing temperature (SCT)	96°F	Model input
5	Backflooding setpoint	94°F	Model input
5	Compressor electric power	11.7 kW	Model input
5	Compressor rated saturated suction temperature (SST)	-25°F	Model input
5	Compressor rated saturated discharge temperature (SDT)	105°F	Model input
5	Compressor rated superheat	90°F	Model input
5	Condenser type	Air-cooled	Model input
5	LT compressor consumption	85,053 kWh	Model output

Applicant Description of Installed Equipment and Operation

The applicant proposed condition consisted of the following:

1. Ninety-six linear feet of vertical open cases with night cover
2. HVAC system utilizes refrigeration heat rejection for heat claim
3. Two destratification fans are installed in the facility
4. Sixty-four linear feet of coffin cases utilize R-290 refrigerant and are equipped with case lids
5. LT system is a CO_2-based system cascading to the R-407A-based MT system

The applicant modelled the proposed condition using eQuest Refrigeration v3.65. For sub-measure 5, because the CO_2-based LT system rejects heat to the suction side of the MT system rather than the outside air, the SDT of the LT system approaches the SST of MT system.

Table 5-129 presents the applicant's proposed key input parameters.

Table 5-163: Applicant proposed key parameters

Sub-measure	Parameter	Value(s)	Source of Parameter Value
1	Air infiltration load	967.2 Btu/h-ft from 11 p.m. through 6 a.m. 1,209 Btu/hr-ft from 6 a.m. through 11 p.m.	Model input
1	Vertical case length	96 ft	Model input
2	Refrigeration heat reclaim	Yes	Model input
3	Heating setpoint when destratification fan on	62°F from 6 a.m. through 11 p.m. 60°F from 11 p.m. through 6 a.m.	Model input
3	Destratification fan hours	3,624 hours	Model input
4	Refrigerant	R-290	Model input
4	Coffin case lid	Yes	Project documentation
4	Surface conduction	181.9 Btu/h-ft	Model input
4	Air infiltration load	131.7 Btu/h-ft	Model input
4	Operating temperature	-8°F	Model input
4	Cases display perimeter	64 ft	Model input
4	Coffin case operating hours	8,760 hours	Model input
4	Coffin case average demand	3.73 kW	Calculated value from model input
5	Refrigerant	R-744	Model input
5	Saturated condensing temperature	25°F	Model input
5	Backflooding setpoint	23°F	Model input
5	Compressor electric power	4.7 kW	Model input
5	Compressor rated saturated suction temperature	-31°F	Model input
5	Compressor rated saturated discharge temperature	14°F	Model input
5	Compressor rated superheat	36°F	Model input
5	Condenser type	Cascaded	Model input
5	LT compressor consumption	22,696 kWh	Model output

Applicant Energy Savings Algorithm

The applicant used eQuest Refrigeration v3.65 to model the baseline and proposed annual energy consumption. The applicant modelled the building systems not impacted by the measure (lighting, HVAC, envelope etc.) identically in both the baseline and proposed models.

For sub-measure 4, the applicant modelled the impacted system as a R-22-based system in the baseline and as R-290-based system with reduced surface conduction and infiltration in the proposed case.

For sub-measure 5, the applicant modelled the impacted system as R-407A-based system with air-cooled condenser in the baseline and R-744-based system cascading onto the R-407A MT system.

For sub-measure 1-3, the applicant modelled the impacted system as having no night cover, heat reclaim and destratification fans in the baseline. Night cover, heat reclaim, and destratification fans were added to the proposed model.

The applicant created two models, one for the baseline and one for the proposed condition. The applicant calculated the project savings as the difference in annual energy consumption between the baseline and proposed models.

Evaluation Assessment of Applicant Methodology

The evaluators found the applicant's use of eQuest Refrigeration v3.65 for modelling baseline and proposed annual energy consumptions appropriate.

The energy savings output from the models provided by the applicant (47,766 kWh) were close but did not a complete match with the reported tracking value (46,467 kWh). The evaluators contacted the implementation vendor and learned that this was due to errors when the vendor submitted the project documentation to the PA.

The evaluators calculated the project savings using eQuest Refrigeration v3.65 with updated input parameters from on-site findings and metered data. More details are provided in the subsequent sections.

On-Site Inspection and Metering

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

Summary of On-site Findings

The evaluators conducted the logger deployment and retrieval site visits on March 08, 2021 and May 19, 2021, respectively. During the site visit, the evaluators interviewed the facilities manager to better understand the operation of the refrigeration and the HVAC systems and visually verified the installation of the evaluated measures. During the site visit, the evaluators performed the following tasks:

- Verified all sub-measures were installed and operating as intended
- Verified the length of the impacted vertical cases reasonably matches the applicant value (96 feet)
- The evaluators found there was a total of 8 coffin cases installed in the project. Based on the performance cutsheet information of the installed cases, the total length of the as-built cases are 56 feet, which is different from the value predicted by the applicant (64 feet)
- Obtained nameplate data and specification cutsheet of the installed coffin cases.
- Obtained mechanical schedule of the LT refrigeration system

Photos 2-1 to 2-7 show the installed measures.

Photo 2-1. Night cover on vertical open cases

Photo 2-2. Refrigeration heat rejection to HVAC system for heat reclaim

Photo 2-3. Destratification fan

Photo 2-4. Coffin cases with R290 system and case lids

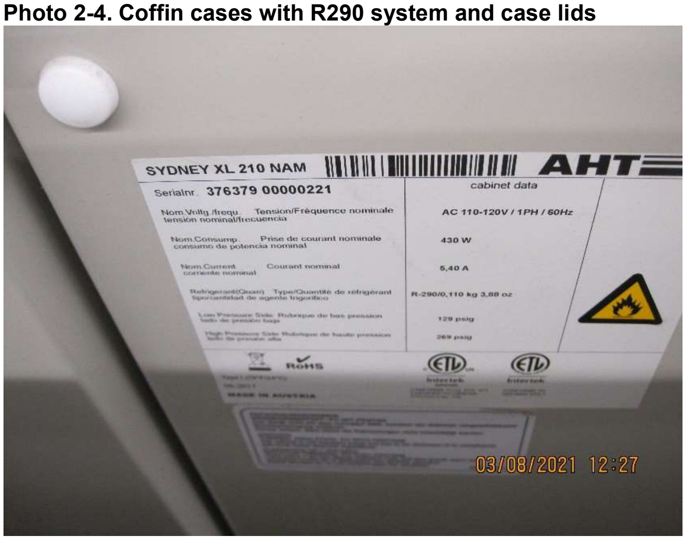


Photo 2-5. Coffin cases – specification cutsheet

e-conomize POWER SAVER PLUS							
250		XL 175		XL 210		XL 250	
(-) VS AD IQ LED	(U)** VS AD IQ LED	(-) VS AD IQ LED	(U)** VS AD IQ LED	(-) VS AD IQ LED	(U)** VS AD IQ LED	(-) VS AD IQ LED	(U)** VS AD IQ LED
1343	1343	957	957	1178	1178	1430	1430
938	927/615/891	658	634/417/608	817	799/528/768	999	887/655/950
1,69	1,69	1,21	1,21	1,49	1,49	1,8	1,8
3L1	3S/3S/3L1	3L1	3S/3S/3L1	3L1	3S/3S/3L1	3L1	3S/3S/3L1
+16 to +25	+16 to +25	+16 to +25	+16 to +25	+16 to +25	+16 to +25	+16 to +25	+16 to +25
−18 to −23	+3 to +15/ 0 to +2/−18 to 23	−18 to −23	+3 to +15/ 0 to +2/−18 to 23	−18 to −23	+3 to +15/ 0 to +2/−18 to 23	−18 to −23	+3 to +15/ 0 to +2/−18 to 23
43,6	43,6	43,6	43,6	43,6	43,6	43,6	43,6
220–240/50	220–240/50	220–240/50	220–240/50	220–240/50	220–240/50	220–240/50	220–240/50
450	450	430	380	430	430	450	450
46	46	34	34	39	39	46	46
2,9	2,9	2,7	2,3	2,7	2,7	2,9	2,9
16	16	16	16	16	16	16	16
5,9	1,7/3,2/5,9	5,3	1,5/3,0/5,3	5,8	1,6/3,2/5,8	6,4	1,8/3,5/6,4
1750	1750	1750	1750	1750	1750	1750	1750
R290	R290	R290	R290	R290	R290	R290	R290
130	130	100	100	110	110	140	140
30	30	30	30	30	30	30	30
2502/2373	2502/2373	1752/1623	1752/1623	2102/1973	2102/1973	2502/2373	2502/2373
993/813	993/813	1043/863	1043/863	1043/863	1043/863	1043/863	1043/863
860/910	860/910	860/910	860/910	860/910	860/913	860/913	860/913
560	580/390/560	560	580/390/560	560	580/390/560	560	580/390/560

Photo 2-6. Coffin cases – operating temperature

Photo 2-7. CO_2-based LT system cascading into R407A-based MT system

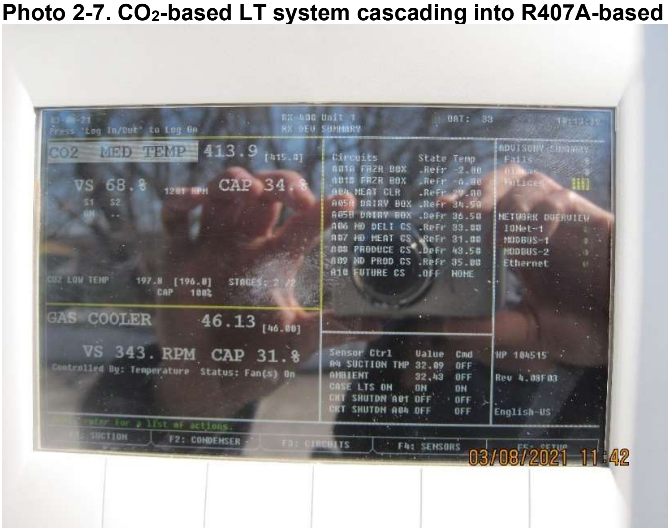


Photo 2-7 above shows that the suction head of the CO_2-based system is at 413.9 psig. The evaluators used the temperature-pressure (PT) chart for R-744 (CO_2) and determined that the saturated condensing temperature (SCT) at 413.9 psig is 21.2°F.

The evaluators also obtained the mechanical schedule of the refrigeration system at the facility. Photo 2-8 and 2-9 present the mechanical schedule.

Photo 2-8. Mechanical Schedule – Compressors

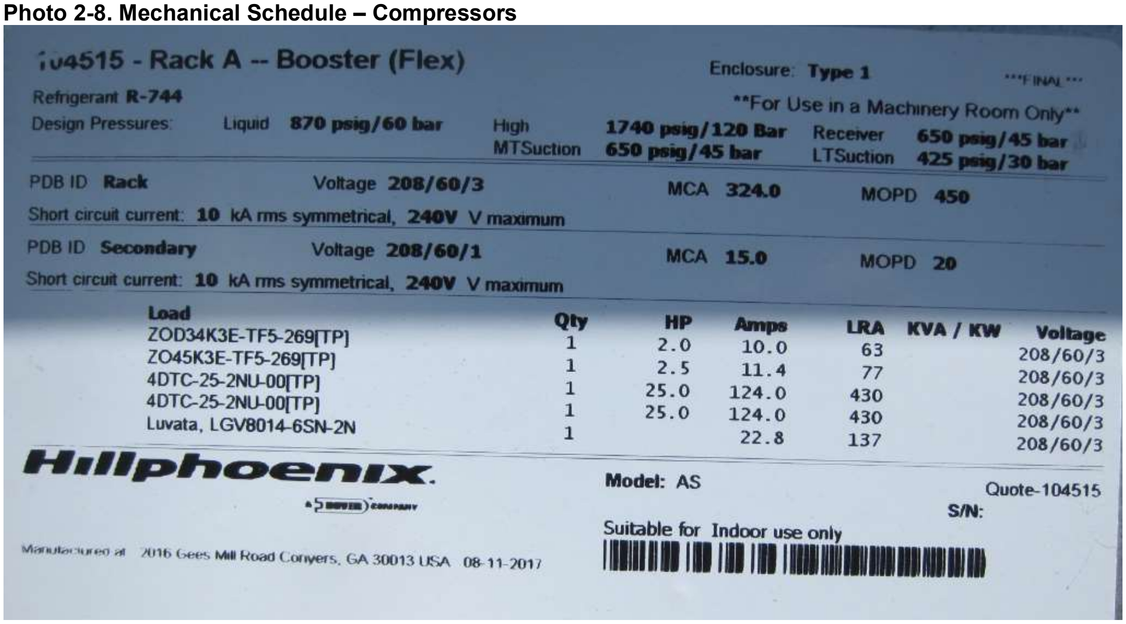


Photo 2-9. Mechanical Schedule – LT Suction Group

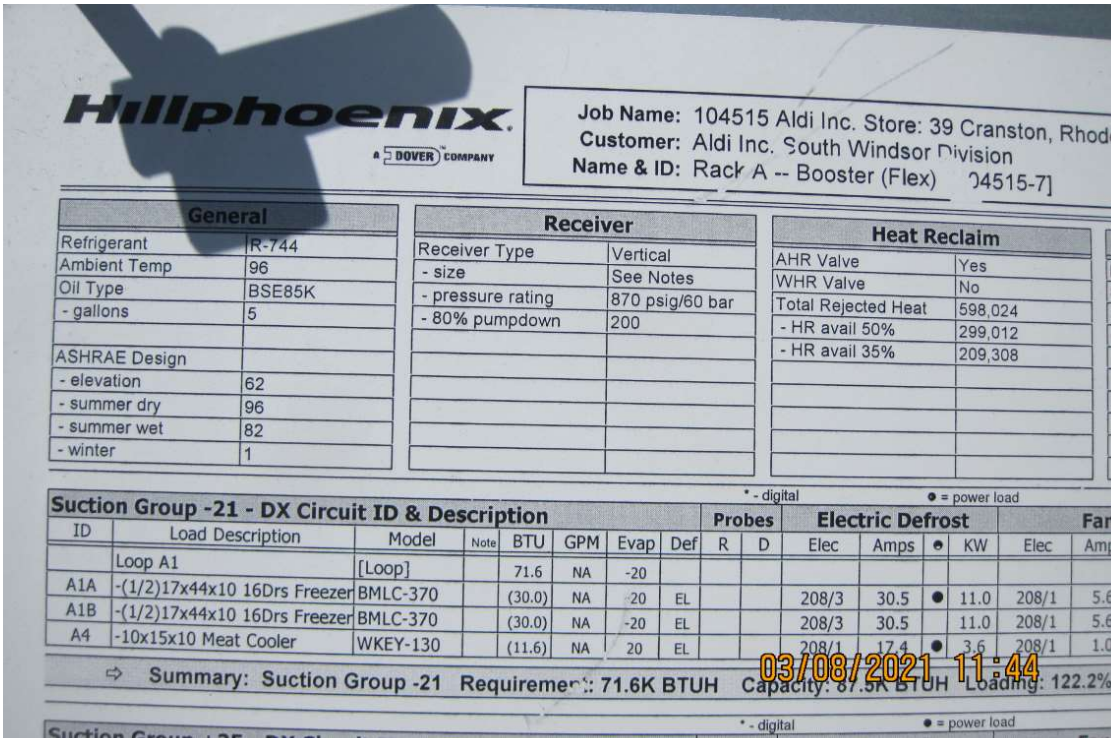


Photo 2-8 and 2-9 above show that the as-built LT compressors (the ones with model numbers ZOD34K3E and ZO45K3E) use R-744 refrigerant, and the design temperature setpoint for the LT suction group is at -21°F.

The evaluators calculated the compressor electric demand based on the information included in the mechanical schedule using the following formula.

$$kW_{comp} = \frac{HP_{comp} \times 0.746}{motor_{eff}}$$

where:

kW_{comp}	= electrical demand for the LT compressors, kW
HP_{comp}	= horsepower of the LT compressors, hp
0.746	= conversion factor from hp to kW
$motor_{eff}$	= motor efficiency, estimated to be 80%

The calculated electric demands for the two LT compressors are 1.9 and 2.3 kW. Table 2-3 provides a summary of the measure verification method.

Table 2-164. Measure Verification

Measure Name	Verification Method	Verification Result
Night cover on vertical open cases	Visual inspection	All inspected covers have been installed.
Refrigeration heat rejection to HVAC system for heat reclaim	Visual inspection	The inspected unit has been installed.
Destratification fans	Visual inspection	Both fans have been installed.
Coffin cases with R290 system and case lids	Visual inspection	All inspected cases have been installed.
CO_2-based LT system cascading into R407A-based MT system with VFDs on condenser fans	Visual inspection	The inspected unit has been installed.

Measured and Logged Data

During the site visit, the evaluators deployed current transformers (CT) with loggers and plug load loggers on the following equipment:

- Compressors serving the LT racks
- Two of seven inspected coffin cases

The metering period was from March 8, 2021 through May 19, 2021. Table 2-4 presents the logger deployment details.

Table 2-4. Evaluation Data Collection – Installed Equipment

Parameter	M&V Equipment Brand and Model	Metering Start/Stop Dates	Metering Interval
Electric current (amperage)	2 x HOBO logger w/current transformer probes	03/08/2021 – 05/19/2021	15 minutes
Electric demand (watt)	2 x Plug load loggers	03/08/2021 – 5/19/2021	1 hour

When reviewing the metered data, the evaluators found that the plug load loggers installed on the coffin cases only recorded the lighting wattage of the cases. It is likely there is a separate electrical circuit that serves the compressor and condenser of the installed cases (as also supported by the information included in Photo 2-5) and the evaluators were not able to identify the other electrical circuit during the site visit. Because the metered data of the installed cases do not account for the whole unit electrical demand, the evaluators were not able to use metered data to evaluate sub-measure 4. Figure 2-1 and 2-2 show the graphical summary of the metered data.

Figure 2-1. LT Compressors Operation from 03/08/2021 through 05/19/2021

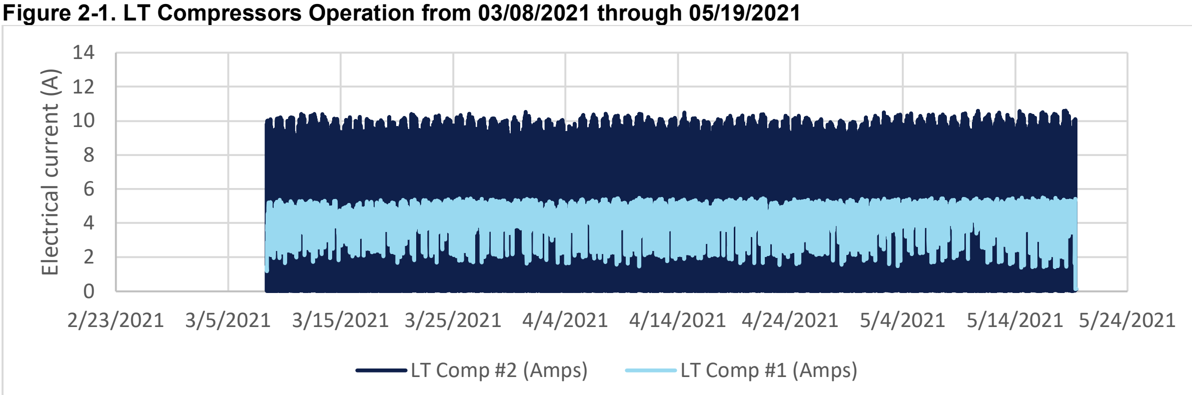


Figure 2-1 shows that the LT compressor 1 is operating at lower load than the full load capacity and the LT compressor 2 is operating at full load capacity.

Figure 2-2. Coffin Case Operation from 03/08/2021 through 05/19/2021

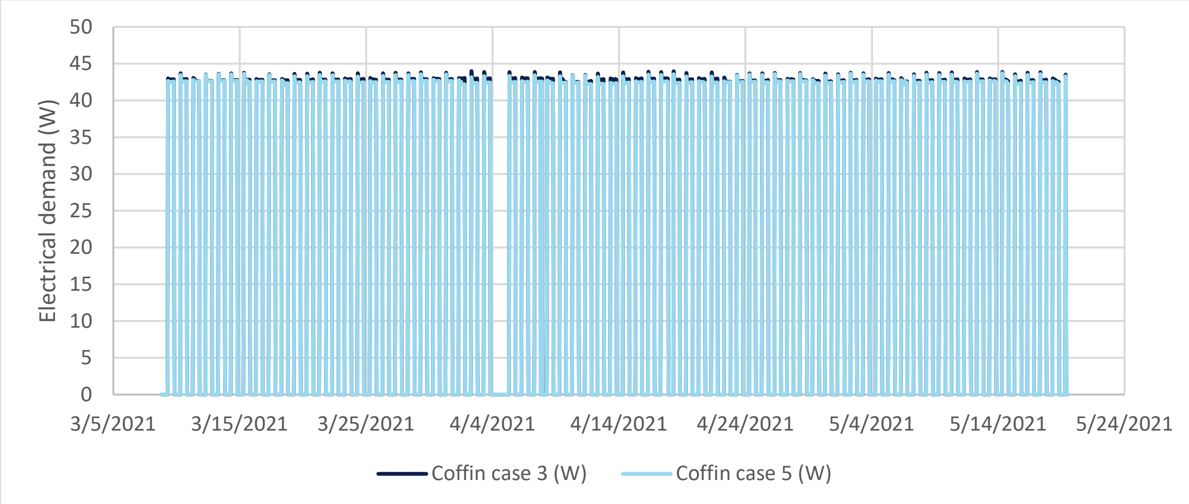


Figure 2-2 above shows that the demand of the metered cases is at the maximum of approximately 43 W. This value is close to the lighting demand information included in Photo 2-5 which indicates that the metered data reflects the lighting load of the metered cases.

During the site visit, the evaluators spot-measured both LT compressors. Table 2-5 presents the spot-measured data.

Table 2-5. Spot-measured Data

Equipment	Electric Current	Voltage	PF	kW
LT#1	3.18	118	0.87	0.77
LT#2	9.5	116	0.89	0.91

The evaluators calculated the electric power of the metered equipment using the following formula:

$$kW = \frac{Amp \times Volt \times PF \times 3}{1{,}000}$$

where:

kW = energy power of the metered equipment, kW

$Volt$ = phase to ground voltage, average of 117 V

PF = power factor, 0.88

The evaluators developed the following relationship between the LT compressors' electrical demand and outside air condition. Figures 2-3 and 2-4 present the developed relationships.

Figure 2-3. Electrical Demand versus Outside Air Temperature – LT Compressor 1

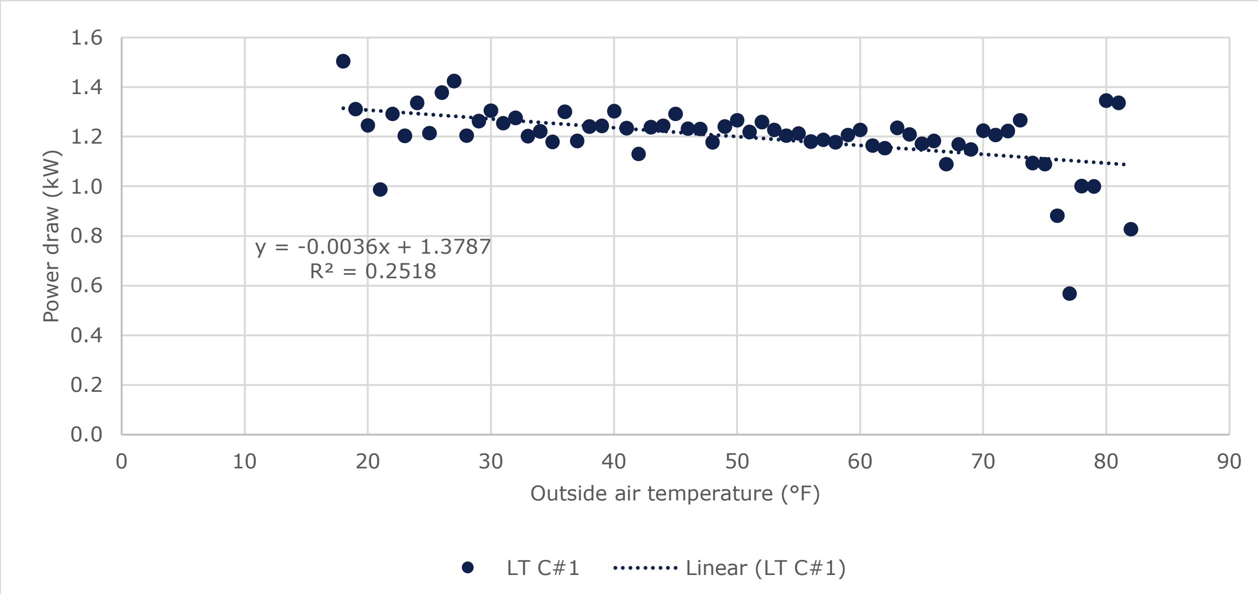
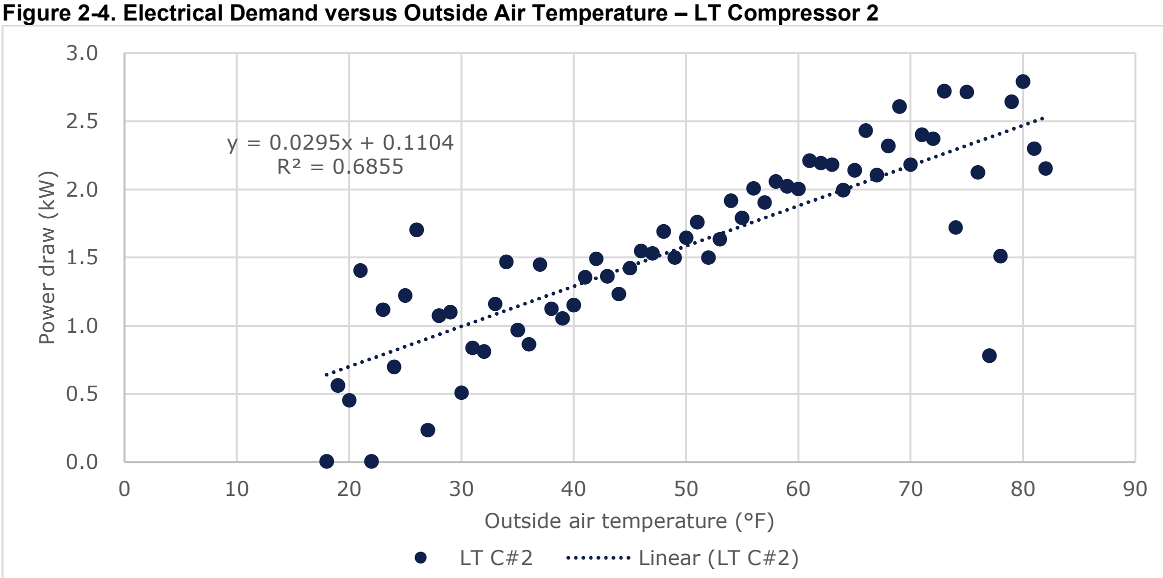


Figure 2-4. Electrical Demand versus Outside Air Temperature – LT Compressor 2



The evaluators used the developed relationships and TMY3 weather data for Providence, RI to calculate the weather-normalized annual energy consumption of the LT compressors. The calculated energy consumption for both compressors is 24,610 kWh.

Evaluation Methods and Findings

This section describes the evaluator methods and findings.

Evaluation Description of Baseline

The evaluator reviewed the project files and interviewed the site contact to gather information on the baseline. Base on the information provided in the project files and by the site contact, the evaluator classified the project as a lost opportunity with ISP as the baseline. For sub-measure 1, 2, 3 and 5, the evaluators used the same baseline information as the applicant. For sub-measure 4, because the evaluators were not able to find any information about coffin cases in 2012 IECC, the evaluators used Federal Energy Conservation Standard (FECS) to determine the baseline for this sub-measure.

Table 2-6 presents the evaluators' baseline key input parameters.

Table 5-6. Evaluator baseline key parameters

Sub-measure	Parameter	Value(s)	Source of Parameter Value
1	Air infiltration load	1.209 Btu/h-ft at all time	Model input – same as the applicant value
2	Refrigeration heat reclaim	No	Same as the applicant value
3	Heating setpoint	68°F from 6 a.m. through 11 p.m. 60°F from 11 p.m. through 6 a.m.	Same as the applicant value
3	Destratification fan hours	0	Same as the applicant value
4	Refrigerant	R22	Same as the applicant value
4	Coffin case lid	No	Project documentation
4	Surface conduction	225.2 Btu/h-ft	Same as the applicant value
4	Air infiltration load	120.00 Btu/h-ft	Adjustment on the model to calibrate to the baseline annual consumption value calculated using FECS
4	Operating temperature	-13.5°F	On-site findings
4	Case display perimeter	56 ft	On-site findings
4	Coffin case operating hours	8,760 hours	Same as the applicant value
4	Coffin case average demand	5.8 kW	Calculated value using FECS
4	Total display area (TDA) per coffin	18.31 sq.ft.	Specification cutsheet of the installed coffin case
4	Installed cases quantity	8	On-site findings
5	Refrigerant	R-407A	Same as the applicant value
5	SCT	96°F	Same as the applicant value
5	Backflood setpoint	94°F	Same as the applicant value
5	Compressor electric power	11.7 kW	Same as the applicant value
5	Compressor SST	-25°F	Same as the applicant value
5	Compressor SDT	105°F	Same as the applicant value
5	Compressor rated superheat	90°F	Same as the applicant value
5	Condenser type	Air-cooled	Same as the applicant value
5	LT compressor consumption	85,053 kWh	Same as the applicant value

Evaluation Calculation Method

Sub-measure 1, 2 and 3:

For sub-measure 1, 2, and 3, the evaluators performed an on-site verification to verify the installation of the sub-measures. The evaluators were not able to install metering equipment on the impacted system because the impacted systems in these sub-measures were not accessible. The evaluators found the applicant's modelling methodology to be reasonable and used the applicant savings values as the evaluated savings for these sub-measures. The total energy savings associated with the sub-measures is 1,919 kWh.

Sub-measure 4:

The evaluators calculated the annual energy consumption of the baseline coffin cases using the following formula:

$$kWh_b = (0.57 \times TDA + 6.88) \times Qty \times day$$

where:

kWh_b	= annual energy consumption of the baseline cases, kWh
TDA	= total display area of the installed coffin case, 18,31 sq.ft.
0.55	= calculation factor, determined by FECS

6.88	= calculation factor, determined by FECS
244	= conversion factor from square inch to square feet
Qty	= quantity of the baseline cases, 8
day	= number of days in a year, 365

The calculated annual energy consumption using the formula above is 50,565 kWh.

Because loggers that the evaluators installed on the as-built coffin cases only captured the lighting load of the cases, the evaluators used information included in Photo 2-5 to determine the annual energy consumption of the as-built cases. Photo 2-4 shows that the model number of the as-built cases is Sydney XL 210, and Photo 2-6 shows that the operating temperature of the as-built cases is -13.5°F. Using these information, the evaluators determined the average daily consumption and the annual consumption of the as-built cases are 5.9 kWh/case and 16,936 kWh, respectively. The calculated annual consumption of the as-built cases is smaller than the applicant predicted value (32,675 kWh). This indicates that the as-built cases have lower infiltration rate and conduction rate than the applicant values. This lower infiltration rate and conduction rate show that the as-built units perform better than predicted by the applicant and do not impact the performance of the baseline cases.

The evaluators updated the following operating points in both evaluated baseline and as-built model for this sub-measure:

- Total case length: from 64 feet (applicant value) to 56 feet (on-site finding)
- Operating temperature of the as-built cases: from -8°F (applicant value) to -13.5°F (on-site findings)

The evaluators also updated the conduction and air infiltration rate in the evaluated eQuest models to calibrate the consumption of the baseline and as-built coffin cases to the calculated consumption values (using FECS and specification cutsheet document). The updates on the conduction and air infiltration rate are the following:

- Infiltration rate of the baseline coffin cases: from 163.08 Btu/h-ft (applicant value) to 110 Btu/h-ft
- Conduction rate of the as-built coffin cases: from 181.87 Btu/h-ft (applicant value) to 110 Btu/hr-ft
- Infiltration rate of the as-built coffin cases: from 131.7 Btu/hr-ft (applicant value) to 30 Btu/hr-ft

Table 2-7 presents the comparison between the consumption of the coffin cases from the calibrated models and the calculated values using FECS and specification cutsheet.

Table 2-7. Energy consumption comparison

Equipment	FESC	Evaluated Calibrated eQuest Model	% Difference
Baseline coffin cases	50,565 kWh	51,585 kWh	1.3%
As-built coffin cases	16,936 kWh	17,587 kWh	4%

Using the outputs of the evaluated calibrated eQuest models, the evaluators determined that the evaluated savings for sub-measure 4 is 30,299 kWh.

Sub-measure 5:

The updated input parameters evaluators used in the eQuest model are presented in Table 2-8:

Table 5-8. Evaluator key parameters (not measure-dependent)

Parameter	Value(s)	Source of Parameter Value
SCT	21.2°F	Determined based on suction group pressure in Photo 2-5
Backflood setpoint	19.2°F	2°F less than SCT (same assumption as the applicant)
Compressor electric power	4.2 kW	Calculated values using information included in the mechanical schedule
Compressor SST	-21°F	Mechanical schedule of the LT suction group
Compressor SDT	21.2°F	Same as SCT

The evaluated modelled annual energy consumption of the LT compressors after the updates included in the table above is 25,269 kWh, which is within reasonable agreement with the evaluators' calculated value (Section 2.3.2 above – 24,610 kWh). This indicates that the modelled refrigeration load for the LT system reasonably reflects the as-built condition. The evaluators used the modelled savings output of the eQuest with the above updated input parameters as the evaluated savings for this sub-measure, the evaluated savings for sub-measure 5 is 18,817 kWh.

Final Results

The project was installed at a grocery store as part of a major renovation project and consisted of installing five sub-measures:

1. Night cover on 96 linear feet of vertical open cases
2. Refrigeration heat rejection to HVAC system for heat reclaim
3. Two destratification fans
4. 64 linear feet of coffin cases with R290 system and case lids
5. CO_2-based LT system cascading into R407A-based MT system

Table 3-1 presents the measure-by-measure evaluated and tracking savings.

Table 3-1. Evaluated savings versus tracking savings

Sub-measure	Evaluated Savings (kWh)	Tracking Savings (kWh)
1	155	146
2	507	146
3	1,257	1,423
4	30,299	22,403
5	18,817	22,349

The project saves energy because it achieves a higher refrigeration efficiency compared to the respective baseline system. For sub-measure 1-3, the evaluator verified the installation of the sub-measures during the site visit and used the savings value in the applicant eQuest models as the evaluated savings. For sub-measure 4 and 5, the evaluators calculated the savings using a similar methodology with the one used by the applicant with updated input parameters. The evaluated savings are greater than the reported values. The parameters impacted the analysis are summarized in Table 3-2.

Table 5-2. Summary of Key Parameters

Sub-measure	Parameter	BASELINE Tracking Value(s)	BASELINE Evaluation Value(s)	PROPOSED / INSTALLED Tracking Value(s)	PROPOSED / INSTALLED Evaluation Value(s)
1	Air infiltration load (Btu/h-ft)	1,209 at all time		967.2 from 11 p.m. to 6 a.m. and 1,209 from 6 a.m. to 11 p.m.	
1	Vertical cases length (ft)	96		96	
2	Refrigeration heat reclaim	No		Yes	
3	Heating setpoint when destratification fan ON (°F)	68 from 6 a.m. to 11 p.m. and 60 from 11 p.m. to 6 a.m.		62 from 6 a.m. to 11 p.m. and 60 from 11 p.m. to 6 a.m.	
3	Destratification fan hours	0		3,624	
4	Refrigerant	R-22		R-290	
4	Coffin case lid	No		Yes	
4	Surface conduction (Btu/h-ft)	225.2	225.2	181.9	110
4	Air infiltration load (Btu/h-ft)	163.1	110	131.7	30
4	Operating temperature (°F)	-8	-13.5	-8	-13.5
4	Case display perimeter (ft)	64	56	64	56
4	Coffin case operating hours	8,760		8,760	
4	Coffin case average demand (kW)	6.4	5.8	4.0	2.0
5	Refrigerant	R-407A		R-744	
5	SCT (°F)	96		25	21.2
5	Backflooding setpoint (°F)	94		23	19.2
5	Compressor electric power (kW)	11.7		4.7	4.2
5	SST (°F)	-25		-31	-21
5	SCT (°F)	105		14	21
5	Compressor rated superheat (°F)	90		36	
5	Condenser type	Air-cooled		Cascaded	
5	LT compressor consumption (kWh)	85,053		22,696	25,269

N/A = Not applicable

Explanation of Differences

The evaluated savings are greater than the reported value primarily because the as-built coffin cases have higher performance than predicted by the applicant (lower infiltration rate and conduction rate). This difference resulted in a greater savings for sub-measure 4. Table 3-3 provides a summary of the difference between the tracking and the evaluated values.

Table 5-3. Summary of Deviations

Measure	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
7651168	Operational	Operating load	30%	**Increased savings** – The electrical energy consumption of the as-built coffin cases was smaller than the applicant value, which indicated that the infiltration rate and the conductance rate of the as-built system are smaller than the applicant value. The lower infiltration rate and conduction rate show that the as-built systems performed better than predicted and does not impact the performance of the selected baseline systems.
7651168	Operational	Operating point	-14%	**Decreased savings** – The evaluators updated the input parameters in the eQuest model to account for the operating condition of sub-measure 4 and 5 based on on-site findings.
7651168	Operational	Operating hour	-9%	**Decreased savings –** The evaluators used FECS to determine the energy consumption of the baseline coffin cases. The calculated energy consumption is lower than the output from the applicant eQuest value.
7651168	Non-operational	Tracking error	+3%	**Increased savings** – There was an error of the vendor's submission of project documentation to the PA which resulted in smaller tracking savings than the applicant savings.
Final RR				**RR% = 110%**

Ancillary impacts

The ancillary impacts from the eQuest model output are 3,240 therms.

RICE18N089

Report Date: 15 November 2022

Application ID(s)	7999568	
Project Type	C&I Initial Purchase & End of Useful Life	
Program Year	2018	
Evaluation Firm	DMI	
Evaluation Engineer	Patrick Terrio	
Senior Engineer	Mickey Bush	

Evaluated Site Summary and Results

This project considers the renovation of an existing 20,000 ft² industrial building into an indoor horticulture cannabis grow facility. Mother, clone and vegetation phase lighting fixtures operate for 18 hours each day. Flower room lighting fixtures operate for 12 hours per day, with the schedule staggered on a room to room basis.

There are two new construction energy savings measures associated with the project:

ECM 1, Phase 1 LED Process Lighting: The customer installed LED grow lighting fixtures in Flower Room 4 (88 x 660W LEDs). The installed LED grow lighting fixtures use less energy than 1,000W high pressure sodium grow lighting fixtures while providing similar photosynthetic photon flux density (PPFD). The energy savings come from a reduction in lighting power and a reduction in CAV RTU fan sizing. Natural gas savings were claimed through a reduction in space reheat load (on account of a reduction in equipment size).

ECM 2, 16 SEER Condensing Units: The customer installed six high performance condensing units to provide dehumidification to the flowering room. The installed condensing units have improved part-load cooling performance (16 SEER) over the energy code required minimum performance (13 SEER).

The evaluator reduced ECM 1 measure savings to account for manual dimming control of the installed LEDs. The baseline HPS fixtures would also need to be dimmed (and/or staged) comparably to maintain the same level of production (i.e. product output and quality).

The evaluator removed ECM 2 from the project based upon a review of the source of performance improvements. The energy efficient features of a 16 SEER condensing unit are not included in this application.

The customer noted that operations were not significantly impacted by the coronavirus pandemic, so a full operational evaluation was done. The evaluation results are presented in Table 1-1.

Table 5-165. 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)
7999568-1	Phase 1 LED Process Lighting	Tracked	248,899	65.0%	52.50	51.34
		Evaluated - ops	84,021	65.7%	16.79	16.79
		Realization Rate	33.8%	101.2%	32.0%	32.7%
7999568-2	16 SEER Condensing Units	Tracked	17,605	49.6%	2.45	2.22
		Evaluated - ops	0	-	0	0
		Realization Rate	0%	0%	0%	0%
Totals		**Tracked**	**266,504**	**64.0%**	**54.95**	**53.56**
		Evaluated - ops	**84,021**	**65.7%**	**16.79**	**16.79**
		Realization Rate	**31.5%**	**102.7%**	**30.6%**	**31.4%**

Explanation of Deviations from Tracking

The evaluator reduced ECM 1 measure savings based upon customer specific operation of the installed LEDs:

- The LEDs are dimmable and the customer operates them at reduced lighting output (and thus reduced wattage). The baseline HPS fixtures would also need to be dimmed (and/or staged) comparably to maintain the same level of production (i.e. product output and quality), which lowers the measure savings opportunity.
- The baseline HPS ballast losses were reduced to match the Cannabis ISP document, which lowered the measure savings.

- Eleven of the eighty-eight flowering fixtures were moved into the vegetation room, which operate at a lower dimming percentage, but for more hours of each day.
- The baseline CAV rooftop units did not need to be re-sized to serve the sensible load, which eliminates fan savings.
- Heating in the space is provided by electric heat pumps which changes a natural gas penalty into an electric penalty.

It was determined that ECM 2 was not a measure based upon a review of the installed condensing unit.

- A 16 SEER performance rating is a system-level rating inclusive of both indoor unit performance (evaporator fan power) and outdoor unit performance (condenser fan power and compressor fan power). The installed compressor and condenser are rated for 16 SEER in HVAC applications when paired with a ’16 SEER’ air handling unit. The condensing unit is instead paired with a Subcooled 705 dehumidifier, which does not have an EC fan motor and serves process dehumidification/cooling loads. The condensing unit also has an outdoor low ambient kit which throttles the saturated condensing temperature. The ‘high performance features’ that represent a performance improvement from 13 SEER to 16 SEER are not applicable for this unit.

Further details regarding deviations from the tracked savings are presented in Section 0.

Recommendations for Program Designers & Implementers

The majority of the savings adjustments were related to the customer’s dimming schedule. This is something that is typically unknown during the early stages of project development, so the TA vendor reasonably assumed that the fixtures would operate at peak output.

It may be recommended for program designers and implementers to assume a process grow LED dimming schedule unless explicitly declared otherwise by the customer. The project savings were small enough that they likely did not trigger a utility commissioning investigation, but there may be an opportunity to consider these standard for cannabis lighting projects regardless of savings magnitude.

Customer Alert

The customer requested a copy of the site report and metered data.

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 application consisted of two new construction measures at the indoor horticulture facility:

- Installation of eighty-eight LED flower room lighting fixtures in Flower Room 4
- Installation of six '16 SEER' condensing units serving dehumidifiers in Flower Room 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.

The applicant files include spreadsheet savings calculations, a screening tool, signed MRD, and a TA study report which details the base case, proposed case and project assumptions.

Applicant Description of Baseline

This section describes the baseline equipment, system, assumptions, and/or control sequence as described by the applicant.

The applicant classified the measures to be lost opportunities – new construction. The applicant used industry standard practice and energy code to specify the baseline equipment.

ECM 1, Phase 1 LED Process Lighting:

> The ECM 1 baseline is eighty-eight 1,000W high pressure sodium grow lighting fixtures (1:1 with the count of installed LED grow lighting fixtures) each with a 100W ballast in Flower Room 4. The fixtures are installed in two-tiers and operate for 12 hours each day. The applicant noted that the ceilings are high enough that two-tiered HPS fixtures would be possible without burning the plants. The fixture lighting output is assumed to be 100%. The applicant's energy model suggested that the CAV RTUs would need increased capacity (~50 tons total) to serve the cooling load. The applicant assumes 453 CFM/ton to get 22,656 CFM of required airflow. This is calculated to be ~17.54 kW of fan power (assuming 3.25" w.g. of TSP, 55% fan efficiency and 89.5% motor efficiency).

ECM 2, 16 SEER Condensing Units:

> The ECM 2 baseline is six standard performance (13 SEER) condensing units (1:1 with the count of installed condensing units). The units are modelled as operating at 10.6 EER throughout the year.

Table 5-166. Applicant baseline key parameters

		BASELINE		
Measure	**Parameter**	**Value(s)**	**Source of Parameter Value**	**Note**
ECM 1: LEDs	Flowering Fixture Count	88 fixtures in flower rooms	Customer	
	Fixture Peak Wattage	1,100 watts	Customer	1000W+100W ballast loss
	Average Fixture Output	100%	Customer	No dimming discussion
	Supply Fan Demand	17.54 kW	Calculation from assumptions	
ECM 2: Condensing Units	Average Dehumidifier Cooling Performance	10.6 EER	IECC 2015	

Applicant Description of Installed Equipment and Operation

This section describes the proposed condition assumed in the application analysis.

ECM 1, Phase 1 LED Process Lighting:

The ECM 1 installed case was eighty-eight 660W LED grow lighting fixtures in Flower Room 4. The fixtures were installed in two-tiers and operate for 12 hours each day. The fixture lighting output was assumed to be 100%. The installed case CAV RTUs operate with 15,860 CFM. This was calculated to be ~12.28 kW of fan power (assuming 3.25” w.g. of TSP, 55% fan efficiency and 89.5% motor efficiency).

ECM 2, 16 SEER Condensing Units:

The ECM 2 installed case was six high performance (16 SEER) condensing units. The units were modelled as operating at 11.7 EER throughout the year.

Table 5-167: Application proposed key parameters

		PROPOSED		
Measure	**Parameter**	**Value(s)**	**Source of Parameter Value**	**Note**
ECM 1: LEDs	Flowering Fixture Count	88 fixtures in flower rooms	Customer	
	Fixture Peak Wattage	660 watts	Customer	
	Average Fixture Output	100%	Customer	No dimming discussion
	Supply Fan Demand	12.28 kW	Assumption	
ECM 2: Condensing Units	Average Dehumidifier Cooling Performance	11.7 EER	Per unit	

Applicant Energy Savings Algorithm

This section describes the tools used for savings estimation and the savings estimation methodologies employed in the application analysis. It also identifies the variables that had the biggest impact on the savings.

ECM 1, Phase 1 LED Process Lighting:

The applicant savings were calculated using a spreadsheet model approach. The applicant created a monthly model with TYM3 data and estimated hourly energy usage for a typical meteorological day of each month. The total (typical) daily energy consumption is then multiplied by the number of days for each month to extrapolate energy consumption.

A sample of the base case calculations are presented for the month of January in Figure 2-47 through Figure 2-50, below. The tool performs an iterative calculation to account for interactivity between HVAC equipment energy usage and HVAC load. The tool calculates load by totalling plant transpiration load, envelope loads, lighting heat gain, fan heat gain, plug loads and hot gas reheat loads.

The model calculates the total energy consumption of the dehumidifiers, fans, grow lights, and RTU cooling and heating for the proposed case and base case grow lighting fixtures. The proposed case CAV RTUs have reduced airflow and thus reduced fan power. Energy savings are calculated as 248,899 kWh and 2,890 therms annually.

ECM 2, 16 SEER Condensing Units:

The applicant savings were calculated using a spreadsheet model approach. The applicant created a monthly model with TYM3 data and estimated hourly energy usage for a typical meteorological day of each month. The total (typical) daily energy consumption is then multiplied by the number of days for each month to extrapolate energy consumption.

The modelled HVAC systems are rooftop condensing units with remote evaporators (dehumidifiers) providing space dehumidification (10.6 EER) and packaged rooftop units providing cooling via DX coils (11.0 EER) and heating via gas-fired furnace (80% thermal efficiency).

The applicant ECM 2 baseline system is the same as the ECM 1 proposed case system. The applicant's ECM 2 proposed case system considers an adjustment to the condensing unit performance: 13 SEER in the baseline (10.6 EER) to 16 SEER in the proposed case (11.7 EER). Energy savings are calculated as 17,605 kWh annually.

Figure 2-47: Base Case Spreadsheet Calculations 1 of 4

Date	Ambient Air		Day	Space	Space	Main Cooling Unit Supply							CO_2	
&	Temp	Hum	Status	Temp	Sensible	Coil Discharge			Supply	OA	Coil	Fan	Space	Load
Time	°F	gr/lb	1 = Yes	°F	kBtu/h	°F	gr/lb	Btu/lb	°F	cfm	cfm	kW	ppm	mol/hr
1/15/18 0:00	21.7	13.8	0	70.0	-21.7	70.9	54.5	25.5	70.9	56	22,656	17.54	1,072	0.00
1/15/18 1:00	20.8	13.6	0	70.0	-21.9	70.9	54.5	25.5	70.9	56	22,656	17.54	1,082	0.00
1/15/18 2:00	20.8	13.4	0	70.0	-21.8	70.9	54.5	25.5	70.9	56	22,656	17.54	1,092	0.00
1/15/18 3:00	20.9	13.1	0	70.0	-21.7	70.9	54.5	25.5	70.9	56	22,656	17.54	1,102	0.00
1/15/18 4:00	20.7	13.2	0	70.0	-21.7	70.9	54.5	25.5	70.9	56	22,656	17.54	1,111	0.00
1/15/18 5:00	20.6	13.1	0	70.0	-21.7	70.9	54.5	25.5	70.9	56	22,656	17.54	1,119	0.00
1/15/18 6:00	20.3	13.1	0	70.0	-21.7	70.9	54.5	25.5	70.9	56	22,656	17.54	1,128	0.00
1/15/18 7:00	21.1	13.9	1	78.0	149.0	71.9	71.5	28.4	71.9	112	22,656	17.54	1,000	19.38
1/15/18 8:00	24.5	14.5	1	78.0	150.2	71.9	71.5	28.4	71.9	112	22,656	17.54	1,000	28.27
1/15/18 9:00	26.5	15.0	1	78.0	150.9	71.8	71.5	28.4	71.8	112	22,656	17.54	1,000	28.27
1/15/18 10:00	29.3	15.3	1	78.0	151.9	71.8	71.5	28.4	71.8	112	22,656	17.54	1,000	28.27
1/15/18 11:00	30.8	15.6	1	78.0	152.4	71.8	71.5	28.4	71.8	112	22,656	17.54	1,000	28.27
1/15/18 12:00	33.5	16.1	1	78.0	153.4	71.7	71.5	28.4	71.7	112	22,656	17.54	1,000	28.27
1/15/18 13:00	33.8	16.2	1	78.0	153.5	71.7	71.5	28.4	71.7	112	22,656	17.54	1,000	28.27
1/15/18 14:00	33.8	16.4	1	78.0	153.5	71.7	71.5	28.4	71.7	112	22,656	17.54	1,000	28.27
1/15/18 15:00	32.9	16.8	1	78.0	153.2	71.7	71.5	28.4	71.7	112	22,656	17.54	1,000	28.27
1/15/18 16:00	30.9	17.0	1	78.0	152.5	71.8	71.5	28.4	71.8	112	22,656	17.54	1,000	28.27
1/15/18 17:00	28.9	16.9	1	78.0	151.7	71.8	71.5	28.4	71.8	112	22,656	17.54	1,000	28.27
1/15/18 18:00	27.7	17.1	1	78.0	151.3	71.8	71.5	28.4	71.8	112	22,656	17.54	1,000	28.27
1/15/18 19:00	26.8	16.6	0	70.0	-20.5	50.3	54.3	20.5	70.8	56	22,656	17.54	1,013	0.00
1/15/18 20:00	25.6	16.0	0	70.0	-20.8	70.8	54.5	25.5	70.8	56	22,656	17.54	1,026	0.00
1/15/18 21:00	24.5	14.9	0	70.0	-21.0	70.9	54.5	25.5	70.9	56	22,656	17.54	1,038	0.00
1/15/18 22:00	23.1	14.3	0	70.0	-21.4	70.9	54.5	25.5	70.9	56	22,656	17.54	1,050	0.00
1/15/18 23:00	22.4	13.9	0	70.0	-21.5	70.9	54.5	25.5	70.9	56	22,656	17.54	1,061	0.00

Figure 2-51: Base Case Spreadsheet Calculations 2 of 4

Humidity to be Removed					Stand-alone Dehumidifier							Main DX Cooling Coil Dehumidification				
Space	Gain	Total	Main	Add'l	Dehum Coil Disch		Load	DX		Fan	DAT	Dehum Coil Disch		Cl Effect	Load	Coil DAT
gr/lb	lb/h	lb/h	lb/h	lb/h	°F	gr/lb	tons	kW/ton	kW	kW	°F	°F	gr/lb	tons	tons	°F
54.5	70.9	70.9	0.0	70.9	39.2	35.9	22.9	0.676	15.5	1.9	77.5	70.9	0.0	0.0	0.0	70.9
54.5	70.8	70.8	0.0	70.8	39.3	36.0	22.9	0.676	15.5	1.9	77.5	70.9	0.0	0.0	0.0	70.9
54.5	70.7	70.7	0.0	70.7	39.3	36.0	22.9	0.676	15.5	1.9	77.5	70.9	0.0	0.0	0.0	70.9
54.5	70.7	70.7	0.0	70.7	39.3	36.0	22.9	0.676	15.4	1.9	77.5	70.9	0.0	0.0	0.0	70.9
54.5	70.6	70.6	0.0	70.6	39.3	36.0	22.9	0.676	15.4	1.9	77.5	70.9	0.0	0.0	0.0	70.9
54.5	70.5	70.5	0.0	70.5	39.3	36.0	22.8	0.676	15.4	1.9	77.5	70.9	0.0	0.0	0.0	70.9
54.5	70.5	70.5	0.0	70.5	39.3	36.1	22.8	0.676	15.4	1.9	77.5	70.9	0.0	0.0	0.0	70.9
71.5	115.0	102.9	0.0	102.9	45.2	44.6	26.9	0.679	18.2	3.1	67.5	71.9	0.0	0.0	0.0	71.9
71.5	115.0	115.0	0.0	115.0	43.2	41.5	29.0	0.679	19.7	3.1	67.5	71.9	0.0	0.0	0.0	71.9
71.5	115.0	115.0	0.0	115.0	43.2	41.5	29.0	0.679	19.7	3.1	67.5	71.8	0.0	0.0	0.0	71.8
71.5	115.0	115.0	0.0	115.0	43.2	41.5	29.0	0.679	19.7	3.1	67.5	71.8	0.0	0.0	0.0	71.8
71.5	115.0	115.0	0.0	115.0	43.2	41.5	29.0	0.679	19.7	3.1	67.5	71.8	0.0	0.0	0.0	71.8
71.5	115.0	115.0	0.0	115.0	43.2	41.5	29.0	0.679	19.7	3.1	67.5	71.7	0.0	0.0	0.0	71.7
71.5	115.0	115.0	0.0	115.0	43.2	41.5	29.0	0.679	19.7	3.1	67.5	71.7	0.0	0.0	0.0	71.7
71.5	115.0	115.0	0.0	115.0	43.2	41.5	29.0	0.679	19.7	3.1	67.5	71.7	0.0	0.0	0.0	71.7
71.5	115.0	115.0	0.0	115.0	43.2	41.5	29.0	0.679	19.7	3.1	67.5	71.7	0.0	0.0	0.0	71.7
71.5	115.0	115.0	0.0	115.0	43.2	41.5	29.0	0.679	19.7	3.1	67.5	71.8	0.0	0.0	0.0	71.8
71.5	115.0	115.0	0.0	115.0	43.2	41.5	29.0	0.679	19.7	3.1	67.5	71.8	0.0	0.0	0.0	71.8
71.5	115.0	115.0	0.0	115.0	43.2	41.5	29.0	0.679	19.7	3.1	67.5	71.8	0.0	0.0	0.0	71.8
54.5	71.7	83.8	3.6	80.2	37.4	33.5	24.8	0.676	16.7	1.9	77.5	50.7	54.2	39.7	39.7	50.7
54.5	71.5	71.5	0.0	71.5	39.1	35.8	23.0	0.676	15.6	1.9	77.5	70.8	0.0	0.0	0.0	70.8
54.5	71.3	71.3	0.0	71.3	39.2	35.8	23.0	0.676	15.5	1.9	77.5	70.9	0.0	0.0	0.0	70.9
54.5	71.2	71.2	0.0	71.2	39.2	35.9	23.0	0.676	15.5	1.9	77.5	70.9	0.0	0.0	0.0	70.9
54.5	71.1	71.1	0.0	71.1	39.2	35.9	22.9	0.676	15.5	1.9	77.5	70.9	0.0	0.0	0.0	70.9

Figure 2-52: Base Case Spreadsheet Calculations 3 of 4

Grow	Space Sensible						Sensible Cooling & Heating Systems							
Lights	Equip	Lights	Proc	Plant Sp	Envelope	Total	Coil Discharge			Supply Air			Mixed Return	
kW	kBtu/h	kBtu/h	kBtu/h	kBtu/h	kBtu/h	kBtu/h	°F	gr/lb	Btu/lb	°F	gr/lb	Btu/lb	wb °F	Btu/lb
0.0	13.9	0.0	55.2	-68.8	-21.9	-21.7	70.9	54.5	25.5	70.9	54.5	25.5	58.4	25.3
0.0	13.9	0.0	55.2	-68.7	-22.2	-21.9	70.9	54.5	25.5	70.9	54.5	25.5	58.4	25.3
0.0	13.9	0.0	55.1	-68.7	-22.2	-21.8	70.9	54.5	25.5	70.9	54.5	25.5	58.4	25.3
0.0	13.9	0.0	55.1	-68.6	-22.2	-21.7	70.9	54.5	25.5	70.9	54.5	25.5	58.4	25.3
0.0	13.9	0.0	55.1	-68.5	-22.3	-21.7	70.9	54.5	25.5	70.9	54.5	25.5	58.4	25.3
0.0	13.9	0.0	55.1	-68.4	-22.3	-21.7	70.9	54.5	25.5	70.9	54.5	25.5	58.4	25.3
0.0	13.9	0.0	55.1	-68.4	-22.4	-21.7	70.9	54.5	25.5	70.9	54.5	25.5	58.4	25.3
96.8	13.9	330.3	-57.4	-112.9	-25.0	149.0	71.9	71.5	28.4	71.9	71.5	28.4	65.0	30.0
96.8	13.9	330.3	-57.4	-112.9	-23.8	150.2	71.9	71.5	28.4	71.9	71.5	28.4	65.0	30.0
96.8	13.9	330.3	-57.4	-112.9	-23.0	150.9	71.8	71.5	28.4	71.8	71.5	28.4	65.0	30.0
96.8	13.9	330.3	-57.4	-112.9	-22.1	151.9	71.8	71.5	28.4	71.8	71.5	28.4	65.0	30.0
96.8	13.9	330.3	-57.4	-112.9	-21.5	152.4	71.8	71.5	28.4	71.8	71.5	28.4	65.0	30.0
96.8	13.9	330.3	-57.4	-112.9	-20.6	153.4	71.7	71.5	28.4	71.7	71.5	28.4	65.0	30.0
96.8	13.9	330.3	-57.4	-112.9	-20.5	153.5	71.7	71.5	28.4	71.7	71.5	28.4	65.0	30.0
96.8	13.9	330.3	-57.4	-112.9	-20.5	153.5	71.7	71.5	28.4	71.7	71.5	28.4	65.0	30.0
96.8	13.9	330.3	-57.4	-112.9	-20.8	153.2	71.7	71.5	28.4	71.7	71.5	28.4	65.0	30.0
96.8	13.9	330.3	-57.4	-112.9	-21.5	152.5	71.8	71.5	28.4	71.8	71.5	28.4	65.0	30.0
96.8	13.9	330.3	-57.4	-112.9	-22.2	151.7	71.8	71.5	28.4	71.8	71.5	28.4	65.0	30.0
96.8	13.9	330.3	-57.4	-112.9	-22.6	151.3	71.8	71.5	28.4	71.8	71.5	28.4	65.0	30.0
0.0	13.9	0.0	55.2	-69.5	-20.1	-20.5	50.7	54.5	20.5	70.8	54.5	25.5	58.4	25.3
0.0	13.9	0.0	55.2	-69.4	-20.6	-20.8	70.8	54.5	25.5	70.8	54.5	25.5	58.4	25.3
0.0	13.9	0.0	55.2	-69.2	-20.9	-21.0	70.9	54.5	25.5	70.9	54.5	25.5	58.4	25.3
0.0	13.9	0.0	55.2	-69.1	-21.4	-21.4	70.9	54.5	25.5	70.9	54.5	25.5	58.4	25.3
0.0	13.9	0.0	55.2	-69.0	-21.7	-21.5	70.9	54.5	25.5	70.9	54.5	25.5	58.4	25.3

Figure 2-50: Base Case Spreadsheet Calculations 4 of 4

Sensible Cooling & Heating Systems					Add'l	Utility Demand		
Load	Cool Cap	DX Cooling		Heating	Heating	Elect	Nat Gas	Propane
tons	tons	kW/ton	kW	therms	kWh	kW	therm/h	gal/hr
-1.8	50.8	0.663	0.0	0	0	39.0	0.3	0.0
-1.8	50.8	0.663	0.0	0	0	39.0	0.3	0.0
-1.8	50.8	0.663	0.0	0	0	39.0	0.3	0.0
-1.8	50.8	0.663	0.0	0	0	39.0	0.3	0.0
-1.8	50.8	0.663	0.0	0	0	39.0	0.3	0.0
-1.8	50.8	0.663	0.0	0	0	39.0	0.3	0.0
-1.8	50.8	0.663	0.0	0	0	39.0	0.3	0.0
12.4	56.2	0.671	8.3	0	0	148.1	0.0	0.0
12.5	56.2	0.671	8.4	0	0	149.7	0.0	0.0
12.6	56.2	0.671	8.4	0	0	149.7	0.0	0.0
12.7	56.2	0.671	8.5	0	0	149.8	0.0	0.0
12.7	56.2	0.671	8.5	0	0	149.8	0.0	0.0
12.8	56.2	0.671	8.6	0	0	149.8	0.0	0.0
12.8	56.2	0.671	8.6	0	0	149.8	0.0	0.0
12.8	56.2	0.671	8.6	0	0	149.8	0.0	0.0
12.8	56.2	0.671	8.6	0	0	149.8	0.0	0.0
12.7	56.2	0.671	8.5	0	0	149.8	0.0	0.0
12.6	56.2	0.671	8.5	0	0	149.8	0.0	0.0
12.6	56.2	0.671	8.5	0	0	149.7	0.0	0.0
-41.2	50.8	0.663	0.0	6	0	40.3	6.2	0.0
-1.7	50.8	0.663	0.0	0	0	39.1	0.3	0.0
-1.8	50.8	0.663	0.0	0	0	39.1	0.3	0.0
-1.8	50.8	0.663	0.0	0	0	39.1	0.3	0.0
-1.8	50.8	0.663	0.0	0	0	39.1	0.3	0.0

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

Evaluation Assessment of Applicant Methodology

The evaluator disagrees with the applicant baseline for ECM 1 and for ECM 2.

The ECM 1 baseline is 1000W high pressure sodium grow lighting fixtures. The 660W LED grow lighting fixtures provide light to plants at the same photosynthetic photon flux density as 1000W high pressure sodium grow lighting fixtures. The photosynthetic photon flux density is understood to be the primary indicator of production output or plant growth, thus the base case and proposed case consider comparable production. However, the baseline HPS fixtures were modelled with 100W of losses at the ballast, for a total of 1100W per fixture. Based upon the evaluator's experience, 100W of ballast losses is too high of an assumption. This is corroborated by the Massachusetts Cannabis Cultivation ISP document, which notes a typical 1000W metal halide fixture has 55W of ballast losses.

The ECM 2 applicant baseline is condensing units serving space dehumidification loads with code-required minimum cooling performance of 13.0 SEER. The condensing units do not serve a comfort cooling application and the energy savings features of the condensing units are not utilized in this dehumidification application (larger condenser, variable compressor capacity). The SEER rating does not apply and thus the condensing unit performance is not a measure.

Site Visit

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

Summary of Site Visit Findings

The evaluator met with the VP of Operations on March 9th, 2021 to perform a walkthrough of the facility. The evaluator set-up metering equipment to record lighting power input and discharge air conditions at the VRF FCU cassettes.

The primary finding was that the customer dims the LED fixtures throughout the grow cycle. This is manually performed using a controller at each rack throughout the grow process, at the operator's discretion. The site contact explained that eleven of the eighty-eight total fixtures in Flower Room 4 were moved to the vegetation room, where they operate at reduced lighting output for 18 hours each day.

In addition, the HVAC layout was slightly different than modelled by the applicant. The dehumidifiers serve the latent loads, and any remaining sensible load is served by VRF heat pumps. The RTUs only operate as back-up.

Table 5-168. Measure Verification

Measure Name	Verification Method	Verification Result
Phase 1 LED Process Lighting	Observed with customer during site visit. Long term metering performed by evaluator	Eighty-eight (88) 660W SpydrX Plus fixtures counted between vegetation room and flower room.
16 SEER Condensing Units	Observed with customer during site visit.	Subcooled 705 units were installed.

The evaluator retrieved the meter data on April 27th, 2021. This data represents nearly a full grow cycle within Flower Room 4 (i.e. 7 weeks of meter data vs. ~8 week typical grow cycle). The lighting panel meter data is presented in Figure 2-54, below. Since Flower Room 4 has plants in various stages of growth and the lighting fixture dimming is performed manually by operators, the schedule appears irregular. It is assumed that the average lighting output during the meter period would be representative of average lighting output throughout the year.

Prior to the end of the meter period, the site contact set the Rack 7 lighting output to 100% for several minutes. The Rack 7 metered data is presented in Figure 2-55, below. In addition, the evaluator performed spot metering of a sample of fixtures in the vegetation room (which are set to a constant dimming point). The discrete metered points are: Flower Room 4 total lighting demand, Rack 7 lighting amperage, Vegetation Room Rack lighting amperage, and VRF FCU Cassettes 1, 2 & 3 discharge db °F / RH%.

Figure 2-54: Flower Room 4 Panel Lighting Demand

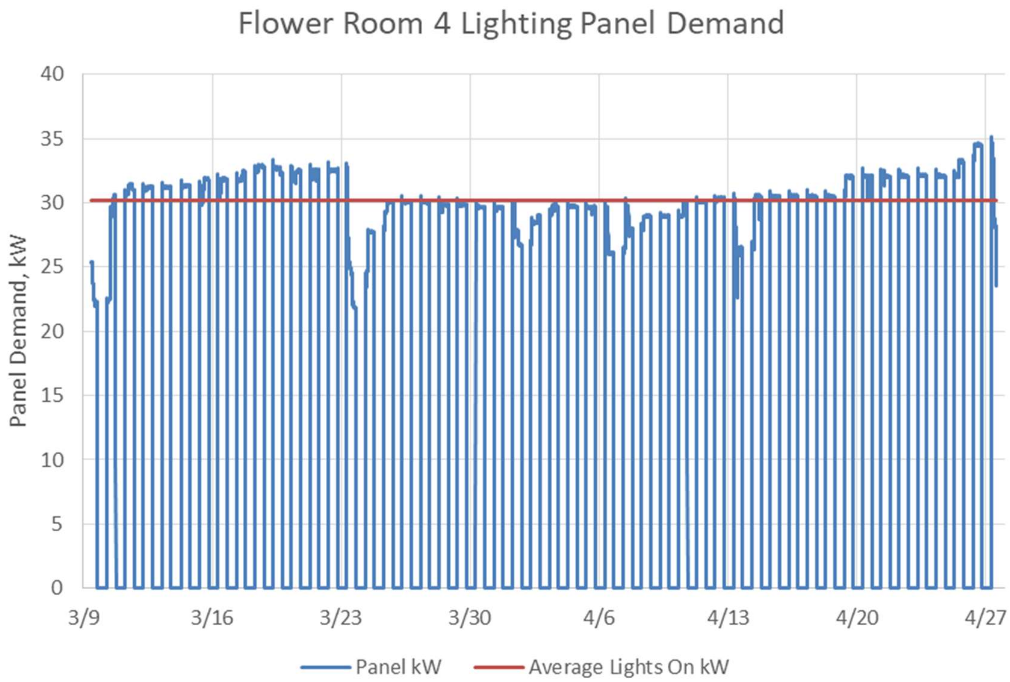
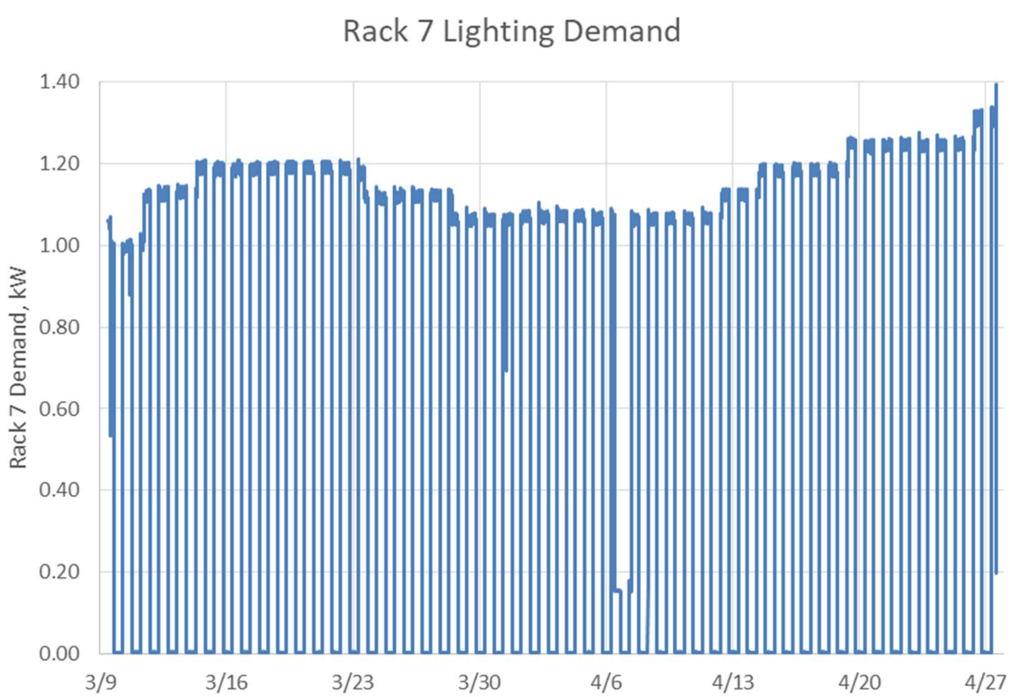


Figure 2-55: Rack 7 Lighting Demand



The evaluator used the power factor of the entire lighting panel to approximate power factor at Rack 7. The peak demand at Rack 7 was 1.38 kW for two fixtures. This peak period occurred at the end of the meter period while the site contact set the Rack 7 fixture lighting output to peak. This comes to a peak output wattage of 690.8W/fixture which is within 1% of the rated (peak) input wattage of 685W.

It is the evaluator's understanding that the lighting fixtures are the only loads on the Flower Room 4 panel and the minor demand draw during the 'lights off' period is assumed to be standby power attributed to the LED drivers. The average 'lights on' demand recorded at the panel was 30.2 kW. This accounts for an average of dimming throughout the entire grow period. There are seventy seven fixtures, thus the peak output demand would be 53.2 kW (77 fixtures × 690.8W/fixture). This corresponds to an average dimming of 56.8% for the flowering fixtures.

The evaluator performed spot metering of three of the eleven vegetation fixtures that had been moved from Flower Room 4. The site contact explained that the lighting output of these fixtures is kept constant at a reduced output. The average amperage while energized was 4.0A compared to a calculated peak of 10.53A (3 fixtures × 3.51A/fixture, per Rack 7). Thus the vegetation room fixtures operate at an average dimming of 38.0%.

The meter data at the VRF cassettes suggest that the VRF FCUs do not need to operate to serve sensible loads for the majority of the grow cycle. During the first four weeks of metering, one of the three units needed to support grow room heating and cooling. The Subcooled 705 dehumidifier units are providing adequate cooling on their own which limits the load on the heat pumps.

Evaluation Methods and Findings

This section describes the evaluator methods and findings.

Evaluation Description of Baseline

The evaluator agrees with the ECM 1 measure classification. The evaluator does not agree with the ECM 2 measure classification.

The evaluator adjusted the baseline lighting systems to include an average of 56.8% dimming output for 12 hours/days. Eleven of the eighty eight grow lighting fixtures were modelled as operating at a constant 38.0% output in the vegetation room for 18 hours/day.

The applicant's TA study noted that the sensible heat gain of the HPS lighting fixtures was large enough that the RTU fans would have to be upsized compared to the installed case. This is no longer necessary when the HPS fixtures are modelled with an average dimming output of 56.8%. The evaluator modelled the baseline RTU unit size identical to the installed system. In addition, since VRF heat pumps have been installed, the RTUs only operate as back-up which further supports removing the supply fan savings from the measure.

The evaluator removed the '16 SEER Condensing Unit' measure from the project. The installed equipment does not include high performance features when used primarily for dehumidification.

Evaluation Calculation Method

The evaluator recalculated the measure savings with the applicant's spreadsheet model. While the applicant's model is large and considers many inputs, only six adjustments were made by the applicant.

1. Adjust Condensing Unit Performance: ECM 2 was removed from the analysis by adjusting the installed case performance to match the baseline condensing unit performance.
2. Adjust Baseline Ballast Losses: The base case HPS fixture total wattage was reduced from 1100W to 1055W to account for typical losses at an electronic ballast.
3. Average Flower Room Fixture Dimming: The base case HPS fixtures and installed case LED fixture wattage were adjusted down to 56.8% of peak output. This had a secondary impact of also reducing sensible heat gain in the baseline and proposed system models. As a result, there is a small reheat penalty in the installed case.
4. Eleven Vegetation Room Fixtures: The applicant modelled 11 of the 88 fixtures in a separate 'vegetation room' sheet. The HVAC systems are modelled similarly to the flower room. The base case HPS fixtures and installed case LED fixture wattages were adjusted down to 38.0% of peak output for 18 hours per day.

5. Downsize Baseline RTU: Between having fewer flower lighting fixtures and operating the fixtures at reduced lighting output, the base case sensible heat load in the space was reduced enough such that the baseline CAV RTU would not have to be 'oversized' to serve sensible space loads. The supply fan horsepower was reduced to match the proposed case system.

6. Reheat Penalty served by VRF FCUs: The reduced sensible heat gain in the installed case grow rooms mean that there is a reheat penalty. Since the site contact noted that the RTUs only operate as back-up, the reheat penalty is instead served by the electric heat pump system. This assessment was supported by the VRF cassette discharge air conditions meter data, which demonstrated one of the VRF FCUs operating in heating mode for part of the meter period. The VRF heat pumps is assumed to operate with an average heating performance of 3.0 COP (based upon average of IECC 2015 air-cooled heat pump heating performance values.

Final Results

This section summarizes the evaluation results determined in the analysis above. The evaluated savings for the lighting project were slightly greater than the applicant-reported savings primarily due to a discrepancy stemming from heating and cooling interaction. Detailed values are shown in Table 5-196. Summary of Key Parameters, comparing changes in the baseline and proposed conditions for both the application and evaluation hours of use for each area.

Table 5-85 presents a summary of key parameters for the project.

Table 5-169. Summary of Key Parameters

	BASELINE		PROPOSED / INSTALLED	
Parameter	Tracking Value(s)	Evaluation Value(s)	Tracking Value(s)	Evaluation Value(s)
Fixture Ballast Losses	100W	55W	n/a	n/a
Flowering Fixture Count	88 fixtures	77 fixtures	88 fixtures	77 fixtures
Flowering Fixture Output	100%	56.8%	100%	56.8%
Vegetation Fixture Count	0	11 fixtures	0	11 fixtures
Vegetation Fixture Output	n/a	38.0%	n/a	38.0%
RTU Supply Fan Demand	17.54 kW	12.28 kW	12.28 kW	12.28 kW
Dehumidifier Average Performance	10.6 EER	10.6 EER	11.7 EER	10.6 EER
Space Heating Load Source	Nat. Gas	Heat Pump	Nat. Gas	Heat Pump
Space Heating Load Performance	80% efficient	3.0 COP	80% efficient	3.0 COP

Explanation of Differences

The evaluator made six changes to the applicant analysis to reflect current operations at the facility. Table 3-2 provides a summary of the differences between tracking and evaluated values.

Table 5-170. Summary of Deviations

Measure	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
7999568-2	Baseline	EER	-6.6%	**Decreased savings –** Removed cooling performance measure from project
7999568-1	Baseline	Ballast Losses Wattage	-7.8%	**Decreased savings –** Reduced baseline HPS ballast losses to match cannabis ISP (100W to 55W)

7999568-1	Operational	Dimming	-34.9%	**Decreased savings –** Reduced average lighting output throughout the year in both baseline and installed case
7999568-1	Quantity	Fixtures	-1.1%	**Decreased savings -** 11 fixtures were moved from flowering room to vegetation room
7999568-1	Baseline	Fan bhp	-17.3%	**Decreased savings -** Base case RTU fans did not need to be oversized to serve updated sensible load
7999568-1	Baseline	COP	-0.8%	**Decreased savings -** Reheat penalty is served by VRF HPs
Final RR				**31.5% realization ratio**

Ancillary Impacts

The applicant calculated natural gas savings for ECM 1 attributed to a reduction in baseline air handler unit sizing. Based upon an updated review of the calculations, the installed system instead includes a reheat load penalty served by an electric heat pump. There are no natural gas savings associated with the measure.

RICE18N106

Report Date: April 16, 2021

Program Administrator	National Grid
Application ID(s)	7185003
Project Type	Existing Building Retrofit
Program Year	2018
Evaluation Firm	DNV GL
Evaluation Type	Non-Ops only
Evaluation Engineer	Ryan Brown
Senior Engineer	Stephen Carlson

Evaluated Site Summary and Results

The evaluated project was implemented at a large industrial manufacturing facility where 166 cfm worth of compressed air leaks were repaired as a result of a survey. Permanent compressed air meters were installed to monitor compressed air demand and determine future irregular spikes in demand.

The program classified the project as a retrofit measure where pre-installation operating conditions were used as a baseline. The applicant baseline included the pre-existing cfm load provided by the existing air compressor with an efficiency of 4.3 cfm/kW. Electric savings result from the conversion of cfm leaks to kW using the compressor CAGI rated efficiency. The evaluated savings were less than the tracking estimates due to a difference in CAGI efficiency used for the compressor between the application and the evaluation. While on-site, it was also discovered that the main 200 HP compressor was replaced with a larger 300 HP compressor a year after the leaks were repaired. The evaluator calculated annual savings for each compressor and averaged the results to get a blended annual kWh for the measure, which would be reflective of the annual savings for the lifetime of the measure. Due to scheduling difficulties with the site; getting access during the COVID-19 pandemic; and the inability to re-install meters after the site accidently removed them, the evaluation for this site only considered non-operational impacts to savings. The evaluation results are presented in Table 5-2.

Table 5-171. Evaluation Results Summary

PA Application ID	Measure Name		Annual Savings (kWh)	% of Energy Savings on Peak	Summer On-Peak Demand (kW)	Winter On-Peak Demand (kW)
7185003	**Compressed air leak repair**	**Tracked**	308,837	48%	38.6	38.6
		Evaluated	245,041	48%	30.6	30.6
		Realization Rate	**79%**	**100%**	**79%**	**79%**

Explanation of Deviations from Tracking

The evaluated savings are 21% less than the applicant-reported savings primarily due to a change in compressor CAGI efficiency. Further details regarding deviations from the tracked savings are presented in Section 3-4.

Recommendations for Program Designers & Implementers

During the on-site visit, the site contact mentioned a walkthrough is done regularly (about once a week) to check for potential air leaks and repair any in-house if discovered. The program is not currently involved in these repairs. It is recommended to ensure repair projects such as these don't fall within the realm of free ridership and that the program is influencing the customer.

Customer Alert

There are no customer alerts.

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 survey and repair of 166 cfm worth of air leaks resulting from a site-wide audit.

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.

Applicant Description of Baseline

The applicant classified the measure as retrofit where pre-existing operating conditions were used as a baseline. The facility runs a three-shift operation where two 200 HP variable speed compressors are connected in a lead/lag configuration to provide compressed air. The main compressor operates approximately 8,000 annual hours, while the trim compressor operates roughly 4,000 hours. The baseline consisted of the metered compressed air demand, where the CAGI compressor efficiency of 4.3 cfm/kW was used, although the CAGI data sheets were not provided to confirm. The four sub-sampled sites in this project are classified as a lighting retrofit project in the application. The majority (95.0%) of the baseline fixtures/lamps are categorized as T8 fluorescents (81.4%) and CFLs (13.6%). The remaining baseline fixtures/lamps are categorized as halogens, high-pressure sodium, incandescent, LEDs, metal halides, T5s, and T12s. The site documentation reported that the baseline consisted of 4,400 fixtures that operated varying watts from 12 to 455 watts. Application baseline usage hours ranged from 760 to 8,760 annual hours. The key applicant baseline parameters are summarized in Table 5-3.

Table 5-3 presents the main parameters of the baseline as defined by the applicant.

Table 5-172. Applicant Baseline Summary

Operation Description	Value
Baseline compressed air load (cfm)	1,270
Compressor efficiency (cfm/kW)	4.3
Operational hours	8,000

Applicant Description of Installed Equipment and Operation

The measure includes the repair of 166 cfm worth of leaks. Equipment and operating parameters are equivalent to the baseline. Table 5-173. Applicant Proposal Summary presents the main parameters of the proposal as defined by the applicant.

Table 5-173. Applicant Proposal Summary

Operation Description	Value
Post compressed air load (cfm)	1,104
Compressor efficiency (cfm/kW)	4.3
Operational hours	8,000

Applicant Energy Savings Algorithm

The applicant calculated the savings using a custom express tool. The difference in compressed air between pre and post-implementation metering, compressor efficiency, and annual operating hours was used to determine electrical savings. The applicant calculated the savings using the following formula:

$$Total\ Savings = \Delta Demand_{Compressed\ Air} \times \frac{1}{\eta_{Compressor}} \times Hours_{Annual}$$

where,

$Total\ Savings$	= measure savings (kWh/year)
$\Delta Demand_{Compressed\ Air}$	= difference in pre/post demand (166 cfm)
$\eta_{Compressor}$	= compressor efficiency (4.3 cfm/kW)
$Hours_{Annual}$	= 8,000

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

Evaluation Assessment of Applicant Methodology

The applicant's overall method for calculating the savings is insufficient in rigor primarily due to the compressor efficiency. Considering the existing 200 hp compressor is a variable speed compressor, the applicant should have developed performance curves based on operating compressor kW, and metered cfm data. Using the developed curves in tandem with CAGI reported information, a more appropriate compressor efficiency could have been used to account for the variation in loading.

On-Site Inspection and Metering

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

Summary of On-site Findings

The evaluators conducted a site visit on March 16, 2020, to confirm if the air leaks were repaired using an ultrasonic detector. A walkthrough with the site contact was performed with the original audit sheet. After the leaks were repaired, the site contact removed the tags, so the evaluator had to rely on third-party location descriptions in the audit report and the site contact's memory to find the repaired leak locations. The evaluator tested as many locations of repair that could be found. Although multiple leaks were discovered during the walkthrough, it appeared all leaks were new and separate from the original audit used for this application. Most of these leaks were due to faulty air guns in workstations or regulators used by the industrial process machinery. Based on these observations that the existing leaks are new, the evaluator determined the air leaks were repaired as per the audit.

The evaluator inventoried the equipment, compressor nameplates, cfm meters, and discharge pressure. At the time of the site visit, the compressed air system changed compared to the time of the air leak repairs. A new 300 HP single speed air compressor was installed to replace the two pre-existing 200 HP oil screw compressors to be able to maintain service for a new nitrogen generator, which requires 400-800 additional cfm. The pre-existing compressors were still online and served as a backup to the 300 HP compressor during maintenance service times, which is expected to be once a quarter. There are also two 100 HP variable speed trim compressors to cover an additional load when the plant falls below 95 psi (they trim to maintain 100 psi minimum). These compressors were pre-existing to the system and were operating in similar conditions for the baseline case. The 100 HP compressors cycle every 168 hours to keep load consistent and preserve lifetime. The site contact mentioned they do not want to run the 200 HP oil screw compressors if not necessary as the oil air mixture may compromise the generated nitrogen, but they are keeping them as an emergency precaution.

Regarding the COVID-19 outbreak: while on-site, the evaluator discussed how the virus might impact process operations. The site contact assured that although the office staff may vacate, the facility will still bring a handful of manufacturing staff to keep the process running. They expected to be able to run normally throughout the outbreak.

A summary of the on-site verification is provided in DNV interviewed the facility staff and verified the equipment installed onsite. DNV completed an initial site visit on 4/8/21 to visually verify and collect data on select measures.

Table 5-34 shows the verification method and result for each of the ten measures evaluated within this report.

Table 5-34.

Table 5-174. Measure Verification

Measure Name	Verification Method	Verification Result
Air leak repairs	Visual confirmation of equipment nameplates. Interview with site staff. Walkthrough with an ultrasonic leak detector.	Although air leaks were found throughout the facility, they appeared to be new as they did not coincide with the descriptions on the audit report and were in new locations. A new air compressor was installed in March 2020 to replace the compressor listed in the application.

Measured and Logged Data

During the site visit, the evaluator deployed data loggers to characterize the operating profile of the main 300 hp compressor and one of the 100 hp trim compressors. Only one of the trim compressors was captured as they are controlled to cycle regularly every 168 hours and follow the same operating conditions. Operation for one trim compressor should mirror the use of the other compressor during periods of cycling.

Table 5-76 presents the logger deployment details.

Table 5-175. Data Logger Deployment Details

Data Logger Type	Parameter	Time Interval	Duration	Quantity
DENT ELITEpro power logger	300 HP compressor: amperage, kW, power factor, voltage	5 minutes	<1 week	1
HOBO H22k amp logger	100 HP trim compressor: amperage	5 minutes	<1 week	1

Unfortunately, a third-party vendor was performing compressed air work and pulled the M&V meters left by the evaluator. The site contact became unresponsive after informing the engineer, so the engineer could not re-install the meters or inform the site contact how to re-install the meters. Therefore, the data could not be used. Due to the pandemic, the evaluator was not able to schedule a secondary visit to re-collect data.

Evaluation Methods and Findings

This section describes the evaluator methods and findings.

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 retrofit add-on where the pre-existing cfm air demand and air compressor were used as the baseline. Although a new air compressor was installed to maintain an increase in demand, the overall baseload profile did not change as the main compressor does not cycle to maintain the load. Instead, the trim compressors throttle on under certain operating conditions to maintain additional load present due to air leaks and other excess spikes in cfm demand.

Evaluation Calculation Method

Considering the site pulled the kW meters within a week, data was not usable to determine compressor trends. Due to the COVID-19 pandemic, the evaluator could not work with the site to perform an additional site visit to re-install the meters and collect data. Therefore, the evaluator limited the analysis methodology just to consider non-operational parameters.

While on-site, the evaluator took photos of the equipment and nameplate information. To keep the methodology consistent with the applicant, the evaluator updated the calculations to use a single value for the compressor efficiency derived from the CAGI sheet. A screenshot of the CAGI information can been seen below in Figure 5-56. CAGI data sheet. Dividing capacity by the associate input power gives the compressor efficiency in cfm/kW at different loadings. The average cfm/kW was used to update the single value used in the application.

Figure 5-56. CAGI data sheet

COMPRESSOR DATA SHEET

In Accordance With Federal Uniform Test Method for Certain Lubricated Air Compressors

Rotary Compressor: Variable Frequency Drive

MODEL DATA - FOR COMPRESSED AIR				
1	Manufacturer: SULLIVAN PALATEK			
2	Model Number: SP20-200 VFD		Date:	02/04/19
	X Air-cooled ☐ Water-cooled		Type:	Screw
			# of Stages:	1
3*	Full Load Operating Pressure[b]	125	psig[b]	
4	Drive Motor Nominal Rating	200	hp	
5	Drive Motor Nominal Efficiency	95.4	percent	
6	Fan Motor Nominal Rating (if applicable)	10	hp	
7	Fan Motor Nominal Efficiency	90.2	percent	
8*	Input Power (kW)	Capacity (acfm)[a,d]	Specific Power (kW/100 acfm)[d]	
	187.2	861	21.74	
	176.0	820	21.46	
	134.8	646	20.87	
	99.3	473	20.99	
	71.9	342	21.02	
9*	Total Package Input Power at Zero Flow[c, d]	0.0	kW	
10	Isentropic Efficiency	71.1%	%	

The evaluator assumed that the air leak repair was still functional and that the estimate (166 cfm) measured by the TA survey is still accurate. Evaluated savings is the product of the 166 cfm of repaired leaks, the updated compressor efficiency, and the operating hours assumed by the applicant.

While on-site, the evaluator discovered the main 200 HP compressors associated with the project were replaced with (1) single speed 300 HP compressor a year after the project was completed. To account for this change, the evaluator calculated first-year annual savings using the 200 HP compressor and the 300 HP compressor individually and took the average annual kWh to be used for the evaluation. This average first year savings can be assumed to be used for the entire measure life of the measure. The 300 HP compressor is a custom unit that was manufactured for the site. To determine the compressor efficiency, the evaluator reached out to the manufacturer and provided the model serial number to get performance information. The manufacturer provided two performance conditions: the standard condition and the estimated performance. Horsepower was converted to compressor kW input power, and compressor flow was divided by compressor input power to get the efficiency (cfm/kW) for each condition. The average value was used as the compressor efficiency for the 300 HP compressor. Figure 5-57. 300 HP compressor data shows the compressor information for each condition.

Figure 5-57. 300 HP compressor data

ECC Standard Cond.		Estimated Perf. Cond. 1
Gas:	AIR	Air
P_{AMB}:	14.4 PSI,A	14.6 PSI,A
P_{IN}:	14.1 PSI,A	14.3 PSI,A
T_{IN}:	95 F	95 F
$T_{Coolant}$:	85 F	78 F
RH:	60 %	80 %
P_{OUT}:	125.0 PSI,G	110.0 PSI,G
Flow:	1398 ACFM	1468 ACFM
Power:	300 HP	303 HP
Specific Power:	20.9 HP/100ICFM	20.0 HP/100ICFM
RPM:	3555	3555

As noted previously, the site has two 100 HP trim compressors which throttle on as backup when the plant falls below 95 psi. However, without metered compressor kW data, the evaluator could not create performance curves for these compressors to determine the impact on efficiency. Therefore, the applicant's methodology of focusing on the main compressor was kept consistent in the evaluation.

Final Results

The project consisted of the survey and repair of air leaks throughout the facility. The evaluated savings are less than the reported values. The parameters impacting the analysis are summarized in The evaluated savings for the lighting project were slightly greater than the applicant-reported savings primarily due to a discrepancy stemming from heating and cooling interaction. Detailed values are shown in Table 5-196. Summary of Key Parameters, comparing changes in the baseline and proposed conditions for both the application and evaluation hours of use for each area.

Table 5-85.

Table 5-176. Summary of Key Parameters

Parameter	Applicant	Evaluator
Baseline air demand (cfm)	1,270	1,270
Repaired air demand (cfm)	1,104	1,104
Compressor efficiency (cfm/kW) first year	4.3	4.7
Compressor efficiency (cfm/kW) remaining life	4.3	6.4
Annual operating hours	8,000	8,000
Annual electric savings (kWh) 200 hp compressor	308,837	281,706
Annual electric savings (kWh) 300 hp compressor	308,837	208,375
Average savings	308,837	245,041
Realization rate first year	79%8	

Explanation of Differences

The evaluated savings are less than the tracked savings due to the difference in CAGI compressor efficiency. Table 5-51 provides a summary of the differences between tracking and evaluated values.

Table 5-177. Summary of Deviations

End-use	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
Compressed Air	Technology	Air compressor efficiency	-9%	**Decreased savings** – the evaluator, found the CAGI efficiency to be greater than what was used in the application. A higher efficient compressor reduces the savings as it provides cfm at a higher rate.
Compressed Air	Technology	Change in installed compressor	-12%	**Decreased savings** – the site installed a larger compressor to replace the main 200 HP compressor after a year, which has a higher efficiency value. Annual savings were calculated for the 200 HP compressor and the 300 HP compressor, then averaged to get the site annual kWh. Decrease is due to change in installed compressor.

Ancillary impacts

There are no ancillary impacts as part of this measure.

RICE18N115

Report Date: November 15, 2022

Application ID(s)	7244682, 7974757	
Project Type	Retrofit	
Program Year	2018	
Evaluation Firm	DMI	
Evaluation Engineer	Joytika Bhargo	
Senior Engineer	Mickey Bush	

14 Evaluated Site Summary and Results

This project took place at a large hospital campus with twenty-two buildings that cover over 2,150,000 ft^2. Approximately one third of the electricity used by the campus is supplied by the on-site power plant; the remaining two thirds are purchased from the grid. The reduction in electric demand from implementing the energy conservation measures (ECMs) in this project would reduce the site's purchased energy. The campus has three central chilled water plants for cooling. Depending on the building, the air handling units have steam coils or hot water coils for heating.

The project includes five energy conservation measures implemented in various buildings. The five measures are classified as retro commissioning or retrofits.

1. ECM 1: Reduced Airflow in Operating Rooms when Unoccupied in Building A
2. ECM 2: Demand Control Ventilation (DCV) in Cafeteria in Building B
3. ECM 3: Removal of AHU-5 and AHU-6 Airflow Stations in Building C
4. ECM 4: VFDs on Boiler Feedwater Pumps in the Central Utility Plant
5. ECM 5: Compressed Air Leak Repairs in Various Buildings

ECM 1 considers the electric savings from implementing ventilation setbacks for two air handling units (AHUs) during unoccupied periods. This measure saves energy by running the AHU fans at a reduced speed (50%) as compared to the occupied design airflow. The applicant analysis only considers fan savings for this measure.

ECM 2 considers installing four CO2 sensors in the cafeteria and modulating the percent of outside air (OA) from two AHUs. This measure saves energy by reducing the amount of outside air that needs to be conditioned, thereby reducing the heating/cooling loads on the HVAC equipment. In addition to the OA control, this measure includes a change to the sequence of operation for the AHUs, where the supply and return fans are modulated to 75% speed when the units are in heating mode. The applicant analysis includes electric and gas savings for this measure.

ECM 3 considers removing abandoned airflow stations in the supply ductwork of two AHUs, which reduces the air-side pressure drop and the associated fan power needed to overcome that pressure drop. The final tracked savings for ECM 3 were determined after a commissioning-based adjustment.

ECM 4 considers the savings from installing variable frequency drives (VFDs) on three boiler feedwater pumps and modulating pump speed to maintain boiler supply pressure. The electric energy savings result from reducing the flow (by closing the bypass valve and installing new VFDs) and reducing supply pressure, which minimizes the wasted pumping energy. The final tracked savings for ECM 4 were determined after a commissioning-based adjustment.

ECM 5 considers the energy savings from repairing compressed air leaks in five buildings. This measure saves energy by decreasing the compressed air demand, resulting in compressor operation at a lower load (i.e. unloaded for 36% of the time, compared to 0% of the time in the pre-measure case) and lower electrical energy consumption.

Measurement and verification and virtual interviews were not conducted due to COVID restrictions for this hospital site. Early in the recruitment process the site was willing to engage, but within a few weeks, the hospital began restricting access to the site. Non-essential personnel were not allowed on site. The utility also requested the evaluator to stop communicating with the site and allow them to focus on pandemic response. Due to the restrictions in communication, the findings in this report reflect the information included in the project's desk review, which are non-operational discrepancies. Even if access to the site was granted, it is likely that COVID operation would have an impact on some measures (i.e. ventilation rates, DCV, operating hours, etc.).

Due to methodology discrepancies, the total evaluated savings are less than the tracked savings. A decrease in ECM4 savings is partially offset by increase in ECM1 savings. For ECMs 2, 3, and 5, the evaluated savings match the tracked savings.

The evaluation results are presented in Table 1-1.

Table 5-178. 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)
7244682	ECM 1: Reduced Airflow in Operating Rooms when Unoccupied in Building A	Tracked	160,798	14%	0.0	0.0
		Evaluated – Non-ops	179,356	14%	0.0	0.0
		Realization Rate	112%	100%	100%	100%
7244682	ECM 2: Demand Control Ventilation (DCV) in Cafeteria in Building B	Tracked	72,435	35%	0.0	0.0
		Evaluated – Non-ops	72,435	35%	0.0	0.0
		Realization Rate	100%	100%	100%	100%
7244682	ECM 3: Removal of AHU-5 and AHU-6 Airflow Stations in Building C	Tracked	91,344	48%	4.2	4.2
		Evaluated – Non-ops	91,344	48%	4.2	4.2
		Realization Rate	100%	100%	100%	100%
7244682	ECM 4: VFDs on Boiler Feedwater Pumps in the Central Utility Plant	Tracked	152,513	80%	12.4	14.7
		Evaluated – Non-ops	113,464	80%	9.21	10.99
		Realization Rate	74%	100%	74%	75%
7974757	ECM 5: Compressed Air Leak Repairs in Various Buildings	Tracked	64,838	46%	10.74	10.74
		Evaluated – Non-ops	64,838	46%	10.74	10.74
		Realization Rate	100%	100%	100%	100%
Totals		**Tracked**	**541,928**	**48%**	**27.34**	**29.64**
		Evaluated – Non-ops	**521,437**	**48%**	**24.15**	**25.93**
		Realization Rate	**96%**	**100%**	**88%**	**87%**

N/A = Not applicable

14.1 Explanation of Deviations from Tracking

The evaluated savings are 4% less than the overall applicant-reported savings due to a methodology discrepancy in ECM 4 savings analysis. The decrease in ECM4 savings is partially offset by an increase in ECM1 savings due to a methodology discrepancy. No adjustments were made to the three other ECM analyses.

ECM 1: Reduced Airflow in Operating Rooms when Unoccupied in Building A

The applicant analysis uses an eQuest fan curve to calculate the % motor kW based on fan speed. The applicant set the occupied/unoccupied fan speed inputs to 100%/50% and used the motor kW at their design (occupied) speed to calculate the fan energy. The applicant uses this approach regardless of the actual fan speed at the design airflow. This approach is reasonable for the supply and return fans in AHU-1, which operate at 100% speed to provide the design airflow, but not for AHU-2, whose supply fan and return fan run at lower % speeds. For AHU-2, the evaluator used the actual fan speeds, kW demands at those fan speeds (presumed to be metered), and the eQuest fan curve to calculate the nominal (100% speed) motor input kW. The nominal motor input kW, baseline AHU-2 fan speeds (78% for supply, 49% for return), and proposed fan speeds (39% for supply, 24.5% for return) are used to calculate the fan energy. This increases the modelled motor kW demand for the AHU-2 fans in the evaluator's proposed case compared to the applicant's proposed case. This reduces the fan savings.

The applicant analysis only calculated the fan savings associated with a ventilation setback. The applicant hard coded the heating and cooling loads in the proposed unoccupied case to match the existing unoccupied case, which underestimates the total measure savings. The evaluator updated the heating and cooling load calculations to consider the reduced supply airflow in the proposed unoccupied case. This resulted in additional electric cooling savings and natural gas heating savings.

The evaluator's updates to the modelled fan kW for AHU-2 and the cooling savings for AHU-1 and AHU-2 resulted in a net increase in the electric savings.

ECM 4: VFDs on Boiler Feedwater Pumps in the Central Utility Plant

The applicant did not include the 0.746 kW/BHP conversion factor in their pump power calculation, which overestimated their measure savings. The evaluator corrected this error. The applicant analysis is based on a steam load profile with 8,784 hours because it relies on data from 2016, a leap year. The evaluator adjusted the savings to reflect a typical year with 8,760 hours. Both updates resulted in a reduction in the measure savings.

Further details regarding deviations from the tracked savings are presented in Sections 2.4 and 3.1.

14.2 Recommendations for Program Designers & Implementers

The applicant files include a TA study report, applicant analyses, screening tools, MRDs, post commissioning memos, and revised applicant analyses. This level of documentation is helpful in determining the measure baselines, the proposed improvements, and methodology for evaluation and for tracking any commissioning-based savings adjustments. However, there are multiple instances of incomplete or inconsistent details between the TA study report and applicant analysis.

One major difference between measures are the equations used to calculate the fan energy. ECM 1 uses an eQuest fan curve to convert fan % speed to the % motor input kW, while ECMs 2 and 3 calculate the % motor input kW by applying a power of 2.5 (labelled as the VFD Affinity Exponent) to the fan % speed. The reason for this decision is not stated. The evaluator recommends using the same equation to model the same type of equipment for all measures within a TA study. If future applicants decide to use different equations, then it is recommended the applicant explain the difference in methodology.

The TA study report mentions trend and metered data are used to establish the existing operating conditions and energy demands for some measures, but these data sets are not included in the applicant documentation. The trend data is used to calculate the fan motor input kW for several measures.

The applicant analyses include one (presumed) measurement (amps) to calculate the kW demand for a fan. These measured values are unique between air handlers and supply and return fans.

For ECM 3, the TA study report states the supply fans do not modulate their speed and continuously provide the design volume of airflow based on trend data collected over 7 months. This data is not provided. Contrary to that statement, the applicant analysis varies the supply fan speed and airflow for both AHUs in the existing and proposed bin models. The supply fan speeds are hardcoded into the analysis; their source is not provided. The TA study report also states the existing supply fan motor kW for the AHUs is calculated using trend data. It is unknown if the calculated motor kW represents an average value or maximum value; if the trend data represent constant speed operation; or if the trend data include measurements for varying fan speeds. It should be noted that after commissioning, the applicant analysis adjusted the baseline supply motor input kW for AHU-5 and noted the source of the update as “kW measured in the field”. This change is not mentioned in the post commissioning memo.

The evaluator recommends including a graphical representation, trend summary, or the raw trend data in the TA study report or applicant files. This additional information will improve the quality of the TA study report and make review easier for PAs.

The evaluator also recommends future applicants include more detail on the existing and proposed controls sequences for all periods. For example, the applicant analyses model economizer controls slightly differently between measures. ECM 2 also includes a proposed fan control update (reduction in fan speed during heating mode), which is mentioned in the report and only modelled in the proposed unoccupied period. The report does not specify the proposed sequences of operation during occupied and unoccupied periods. Additionally, a reduction in fan speed may affect the total ventilation to the space, and affect the heating load on the air handling units.

The analysis also includes minor inconsistencies that could have been caught during review.

For ECM 1, the TA study states the airflow will be set back from 8pm to 5am (9 hours daily) when the operating rooms are unoccupied, but the applicant analysis models 3,650 (10 hours daily) unoccupied hours. The savings are dependent on the total unoccupied hours so the applicant may be overestimating the kWh savings.

For ECM 2, the TA study states peak occupancy occurs from 10am to 3pm (5 hours) each day and proposes that demand control ventilation will allow the air handlers to reduce the percent outside air during off peak hours. The analysis models 2,190 (6 hours daily) occupied hours, which may be underestimating savings.

The savings for ECM 4 are based on a 2016 (leap year) load profile, which includes 8,784 hours. If the savings are adjusted to consider a typical year with 8,760 hours annually, then the annual savings would decrease.

For ECMs 1 and 5, the analysis kWh savings are slightly different (<2%) from those listed in the report and screening tool. These may be typos, but it is unclear. The applicant files for ECM 5 includes two “finance” files dated 8 months apart. The first finance file lists the calculated savings, while the second lists the tracked savings, but there is no source to justify the claimed kWh savings.

- ECM 1 considers savings from ventilation setbacks, but the applicant analysis only includes fan savings. It is reasonable to assume the reduction in airflow during unoccupied hours would affect the heating and cooling loads. Upon closer inspection, the evaluator learned the applicant hard coded the proposed conditioning loads to match the existing loads, rather than calculating them.

The evaluator recommends future applicant and reviewers perform a targeted quality check focused on confirming the annual hours, occupied hours, and, if provided, the expected savings by source (heating, cooling, supply fan, etc.).

14.3 Customer Alert

There are no customer alerts.

15 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 includes the following retrofit measures, which were implemented in various buildings.

1. ECM 1: Reduced Airflow in Operating Rooms when Unoccupied in Building A
   This measure consists of resetting the unoccupied airflow to be 50% of the design occupied airflow. It impacts two AHUs (AHU-1, AHU-2) serving operating rooms. The operating rooms are typically occupied from 6 am to 7 pm, Monday through Sunday.
2. ECM 2: Demand Control Ventilation (DCV) in Cafeteria in Building B
   This measure consists of the installation of four CO_2 sensors in the cafeteria and modulating the amount of outside airflow to maintain an average zone CO_2 reading of <1,000 ppm. The measure also includes ramping the supply and return fan speeds down to 75% when the air handing units (SD-1, SD-2) are in heating mode.
3. ECM 3: Removal of AHU-5 and AHU-6 Airflow Stations in Building C
   This measure consists of the removal of two clogged and abandoned airflow monitoring stations in the supply ductwork of AHU-5 and AHU-6 and reducing the total pressure in the supply ductwork.
4. ECM 4: VFDs on Boiler Feedwater Pumps in the Central Utility Plant
   This measure consists of the installation of VFDs on three 100 HP boiler feedwater pumps.
5. ECM 5: Compressed Air Leak Repairs in Various Buildings
   This measure consists of the repair of 36 identified leaks in the compressed air system in five different buildings. The compressed air system is comprised of two 30 hp Gardner Denver EBE99K rotary screw compressors. The compressors load at 85 psig and unload at 95 psig.

15.1 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.

The applicant files include the updated spreadsheet savings calculations and screening tools for each of the five measures. For ECMs 1-4 (covered under App: 7244682), the applicant files include a TA study report detailing the base case, proposed case, and built-in assumptions. The TA study states metered data was used to establish the existing case operation/demand; however, this data is not included in any form in the report or applicant files. The 7244682 applicant files also include pre-approval letters, MRDs, a post commissioning memo, and revised savings calculations for ECMs 3 and 4.

The applicant files for ECM 5 (covered under App: 7974757) include a compressed air leak audit, audit summary and post commissioning memos, an MRD, and a post inspection MRD.

The applicant files for App: 7244682 and App: 7974757 detail the existing operation of the equipment, proposed updates, and the measure savings methodology.

15.2 Applicant Description of Baseline

This section will describe the baseline equipment, system, assumptions, and/or control sequence as described by the applicant.

1. ECM 1: Reduced Airflow in Operating Rooms when Unoccupied in Building A
   The applicant classified this measure as retro commissioning in the custom screening tool, so the pre-implementation operating conditions were used as the baseline. A retro-commissioning project is a considered an add-on retrofit measure type with a single baseline. In the existing (baseline) case, the supply and return fans in AHU-1 and AHU-2 provided 100% of the design airflow 24 hours per day, 7 days per week, regardless of the operating rooms' occupancy.
2. ECM 2: Demand Control Ventilation (DCV) in Cafeteria in Building B
   The applicant classified this measure as retro commissioning, so the pre-implementation operating conditions were used as the baseline. A retro-commissioning project is a considered an add-on retrofit measure type with a single baseline. In the existing (baseline) case the (constant volume) air handling

units ran continuously and each provided 22,246 cfm of supply airflow with a minimum setpoint of 10% outside air.

3. ECM 3: Removal of AHU-5 and AHU-6 Airflow Stations in Building C
The applicant classified this measure as a retrofit with a single baseline, so the pre-installation operating conditions were used as the baseline. Before removal of the abandoned airflow stations, the supply fan in AHU-5 operated at a total pressure of 6.5 in. w.c. and the supply fan in AHU-6 operated at a total pressure of 3.0 in. w.c. The TA study report states the supply fans did not modulate their speed and continuously provided the design volume of airflow. The report states the existing supply fan kW for AHU-5 and AHU-6 was calculated using trend data from October 2016 to May 2017. After commissioning, the applicant analysis updated the baseline supply motor input kW for AHU-5 based on a measured value (source and airflow conditions not stated) and corrected errors in the analysis for AHU-6. AHU-6 calculations previously had the wrong baseline and proposed supply fan kW; these were updated to reference the values stated in the TA study report.
4. ECM 4: VFDs on Boiler Feedwater Pumps in the Central Utility Plant
The applicant classified this measure as add-on retrofit with a single baseline, so the pre-installation conditions were used as the baseline. The three boiler feedwater pumps are staged manually (lead/lag/standby) with a maximum of two pumps operating at a time. A second feedwater pump is energized when the steam load exceeds 80,000 lb/hr. The pump design flow is assumed to be 300 gpm. The pump supply pressure is 360-365 psi. The pump discharge was headered together and piped with a bypass line. The bypass valve maintains a fixed flow in the system and a supply pressure of 325-340 psi to the boilers. The base pump power (kW) is calculated using the following equations, where flow is in units of gpm and pressure is in units of psi. The applicant neglects to include the 0.746 kW/BHP conversion factor in the second equation. This methodology discrepancy is discussed further in Section 2.4.2.
$$Pump\ BHP = \frac{Flow * (Discharge\ Pressure - Suction\ Pressure) * 2.31}{(3960 * Pump\ Efficiency)}$$
$$Base\ Pump\ Power\ = \frac{Pump\ BHP}{Motor\ Efficiency}$$
Please note, the savings are adjusted using trend data from post commissioning efforts. Post commissioning only affected the proposed/installed case discharge pressure.
5. ECM 5: Compressed Air Leak Repairs in Various Buildings
The applicant classified this measure as add-on retrofit with a single baseline so the pre-repair conditions were used as the baseline. The compressors operated constantly at full load (145 cfm) and rarely in the unloaded state. There are two 30 HP compressors. Ten days of metered data from both compressors are used to calculate the existing (baseline) energy use.

Table 2-1 provides a summary of the key baseline parameters.

Table 5-179. Applicant baseline key parameters

		BASELINE		
Measure	**Parameter**	**Value(s)**	**Source of Parameter Value**	**Note**
ECM 1	AHU-1 Unoccupied Supply Fan Speed Input	100%	TA Study	The occupied and unoccupied parameters are the same in the base case.
ECM 1	AHU-1 Unoccupied Supply Fan Power	21.55 kW	TA Study	
ECM 1	AHU-1 Unoccupied Return Fan Speed Input	100%	TA Study	
ECM 1	AHU-1 Unoccupied Return Fan Power	6.36 kW	TA Study	
ECM 1	AHU-1 Occupied (Design) Airflow	15,860 cfm	TA Study	

ECM 1	AHU-1 Unoccupied Airflow	15,860 cfm	TA Study	
ECM 1	AHU-2 Unoccupied Supply Fan Speed Input	100%	TA Study	The applicant analysis uses a speed input of 100%, but the stated existing speed is 78%.
ECM 1	AHU-2 Unoccupied Supply Fan Power	23.32 kW	TA Study	The motor input kW at 78% speed is used to calculate the fan power at the design airflow.
ECM 1	AHU-2 Unoccupied Return Fan Speed Input	100%	TA Study	The applicant analysis uses a speed input of 100%, but the stated existing speed is 49%.
ECM 1	AHU-2 Unoccupied Return Fan Power	3.96 kW	TA Study	The motor input kW at 49% speed is used to calculate the fan power at the design airflow.
ECM 1	AHU-2 Occupied (Design) Airflow	36,496 cfm	TA Study	
ECM 1	AHU-2 Unoccupied Airflow	36,496 cfm	TA Study	
ECM 2	Occupied Minimum % Outside Air	10% (2,225 cfm)	TA Study	The parameter values for SD-1 and SD-2 are the same.
ECM 2	Unoccupied Minimum % Outside Air	10% (2,225 cfm)	TA Study	
ECM 2	Minimum Unoccupied, Heating Mode, Supply Fan Speed	100%	Applicant Analysis	
ECM 2	Minimum Unoccupied Heating Mode, Return Fan Speed	100%	Applicant Analysis	
ECM 3	AHU-5 Static Pressure	5.5 in w.g.	TA Study	
ECM 3	AHU-5 Supply Fan Power	25.38 kW	TA Study	
ECM 3	AHU-6 Static Pressure	2.5 in w.g.	TA Study	
ECM 3	AHU-6 Supply Fan Power	7.36 kW	TA Study	
ECM 4	Pump Supply Pressure	365 psi	Applicant Analysis	
ECM 4	Average Pump Input Power	95.93 kW/pump	Applicant Analysis	Pump power is calculated based on flow, pressure, and pump and motor efficiency. The applicant did not apply the kW/BHP conversion factor.
ECM 5	Total Identified Air Leaks	51.5 cfm	Applicant Analysis	36 leaks
ECM 5	Time Spent at Full Load (145 cfm)	100%	Applicant Analysis	

15.2.1 Applicant Description of Installed Equipment and Operation

This section describes the proposed conditions assumed in the application analysis.

The proposed parameter values include information referenced in the TA study report, original applicant analyses, and revised (post commissioning) applicant analyses. The proposed measure are summarized below:

1. ECM 1: Reduced Airflow in Operating Rooms when Unoccupied in Building A
   This measure considers a 50% reduction in fan speed during scheduled unoccupied hours for two AHUs (AHU-1, AHU-2). The applicant assumes % speed is equal to % airflow so a 50% reduction in fan speed is equivalent to a 50% reduction in airflow. In practice, % speed is not directly equal to % flow; it is dependent on the fan controls. There is no information provided on the existing fan controls.
2. ECM 2: Demand Control Ventilation (DCV) in Cafeteria in Building B
   The measure reduces the amount of outside air being conditioned and modulates fan speeds down to 75% during heating mode for two air handlers (SD-1, SD-2).
3. ECM 3: Removal of AHU-5 and AHU-6 Airflow Stations in Building C
   Removal of the airflow stations reduces the total pressure in the supply ductwork for AHU-5 and AHU-6. AHU-6 previously referenced the wrong baseline and proposed supply fan kW. These errors were corrected after commissioning; the applicant also updated the proposed supply static pressure based on a BMS screenshot (image not included in applicant files).
4. ECM 4: VFDs on Boiler Feedwater Pumps in the Central Utility Plant
   This measure includes the installation of variable frequency drives on three pumps, closing a bypass valve, and modulating the pump speed to maintain a reduced supply pressure. The proposed supply pressure in the calculations was adjusted after commissioning efforts.
5. ECM 5: Compressed Air Leak Repairs in Various Buildings
   This measure considers repairing compressed air leaks and reducing the overall load on two existing compressors. Commissioning was done after 67% of the 36 identified repairs were completed. The commissioning memo states the site was on track to meet its initial savings estimates upon completion of all compressed air leak repairs. The applicant files did not include any details on additional commissioning done to verify all air leak repairs. There is no documentation to verify if all the identified leaks were repaired. The savings were not adjusted post commissioning.

Table 2-2 provides a summary of the key proposed measure parameters.

Table 5-180: Application proposed key parameters

		PROPOSED		
Measure	**Parameter**	**Value(s)**	**Source of Parameter Value**	**Note**
ECM 1	AHU-1 Unoccupied Supply Fan Speed Input	50%	Applicant Analysis	
ECM 1	AHU-1 Unoccupied Supply Fan Power	5.42 kW	Applicant Analysis	
ECM 1	AHU-1 Unoccupied Return Fan Speed Input	50%	Applicant Analysis	
ECM 1	AHU-1 Unoccupied Return Fan Power	1.60 kW	Applicant Analysis	
ECM 1	AHU-1 Occupied (Design) Airflow	15,860 cfm	TA Study	
ECM 1	AHU-1 Unoccupied Airflow	7,930 cfm	Applicant Analysis	

ECM 1	AHU-2 Unoccupied Supply Fan Speed Input	50%	Applicant Analysis	The applicant analysis uses a speed input of 50%, but the proposed speed would be 50% of 78%, which is 39%.
ECM 1	AHU-2 Unoccupied Supply Fan Power	5.86 kW	Applicant Analysis	
ECM 1	AHU-2 Unoccupied Return Fan Speed Input	50%	Applicant Analysis	The applicant analysis uses a speed input of 50%, but the proposed speed would be 50% of 49%, which is 24.5%.
ECM 1	AHU-2 Unoccupied Return Fan Power	0.99 kW	Applicant Analysis	
ECM 1	AHU-2 Occupied (Design) Airflow	36,496 cfm	TA Study	
ECM 1	AHU-2 Unoccupied Airflow	18,248 cfm	Applicant Analysis	
ECM 2	Occupied Minimum % Outside Air	10% (2,225 cfm)	TA Study	
ECM 2	Unoccupied Minimum % Outside Air	5% (1,113 cfm)	Applicant Analysis	
ECM 2	Minimum Unoccupied, Heating Mode, Supply Fan Speed	75%	Applicant Analysis	The fan speed varies from 100% to 75% as the OAT decreases. Below 50°F, the fan speed is 75%.
ECM 2	Minimum Unoccupied Heating Mode, Return Fan Speed	75%	Applicant Analysis	The fan speed varies from 100% to 75% as the OAT decreases. Below 50°F, the fan speed is 75%.
ECM 3	AHU-5 Static Pressure	4.2 in w.g	Revised Applicant Analysis	Updated based on a BMS screenshot from commissioning.
ECM 3	AHU-5 Supply Fan Power	14.8 kW	Revised Applicant Analysis	Updated based on metered value during commissioning.
ECM 3	AHU-6 Static Pressure	2.45 in w.g.	Revised Applicant Analysis	Typo corrected during commissioning.
ECM 3	AHU-6 Supply Fan Power	7.10 kW	Revised Applicant Analysis	Typo corrected during commissioning

ECM 4	Pump Supply Pressure	305 psi	Revised Applicant Analysis	Updated based on measured value during commissioning.
ECM 4	Average Pump Input Power	84.67 kW/pump	Revised Applicant Analysis	Dependant on pump pressure, recalculated after commissioning.
ECM 5	Total Identified Air Leaks	0 cfm		Repair of all known leaks.
ECM 5	Time Spent at Full Load	64%	Applicant Analysis	

15.2.2 Applicant Energy Savings Algorithm

This section describes the tools used for savings estimation and the savings estimation methodologies employed in the application analysis.

The savings calculations and commissioning-based adjustments for each measure are detailed below. Additional details on the applicant algorithm can be found in the project files.

1. ECM 1: Reduced Airflow in Operating Rooms when Unoccupied in Building A
   The applicant analysis calculates the energy savings from AHU-1 and AHU-2 using temperature-based bin models with TMY3 weather data for Providence, RI. The analysis has eight separate bin models to cover the occupied and unoccupied periods in the existing (base) and proposed case for each AHU. The TA study states the unoccupied reset will be implemented from 8 PM to 5 AM (9 hours daily). The applicant analysis models 5,110 hours in the occupied periods and 3,650 hours (10 hours daily) in the unoccupied periods.
   Each bin model calculates the cooling load, heating/reheat load, and supply and return fan power of each AHU. The applicant analysis includes discharge air temperature resets, economizer (drybulb) controls, and a minimum outside air percentage of 20%. The cooling efficiency is assumed to be 0.9 kW/ton and the (hot water) heating system is assumed to be 75% efficient. The fan power is modelled using the following equations, where A, B, C, and D are coefficients from an eQuest fan curve (% power).
   $$Fan\ Energy\ kWh = \ Cycle\ Ratio * Hours * Motor\ Input\ kW * \%\ power$$
   $$\%\ power = (A + B * Fan\ \%\ Speed + C * (Fan\ \%\ \ Speed)^2 + D * (Fan\ \%\ Speed)^3)$$
   where:
   A = 0.19904813
   B = -0.41420984
   C = 0.81074399
   D = 0.45400733
   The eQuest fan curve calculates the % motor load as a function of % fan speed. The supply and return fans are always running so the cycle ratio is 100%. The motor input kW values are calculated based on a voltage of 480V, the measured current (amps) when the fans run at their design airflow, and the equation below. For AHU-1, the supply and return fans run at 100% speed at their design airflow. For AHU-2, the supply fan runs at 78% speed and the return fan runs at 49% speed at its design airflow.
   $$Motor\ Input\ kW = \frac{\sqrt{3} * Volts * Amps * 0.85}{1000}$$
   In the occupied bin models, the existing and proposed cases are modelled with the same inputs and have identical energy use. In the existing unoccupied case, the AHUs operate at their design airflows with the speed input as 100%. The total cooling and heating loads are calculated based on the supply airflow, mixed air temperature, and discharge air temperature. In the unoccupied proposed case, the AHUs operate at half their design airflows with the speed input set to 50%. The cooling and heating loads are hard-coded to reference the same values in the existing case. The applicant analysis only calculates fan savings from this measure.
2. ECM 2: Demand Control Ventilation (DCV) in Cafeteria in Building B

The applicant analysis calculates the energy savings from the constant volume units, SD-1 and SD-2 using temperature-based bin models with TMY3 weather data for Providence, RI. The analysis has eight separate bin models to cover the occupied and unoccupied periods in the existing (base) and proposed cases for each air handling unit. The TA study states the cafeteria is modelled with a peak occupancy period from 10am to 3pm everyday (5 hours daily), while the applicant analysis models 2,190 hours in the occupied periods (6 hours daily) and 6,570 hours in the unoccupied periods.

Each bin model calculates the cooling load, heating/reheat load, and supply and return fan power of each air handling unit. The applicant analysis includes economizing in the occupied periods, when the HVAC system is in economizing or heating mode. The occupied minimum outside air percentage is 10%. The applicant analysis does not include economizing during the unoccupied periods; the % OA is set to its minimum values. To model the impact of the demand control ventilation measure, the applicant analysis sets the existing unoccupied OA to 10% and the proposed unoccupied OA to 5%. It is assumed that the site will be able to reduce their average amount of outside air (to 5%) in the proposed unoccupied period by implementing DCV controls and adjusting the amount of outside air based on average CO_2 concentration. Consistent with ECM 1, the cooling efficiency is assumed to be 0.9 kW/ton and the (hot water) heating system is assumed to be 75% efficient.

ECM 2 also includes a fan control update, where the supply and return fan speeds are reduced as the outside air temperature decreases (100% to 75% speed as OAT varies from 70°F to 50°F). This fan control update is only modelled in the proposed unoccupied period. Otherwise, the supply and return fan speeds are modelled at 100%.

SD-1 and SD-2 each provide ~22,000 cfm of airflow, but the size of their supply and return fans is unknown. The applicant analysis assumes the supply fans are 10 HP and the return fans are 7.5 HP for each unit. These sizes are consistent with the following relationship.

$$Fan\ HP = \frac{Airflow * SP}{6356 * Fan\ Efficiency}$$

where:

Airflow = 22,246 cfm

Supply Static Pressure = 2 in w.g.

Return Static Pressure = 1.5 in w.g.

Fan Efficiency = 70%

These values are pulled from the applicant analysis, but their source is not stated. The applicant analysis models the fan power for this measure using the following equations.

$$Fan\ Energy\ kWh = Cycle\ Ratio * Hours * Motor\ Input\ kW * Fan\ \%\ Speed^{VFD\ Affinity\ Exponent}$$

$$Motor\ Input\ kW = \frac{Fan\ Motor\ HP\ * \ 0.745\frac{kW}{bhp}}{Efficiency}$$

The fans are always running so the cycle ratio is 100%. The applicant analysis uses a VFD affinity exponent of 2.5 and a motor efficiency of 90.2%.

In the occupied bin models, the existing and proposed cases are modelled with the same inputs and have identical energy demands. The applicant analysis only shows energy savings in the unoccupied bin models, where the majority (~96%) of the electric savings come from the proposed reduction in the supply and return fan speed. The remaining electric savings result from a reduction in the cooling loads due to a lower outside airflow. Each unit continues to provide a constant mixed airflow of 22,246 cfm.

3. ECM 3: Removal of AHU-5 and AHU-6 Airflow Stations in Building C

   The applicant analysis calculates the energy savings from AHU-5 and AHU-6 using temperature-based bin models with TMY3 weather data for Providence, RI. The analysis has four separate bin models to cover the existing (base) and proposed case for each air handling unit. Please note, this section details the methodology in the revised applicant analysis, which was updated after commissioning.

   The report in the applicant files states the supply fans do not modulate their speeds and continuously provide the design volume of airflow. The report states the existing supply fan kW for AHU-5 and AHU-6 is calculated using trend data from October 2016 to May 2017. However, the applicant analysis varies the supply fan speed (between 100% and 98% speed for AHU-6 and between 55% and 41% speed for AHU-6) and supply airflow in the existing and proposed bin models. In each temperature bin, the supply fan speeds are hardcoded into the analysis; their relationship with outside air temperature is unclear. Regarding the calculated supply fan kW, the applicant does not state the speed or airflow to which it corresponds.

The applicant analysis uses the same equation as ECM 2 to calculate the fan energy, with the same cycle ratio of 100% and VFD affinity exponent of 2.5.

$$Fan\ Energy\ kWh = \ Cycle\ Ratio * Hours * Motor\ Input\ kW * Fan\ \%\ Speed^{VFD\ Affinity\ Exponent}$$

The proposed supply motor input kW is calculated using the following equation. The applicant report states the pressure drop across airflow station was measured using a pressure gauge on each side of the airflow station on the supply ductwork for each unit. The base supply static pressure and the pressure drop across each airflow station were used to calculate the proposed supply static pressure.

$$Proposed\ Supply\ Motor\ Input\ kW = \left(\frac{Proposed\ Supply\ \ Static\ Pressure}{Base\ Supply\ \ Static\ Pressure}\right)^2 * Base\ Supply\ Motor\ Input\ kW$$

ECM 4: VFDs on Boiler Feedwater Pumps in the Central Utility Plant

The applicant uses a spreadsheet analysis with the hourly steam load profile (converted to condensate flowrate in units of lb/hr) to calculate the energy savings for this measure. The analysis models one pump as energized when the steam load ≤ 80,000 lb/h and two pumps energized when the steam load > 80,000 lb/hr. The load never exceeds the capacity of two feedwater pumps, so the three feedwater pumps never operate concurrently (lead/lag/standby).

The savings are based on the Valliencourt Equation, shown below.

$$\left[\left(1 - \frac{\sqrt{H_{min}}}{\sqrt{H_D}}\right) * \left(\frac{F_2}{F_D}\right) + \frac{\sqrt{H_{min}}}{\sqrt{H_D}}\right]^3 = \left(\frac{HP_2}{HP_1}\right)$$

H_{min} is the proposed supply pressure (psi). H_D is the base case supply pressure. F_2 is the proposed pump design flowrate (gpm). F_D is the base case pump design flowrate. HP_1 is the base case pump power. The equation is rearranged to solve for HP_2, which is the proposed case pump power (kW). The Valliencourt Equation is also adjusted to include the VFD efficiency and number of pumps operating as shown below.

$$\begin{aligned} &Proposed\ Pump\ kW \\ &= \frac{Base\ Pump\ Power}{VFD\ Efficiency} * \#\ of\ pumps \\ &* \left[\left(1 - \sqrt{\frac{Proposed\ Pressure}{Base\ Pressure}}\right) * \frac{\frac{Total\ Flow}{\#\ of\ pumps}}{Base\ Flow} + \sqrt{\frac{Proposed\ Pressure}{Base\ Pressure}}\right]^3 \end{aligned}$$

The applicant assumed a proposed pressure of 325 psi for the boilers. This minimum setpoint was provided by the on-site power plant staff. Please note, the final measure savings were updated post commissioning. The revised calculation updated the installed supply pressure to 305 psi and the VFD efficiency to 97% (previously 98%). The methodology was not affected.

ECM 5: Compressed Air Leak Repairs in Various Buildings

The applicant analysis includes a spreadsheet savings calculation and a compressed air leak audit summary. The applicant uses 10 days of metered data (amps) to determine the existing energy use of the two compressors.

$$Base\ kWh = Average\ Compressor\ kW\ demand * 8760$$

In the existing case, the compressors always operate in their fully loaded state, so the existing average compressors kW demand is the same as the full load kW demand.

$$Baseline\ Average\ Compressor\ kW\ demand = Full\ Load\ kW\ demand$$

The applicant assumes the compressors use 20% of their full load kW demand when in an unloaded state.

The applicant uses the pressure and dB reading at each leak to calculate the raw leak rate and applies a diversity factor of 75% to determine an adjusted leak rate. The total adjusted leak rate and the capacity of the compressors are used to calculate the amount of time the compressors are fully loaded in the proposed case (all leaks repaired).

$$\%\,Time\ at\ Full\ Load = \frac{(Rated\ CFM - Leak\ Rate)}{Rated\ CFM}$$

$$\%\,Time\ Unloaded = 1 - \%\,Time\ at\ Full\ Load$$

The following equation is used to calculate the proposed annual energy use.

$$Proposed\ kWh = (Full\ Load\ kW\ ) * \%\,Time\ at\ Full\ Load * 8760 + Unloaded\ kW * \%\,Time\ Unloaded * 8760$$

15.2.3 Evaluation Assessment of Applicant Methodology

This section summarizes the evaluator's assessment of the application's savings methodology for each measure.

1. ECM 1: Reduced Airflow in Operating Rooms when Unoccupied in Building A

   The evaluator agrees with the spreadsheet modelling approach for the bin models. However, the evaluator does not agree with how the applicant models the fan speed input, motor kW inputs, or the unoccupied proposed heating/cooling loads.

   The applicant should use the actual fan speeds (%) and motor input kW at the design airflows and the eQuest fan curve to calculate the nominal motor input kW at full speed. The fan power should be calculated based on this nominal motor input kW and the proposed fan speeds. This approach would affect the fan savings for AHU-2, whose supply and return fans operate at less than 100% speed at design airflow during occupied periods and less than 50% speed during unoccupied periods. The evaluator will adjust the measure savings based on this methodology discrepancy.

   The applicant analysis also underestimates the heating and cooling savings from the ventilation setback. The applicant should calculate the heating and cooling loads in the proposed unoccupied case based on the (reduced) supply airflow, mixed air temperature, and discharge air temperature. The discrepancy in the proposed unoccupied heating/cooling loads calculation falls into the methodology category. The evaluator will adjust the measure savings for this methodology discrepancy.

   The applicant analysis does not include economizing when the air handlers are in cooling mode, where economizing would be beneficial in reducing mechanical cooling loads. The existing control sequences for economizing is not described in the report or MRDs. Due to COVID related evaluation limitations, the evaluator could not investigate the controls sequences nor the equipment operation. The evaluator will not adjust the applicant savings based on this potential operational discrepancy.

   The applicant also models a 50% reduction in speed as equivalent to a 50% reduction in airflow. Depending on the fan speed control method, the % flow will be different than the % speed; they are only the same when affinity laws apply. This false equivalency (% speed = % flow) does not affect the applicant saving calculation for this measure because the conditioning loads are hard coded. This error will affect the evaluator savings calculation, which calculates the heating and cooling loads based on airflow. Due to COVID related evaluation limitations, the evaluator could not determine the unoccupied airflow at which each AHU operates. The evaluator will not adjust the measure savings based on this operational discrepancy.

   The discrepancy between the stated unoccupied hours (9 hours daily) and the modelled unoccupied hours (10 hours daily) also falls into the operations category. The evaluator will not adjust the applicant savings based on this operational discrepancy.

2. ECM 2: Demand Control Ventilation (DCV) in Cafeteria in Building B

   The evaluator agrees with the spreadsheet modelling approach for the bin models. However, the existing control sequences for economizing and the proposed control sequence for fan speed in heating mode are not fully described in the report or MRDs. The applicant analysis does not include economizing when the air handlers are in cooling mode nor during unoccupied periods, where economizing would be beneficial in reducing mechanical cooling loads. The applicant does not clarify why the reduction in fan speed only occurs during the proposed unoccupied period and not during the occupied period as well. Additionally, a reduction in fan speed during heating mode may reduce the total mixed airflow to the space and affect the heating loads on the HW coils. Due to COVID related evaluation limitations, the evaluator could not investigate the controls sequences nor the equipment operation. The evaluator will not adjust the applicant savings based on these operational discrepancies.

The applicant analysis for ECM 2 uses a different equation to model fan energy than ECM 1. The reason for this inconsistency in the methodology is not stated. However, due to the limited scope of this site's evaluation assessment, the evaluator will not change the applicant savings based on this discrepancy.

The discrepancy between the peak occupancy period in the TA report (5 hours daily) and the modelled occupied period (6 hours daily) falls into the operations category. The evaluator will not adjust the applicant savings based on this operational discrepancy.

3. ECM 3: Removal of AHU-5 and AHU-6 Airflow Stations in Building C

   The evaluator agrees with the spreadsheet modelling approach for the bin models. However, the existing operation of the AHUs is unclear. In the existing case, the TA report states that supply fan speed does not modulate and the units provide the design volume of airflow (constant volume), while the applicant analysis models variable volume operation with variations in fan speed. Because the applicant does not provide the trend data (% speed or cfm) nor the metered data (amps) referenced in the TA report, the applicant cannot verify the existing supply fan speed or kW demand. This discrepancy falls into the operational category. Due to the limited scope of this site's evaluation assessment, the evaluator will not change the applicant savings based on this discrepancy.

4. ECM 4: VFDs on Boiler Feedwater Pumps in the Central Utility Plant

   The evaluator agrees with the applicant analysis, but there is an error in the applicant's calculation of the baseline pump kW. The applicant neglects to include the 0.746 kW/BHP conversion factor when calculating the pump input power based on pump BHP. The evaluator will adjust the measure savings based on this methodology discrepancy.

   It should be noted the spreadsheet analysis includes 8,784 hours in its steam load profile. The load profile is based on the year 2016, which is a leap year. The evaluator will adjust the measure savings to consider a typical year with 8,760 hours annually to correct this methodology discrepancy.
5. ECM 5: Compressed Air Leak Repairs in Various Buildings

   The evaluator agrees with the applicant analysis.

15.3 Virtual Inspection

No virtual inspection, interview or other M&V tasks were completed. This site is a large hospital campus. Per COVID restrictions, the evaluator was not permitted to conduct these tasks or communicate with hospital staff.

15.4 Evaluation Methods and Findings

This section describes the evaluator methods and findings.

15.4.1 Evaluation Description of Baseline

The evaluator reviewed the project files to gather information on the baseline.

For all five measures, the evaluator agrees with the applicant baseline measure classification of retro commissioning/retrofit. The existing controls and equipment could have been left as-is or replaced in-kind. Based on the TA study report, all relevant equipment (AHUs, SDs, pumps, compressors, etc.) was in good, operating condition.

15.4.2 Evaluation Calculation Method

The evaluator reviewed the TA study report, applicant analyses, and revised (post commissioning) analyses to determine the applicant's savings methodology and identify any inconsistencies. Section 2.2.3 details the discrepancies found during the evaluation process. Due to the limited scope of the evaluator's review and savings adjustments, the savings for ECM 2, 3, and 5 remain unchanged. The evaluator updated the applicant analyses for ECM 1 and ECM 4 to correct methodology discrepancies.

ECM 1 considers the savings from reducing fan speed (and airflow) by 50% when operating rooms are unoccupied. This measure affects AHU-1, whose supply and return fans run at 100% speed to provide the design (occupied) airflow, and AHU-2, whose supply fan runs at 78% speed and return fan runs at 49% speed to provide the design (occupied) airflow.

The applicant analysis sets the base case speed to 100% and the proposed case speed to 50% for both AHUs. The applicant uses the motor input kW calculated at the design airflows and the equations below to calculate the savings.

$$Fan\ Energy\ kWh = \ Cycle\ Ratio * Hours * Motor\ Input\ kW * \%\ power$$

$$\%\ power = (A + B * Fan\ \%\ Speed + C * (Fan\ \%\ \ Speed)^2 + D * (Fan\ \%\ Speed)^3)$$

This approach is valid for AHU-1 because it operates at 100% speed in the existing case and will be reset to 50% speed in the proposed case. For AHU-2, the evaluator uses the eQuest fan curve, the actual supply fan speed of 78%, and the kW demand of 23.32 kW at that speed to calculate the supply fan's nominal motor kW input (at full speed). The evaluator uses the nominal motor input kW and the actual (existing and proposed) fan speed to calculate the measure savings. This process is repeated for the return fan. The evaluator uses the following equation to calculate the fan energy use.

$$Fan\ Energy\ kWh = Cycle\ Ratio * Hours * Nominal\ Motor\ Input\ kW * \%\ power$$

$$Nominal\ Motor\ Input\ kW(at\ full\ speed) = \frac{Motor\ Input\ kW(at\ given\ \%\ fan\ speed)}{y(at\ given\ \%\ fan\ speed)}$$

Figures 2-1 and 2-2 compare the applicant's and evaluator's calculated fan kW at different airflows. Please note, the x-axis refers to the % of the design airflow, where 100% is the design (occupied) airflow and 50% is the unoccupied airflow. The x-axis is does not directly represent the fan % speed. Tables 2-4 and 2-5 include the same information as the figures below with their associated fan speeds. To reiterate, these fan speeds and the eQuest fan curve are used to calculate the Fan kW demand.

Figure 2-181. Comparison of Applicant and Evaluator Supply Fan kW at Different Airflows

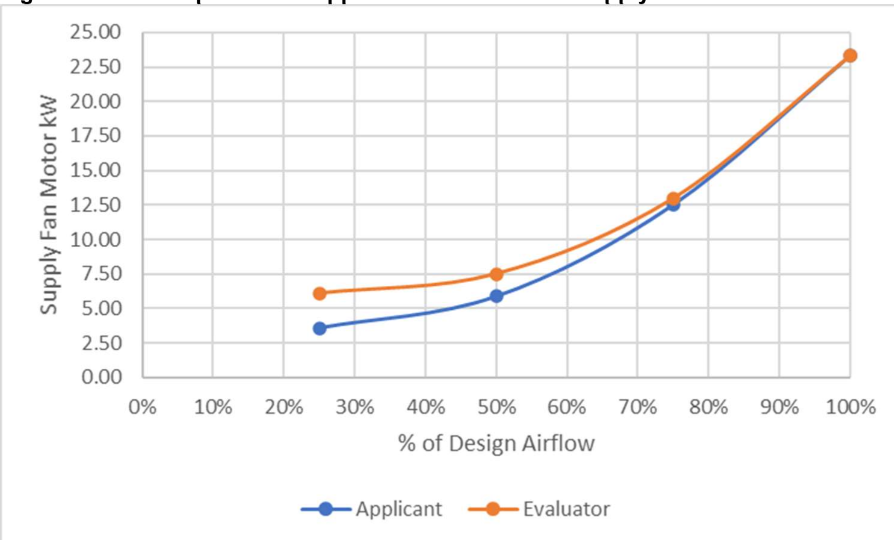


Table 2-4. Summary of AHU-2 Supply Fan kW Calculation

	Applicant		Evaluator	
% of Design Flow	**Speed Input**	**Supply Fan kW**	**Speed Input**	**Supply Fan kW**
Nominal Motor Input kW	100%	23.32	100%	39.89
100% (design)	100%	23.32	78.0%	23.32
75%	75%	12.50	58.5%	12.97
50% (unoccupied)	50%	5.86	39.0%	7.49
25%	25%	3.57	19.5%	6.08

Figure 2-2. Comparison of Applicant and Evaluator Return Fan kW at Different Airflows

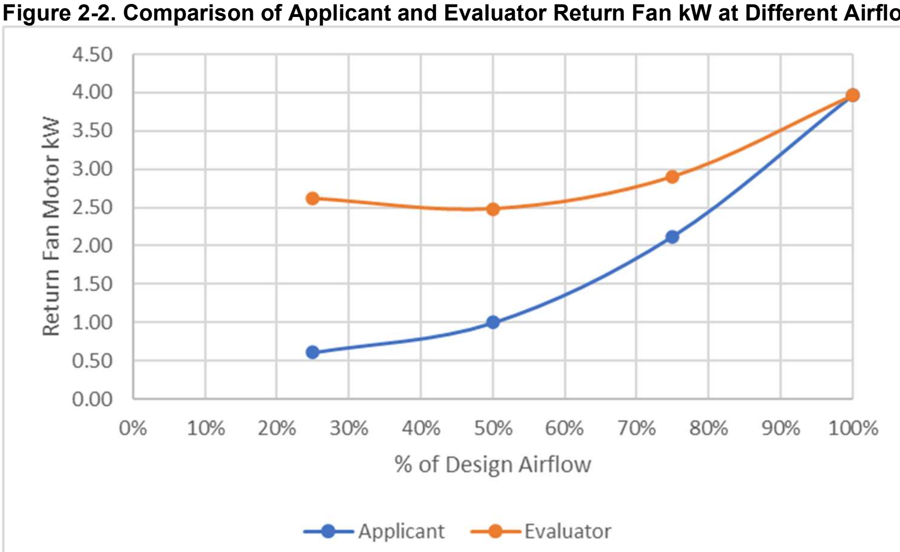


Table 2-5. Summary of AHU-2 Return Fan kW Calculation

	Applicant		Evaluator	
% of Design Flow	**Speed Input**	**Return Fan kW**	**Speed Input**	**Return Fan kW**
Nominal Motor Input kW	100%	3.96	100%	16.22
100% (design)	100%	3.96	49.0%	3.96
75%	75%	2.12	36.8%	2.90
50% (unoccupied)	50%	1.00	24.5%	2.48
25%	25%	0.61	12.3%	2.62

ECM 1 considers the energy savings from implementing ventilation setbacks when the operating rooms are unoccupied. The applicant models a 50% reduction in the supply airflow during unoccupied periods, but they hard coded the proposed heating and cooling loads to match the existing unoccupied values. The applicant analysis only includes fan savings.

The evaluator analysis calculates the heating and cooling loads in the proposed unoccupied case based on the reduced supply airflow, mixed air temperature, and discharge air temperature. To be consistent with the applicant analysis, the cooling efficiency is assumed to be 0.9 kW/ton and the (hot water) heating system is assumed to be 75% efficient. The evaluator analysis includes an additional 34,845 kWh of cooling savings and 12,652 therms of heating savings.

For ECM 4, the applicant calculated the base pump power (kW) using the following equations.

$$Pump\ BHP = \frac{Flow * (Discharge\ Pressure - Suction\ Pressure) * 2.31}{(3960 * Pump\ Efficiency)}$$

$$Base\ Pump\ Power\ = \frac{Pump\ BHP}{Motor\ Efficiency}$$

The evaluator updated the second equation to include a kW/BHP conversion factor. Because the savings methodology relies on the Valliencourt Equation, adjusting the base pump power also affects the proposed/installed pump power. The corrected base pump power equation and the Valliencourt Equation (reorganized to solve for proposed pumps kW) are shown below.

$$Base\ Pump\ Power\ = \frac{Pump\ BHP}{Motor\ Efficiency} * 0.746 \frac{kW}{BHP}$$

$$\begin{aligned} Proposed\ Pump\ kW \\ &= \frac{Base\ Pump\ Power}{VFD\ Efficiency} * \#\ of\ pumps \\ &* \left[\left(1 - \sqrt{\frac{Proposed\ Pressure}{Base\ Pressure}}\right) * \frac{\frac{Total\ Flow}{\#\ of\ pumps}}{Base\ Flow} + \sqrt{\frac{Proposed\ Pressure}{Base\ Pressure}} \right]^3 \end{aligned}$$

The applicant updated the proposed pressure after commissioning, so the evaluator analysis is based on the corrected proposed pump kW and the pressure observed post commissioning.

The applicant analysis spreadsheet for ECM 4 is based on the site’s 2016 steam load profile. The analysis include savings from 8,784 annual hours for the 2016 leap year. The evaluator used the following equation to adjust the savings to consider a typical year with 8,760 hours.

$$Typical\ Annual\ kWh\ Savings = \frac{Leap\ Year\ kWh\ Savings}{8784\ hours} * 8760\ hours$$

16 Final Results

This section summarizes the evaluation results determined in the analysis above. The tables below include a summary of the key parameters and savings in the baseline, proposed, and installed cases.

The evaluator did not perform measurement and verification; however, the applicant files were reviewed to identify any discrepancies. Due to the impact of COVID on evaluation efforts, the savings are not updated to reflect any operational discrepancies. The savings for ECM 1 and ECM 4 are adjusted to correct methodology discrepancies. The evaluated savings for the entire project differ from the tracked savings.

Table 5-182. Summary of Key Parameters

Parameter	BASELINE Tracking Value(s)	BASELINE Evaluation Value(s)	PROPOSED / INSTALLED Tracking Value(s)	PROPOSED / INSTALLED Evaluation Value(s)
ECM 1: AHU-1 Unoccupied Supply Fan Speed Input	100%	100%	50%	50%
ECM 1: AHU-1 Unoccupied Supply Fan Power	21.55 kW	21.55 kW	5.42 kW	5.42 kW
ECM 1: AHU-1 Unoccupied Return Fan Speed Input	100%	100%	50%	50%
ECM 1: AHU-1 Unoccupied Return Fan Power	6.36 kW	6.36 kW	1.60 kW	1.60 kW
ECM 1: AHU-2 Unoccupied Supply Fan Speed Input	100%	78%	50%	39%
ECM 1: AHU-2 Unoccupied Supply Fan Power	23.32 kW	23.32 kW	5.86 kW	7.49 kW
ECM 1: AHU-2 Unoccupied Return Fan Speed Input	100%	49%	50%	24.5%
ECM 1: AHU-2 Unoccupied Return Fan Power	3.96 kW	3.96 kW	0.99 kW	2.48 kW
ECM 2: Unoccupied Minimum % Outside Air	10%	10%	5%	5%
ECM 2: Minimum Unoccupied, Heating Supply Fan Speed	100%	100%	75%	75%
ECM 2: Minimum Unoccupied, Heating Return Fan Speed	100%	100%	75%	75%
ECM 3: AHU-5 Static Pressure	5.5 in w.g.	5.5 in w.g.	4.2 in w.g.	4.2 in w.g.
ECM 3: AHU-5 Supply Fan Power	24.5 kW	24.5 kW	14.8 kW	14.8 kW
ECM 3: AHU-6 Static Pressure	2.5 in w.g.	2.5 in w.g.	2.45 in w.g.	2.45 in w.g.
ECM 3: AHU-6 Supply Fan Power	7.4 kW	7.4 kW	7.1 kW	7.1 kW
ECM 4: Pumps Supply Pressure	365 psi	365 psi	305 psi	305 psi
ECM 4: Average Pump Input Power	95.93 kW/pump	71.56 kW/pump	84.67 kW/pump	63.16 kW/pump
ECM 5: Total Identified Leaks	51.5 cfm	51.5 cfm	0 cfm	0 cfm
ECM 5: Time Spent at Full Load	100%	100%	64%	64%

16.1 Explanation of Differences

Table 5-51 provides a summary of the differences between the overall tracked and evaluated savings.

Table 5-183. Summary of Deviations

Measure	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
7244682, ECM 4	Methodology	Pump kW	-7%	**Decreases savings –** The applicant excluded the 0.746 kW/BHP conversion factor when calculating the boiler feedwater pump power. The evaluator corrected this error, which reduced the savings.
7244682, ECM 1	Methodology	Unoccupied Cooling Load	+6%	**Increases savings –** The applicant hard coded the proposed unoccupied cooling loads to match the existing cooling loads, resulting in zero cooling savings from implementing the ventilation setback. The evaluator analysis calculated the proposed unoccupied cooling loads based on the proposed reduction in supply airflow, which resulted in a reduction in the proposed unoccupied cooling load and increased savings.
7244682, ECM 1	Methodology	AHU-2 Proposed Fan Power	- 3%	**Decreases savings –** The applicant set the occupied/unoccupied fan speed inputs to 100%/50%, the motor kW at their design speed (78% for supply and 49% for return for AHU-2), and the eQuest fan curve to calculate the proposed fan energy. For AHU-2, the evaluator used the actual fan speeds, kW demands at those fan speeds, and the eQuest fan curve to calculate the nominal motor input kW. The nominal motor input kW, actual fan speeds (78% for supply, 49% for return), and proposed fan speeds (39% for supply, 24.5% for return) are used to calculate the fan savings. This update decreased the measure savings.
7244682, ECM 4	Methodology	Annual Hours	-0%	**Decreases savings –** The applicant spreadsheet analysis is based on the site's 2016 (leap year) steam load profile, which calculates savings based on 8,784 annual hours. The

				evaluator adjusted the savings to consider a typical year with 8,760 hours.
7244682, ECM 1	Admin	Final Savings	- 0%	**Decreases savings –** The applicant files have a typo. The calculated applicant savings are 160,842 kWh, but the values listed in the report and screening tool is 160,798 kWh. This minor error (44 kWh difference) was carried over to the tracked savings.
Final RR				**96%**

RR = Realization rate

16.2 Ancillary Impacts

The purpose of this custom electric evaluation is to evaluate the tracked electric savings. However, the applicant analyses modelled heating and cooling loads for multiple measures. Some measures include or have the potential for natural gas savings.

For ECM 1: Reduced Airflow in Operating Rooms when Unoccupied in Building A, the applicant hard coded the proposed case heating/cooling loads to match the existing case loads so the heating/cooling savings were zero. The applicant should calculate the heating and cooling loads in the proposed unoccupied case based on the reduced supply airflow, mixed air temperature, and discharge air temperature. The applicant analysis underestimates the savings from the ventilation setback by only considering the fan savings. The evaluator analysis updated the load calculation, which increased the cooling savings to 34,845 kWh and the heating savings to 12,652 therms savings.

For ECM 2: Demand Control Ventilation (DCV) in Cafeteria in Building B, the applicant claimed kWh and therm savings. The applicant analysis includes 3,644 therm savings from a reduced heating load in the proposed case.

RICE18N148

Report Date: 6/18/2021

Application ID(s)	8206773	
Project Type	C&I Initial Purchase & End of Useful Life	
Program Year	2018	
Evaluation Firm	DNV	
Evaluation Engineer	Long Vu	
Senior Engineer	George Sorin IOAN	

Evaluated Site Summary and Results

The evaluated project was installed at a supermarket and consisted of the installation of four new self-contained coffin cases with solid doors. All new coffin cases operate continuously.

The applicant classified the measure as a new construction with an industrial standard practice (ISP) baseline. The applicant baseline consisted of four coffin cases that meet the 2015 IECC minimum requirements for commercial refrigerators (no doors). The project saves energy because the installed coffin cases have smaller infiltration into the refrigerated spaces than the baseline system.

The operation of the facility and of the installed coffin cases were not significantly impacted by the current pandemic and the evaluators conducted metering and verification to evaluate the measure. The results of the evaluation include updates on both non-operational and operational parameters associated with the evaluated measure.

Based on the on-site findings and the review of the project documentation, the evaluators classified the project as a lost opportunity with ISP baseline. The evaluators defined the ISP using the Federal Energy Conservation Standard (FECS) Title 10, section 431.66. The evaluator calculated the project impacts using eQuest Refrigeration v3.65, which is the same as the applicant's, with updated input parameters. The evaluated savings were greater than the reported tracking value primarily because the average electrical demand (which is an indication of operating load) of the installed cases is smaller than the applicant value. The evaluation results are presented in Table 1-1.

Table 5-184. 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)
8206773	Install coffin cases with solid doors	Tracked	9,635	46%	0.88	0.73
		Evaluated	10,713	46%	1.22	1.22
		Realization Rate	**111%**	**100%**	**139%**	**168%**

Explanation of Deviations from Tracking

The evaluated savings are 8% more than the applicant-reported savings primarily because the operating load of the installed cases is smaller than the applicant value. Further details regarding deviations from the tracked savings are presented in Section 3-1.

Recommendations for Program Designers & Implementers

There are no recommendations currently.

Customer Alert

There were no customer alerts.

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 four new coffin cases equipped with solid doors.

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.

Applicant Description of Baseline

Based on the project files, the applicant classified the project as a new construction with an ISP baseline. The applicant baseline consisted of four coffin cases that meet the 2015 IECC minimum requirements for commercial refrigerators (no solid doors). Table 2-1 presents the applicant's baseline key input parameters.

Table 5-185. Applicant Baseline Key Parameters

Parameter	Value(s)	Source of Parameter Value
Average case electrical demand	1.4 kW	Applicant model inputs
Operating hours	8,760 hours	Applicant model inputs
Installed cases quantity	4	Project documentation
Total display area (TDA) per coffin	2.6 sq.ft.	Project documentation
Modelled electricity consumption	1,793,248 kWh	Applicant model outputs

Applicant Description of Installed Equipment and Operation

The applicant's installed condition consisted of four coffin cases with solid doors. Table 2-2 presents the applicant's proposed key input parameters

Table 5-186: Application proposed key parameters

Parameter	Value(s)	Source of Parameter Value
Average case electrical demand	0.3 kW	Applicant model inputs
Operating hours	8,760 hours	Applicant model inputs
Installed cases quantity	4	Project documentation
TDA per coffin	2.6 sq.ft.	Project documentation
Modelled electricity consumption	1,783,611 kWh	Applicant model outputs

Applicant Energy Savings Algorithm

The applicant calculated the project impacts using eQuest Refrigeration v3.65 and a spreadsheet-based analysis. The applicant calculated the average electrical demand of the baseline coffin cases using the following formula:

$$kW_b = \frac{\left(0.57 \times \frac{L \times W}{244} + 6.88\right) \times Qty}{24}$$

where:

kW_b	= electrical demand of the baseline cases, kW
L	= length of display of each case, in
W	= width of display of each case, in
0.57	= calculation factor, determined by 2015 IECC

6.88	= calculation factor, determined by 2015 IECC
244	= conversion factor from square inch to square feet
Qty	= quantity of the baseline cases, 4
24	= hours per day

The applicant's average electrical demand of the baseline cases is 1.4 kW. The applicant determined the electrical demand of the proposed cases to be 0.3 kW based on the specification cutsheet of the proposed units.

The applicant used the electrical demand information of the baseline and proposed units as inputs to the energy model in eQuest.

Evaluation Assessment of Applicant Methodology

The evaluators found the applicant's savings methodology reasonable and used the same methodology to calculate the project savings.

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.

Summary of On-site Findings

The evaluators conducted the site visit on April 30th, 2021 with the help of the store manager. During the site visit, the evaluators performed the following tasks:

- Verified that the coffin cases with solid doors were installed and operating as intended.
- The evaluators found only two coffin cases at the site, the site contact mentioned that the cases are moved to different supermarkets in RI (under the same management). The site contact also mentioned that the two incentivized cases were likely moved to other locations at least one year after they were installed at the inspected location. Even though the units could not be inspected, the evaluators took the word of the site contact that were likely used in another store in a similar manner, thus saving were claimed for the units moved to another store at the same rate as the ones found on-site.
- Gathered nameplate information of the installed cases, the nameplate information matched with the information included in the project documentation.

Photo 2-1 shows the nameplate information of the installed cases.

Photo 2-1. Nameplate Information – Installed Cases

Photo 2-1 shows that the TDA of the installed coffin cases is 2.85 sq.ft., which is greater than the value predicted by the applicant.

Table 2-3 provides a summary of the measure verification method.

Table 5-187. Measure Verification

Measure Name	Verification Method	Verification Result
Install coffin cases with solid doors	Visual inspection of the installed cases	All installed coffin cases were equipped with solid doors and operating as intended

Measured and Logged Data

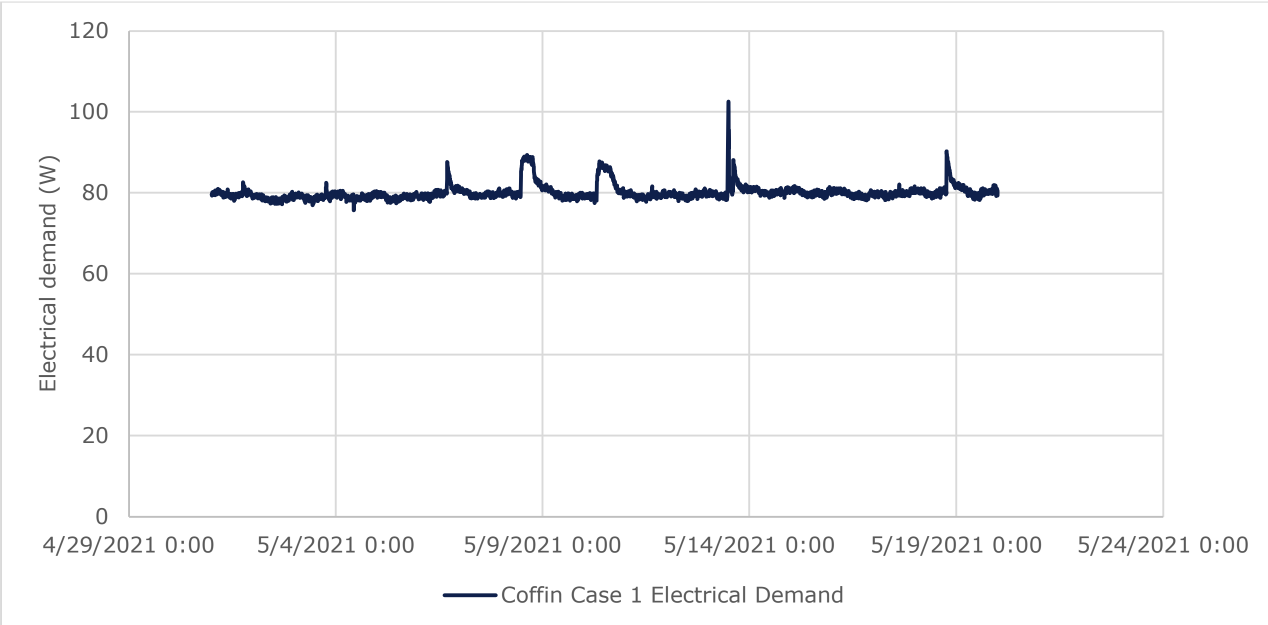
During the site visit, the evaluators deployed plug load logger data on two installed coffin cases. Because the installed units are packaged units, the plug load loggers metered the whole unit power which consisted of lighting, compressor and condenser fan. The metering period was from April 30th through May 19th, 2021. Table 2-4 presents the logger deployment details.

Table 2-4. Evaluation Data Collection – Installed Equipment

Parameter	M&V Equipment Brand and Model	Metering Start/Stop Dates	Metering Interval
Electric demand (kW)	2 x HOBO plug load logger	04/30/2021 – 05/19/2021	5 minutes

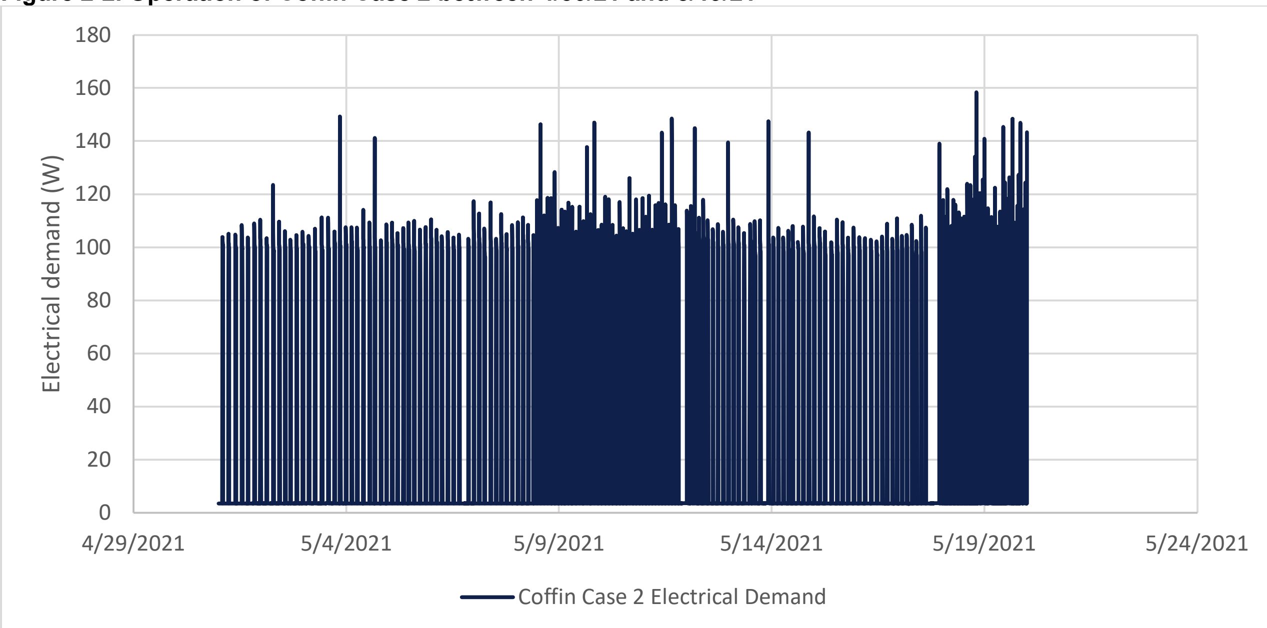
Figure 2-1 and 2-2 show the graphical summary of the plug load loggers.

Figure 2-1. Operation of Coffin Case 1 between 4/30/21 and 5/19/21



120
100
80
60
40
20
0
Electrical demand (W)
4/29/2021 0:00
5/4/2021 0:00
5/9/2021 0:00
5/14/2021 0:00
5/19/2021 0:00
5/24/2021 0:00
Coffin Case 1 Electrical Demand

Figure 2-2. Operation of Coffin Case 2 between 4/30/21 and 5/19/21



The evaluators developed an average electrical load profile (in watts) for the installed coffin cases. Table 2-5 presents the developed load profile.

Table 2-5. Electrical Load Profile – Installed Coffin Case

Hour/ Weekday	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Sun	41.921	53	42	54	49	47	47	54	47	46	49	55	41	55	48	47	49	51	43	49	54	41	53	50
Mon	45.638	48	51	45	54	41	56	47	46	49	56	42	54	48	51	48	42	53	42	46	50	46	47	52
Tue	50.245	47	48	50	49	44	58	44	48	53	50	46	47	54	46	51	55	52	46	57	44	45	52	47
Wed	54.529	49	56	45	56	50	47	48	54	53	45	55	48	44	60	48	45	57	45	45	57	45	47	58
Thu	45.485	42	58	48	42	56	47	41	52	52	41	49	59	42	55	53	43	56	43	42	48	46	56	47
Fri	52.467	46	46	57	42	46	59	42	42	64	41	48	56	42	73	54	42	52	54	42	49	58	42	48
Sat	51.46	43	50	55	42	51	55	42	42	63	42	48	47	61	43	52	54	49	45	55	50	48	50	54

Table 2-5 shows that the metered coffin cases are on a 24/7 schedule. The evaluators calculated the average demand of the metered coffin case to be 49 watts. The evaluators then estimated the average demand for all four installed coffin cases to be 197 watts. The average demand of the as-built units is smaller than the applicant value (300 watts), which indicates that the as-built units have lower infiltration rate and operating load than predicted by the applicant. This lower infiltration rate of the as-built system does not impact the baseline system's infiltration rate and refrigeration load.

Evaluation Methods and Findings

This section describes the evaluator methods and findings.

Evaluation Description of Baseline

Based on the on-site findings and the project documentation, the evaluators classified the measure as a new construction with an ISP baseline. At the time the project was installed (2017), IECC 2015 was not in effect in Rhode Island, therefore, the evaluators used Federal Energy Conservation Standard (FECS) to determine the baseline. The evaluated baseline consisted of four coffin cases that meet the FECS requirements for commercial refrigerators (Title 10, section 431.66) which are four coffin cases with no solid doors. Table 2-6 presents the evaluators' baseline key input parameters.

Table 5-6. Evaluator Baseline Key Parameters

Parameter	Value(s)	Source of Parameter Value
Average case electrical demand	1.42 kW	Calculated using FECS
Operating hours	8,760 hours	Same as applicant
Installed cases quantity	4	Project documentation
Total display area (TDA) per coffin	2.85 sq.ft.	Name plate data
Modelled electricity consumption	1,793,423 kWh	Evaluated model outputs

Evaluation Calculation Method

The evaluators calculated the project savings using the same methodology as the applicant. The evaluators calculated the electrical demand of the baseline units using the following formula.

$$kW_b = \frac{(0.57 \times TDA + 6.88) \times Qty}{24}$$

where:

kW_b	= electrical demand of the baseline cases, kW
TDA	= total display area of the installed coffin case, 2.85 sq.ft.
0.55	= calculation factor, determined by FECS
6.88	= calculation factor, determined by FECS
244	= conversion factor from square inch to square feet
Qty	= quantity of the baseline cases, 4
24	= hours per day

The evaluated electrical demand of the baseline system was 1.42 kW.

The evaluators updated the eQuest energy model with the evaluated baseline and as-built electrical demand (as calculated in the formula above and in section 2.3.2).

Final Results

The project was installed at a supermarket and included the installation of four new coffin cases equipped with solid doors. The measure saves energy because the as-built system has a smaller infiltration rate than the ISP baseline system. The evaluators calculated the savings using the same methodology with the one used by the applicant. Based on the metered data, the evaluators found that the electric demand of as-built units are smaller than the applicant value, which indicates that the infiltration rate and operating load of the as-built system are smaller than predicted by the applicant. This lower infiltration rate shows that the as-built system performs better than predicted by the applicant and does not impact the infiltration rate or the operating load of the baseline system. The evaluated savings are greater than the reported values. The parameters impacted the analysis are summarized in Table 3-1.

Table 5-188. Summary of Key Parameters

	BASELINE		PROPOSED / INSTALLED	
Parameter	Tracking Value(s)	Evaluation Value(s)	Tracking Value(s)	Evaluation Value(s)
Average case electrical demand (kW)	1.4	1.42	0.3	0.2
Operating hours	8,760	8,760	8,760	8,760
Installed case quantity	4	4	4	4

Total TDA per coffin (sq.ft.)	2.6	2.6	2.6	2.6
Modelled electricity consumption (kWh)	1,793,248	1,793,423	1,783,611	1,782,710

Explanation of Differences

The evaluated savings are greater than the reported value primarily because the electrical demand of the as-built system is smaller than the applicant's value, which indicated that the infiltration rate and operating load of the as-built system is smaller than the applicant's value. Table 3-2 provides a summary of the differences between tracking and evaluated values.

Table 5-189. Summary of Deviations

Measure	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
8206773	Operational	Operating load	+9%	**Increased savings –** The evaluated electrical demand of the as-built system was smaller than the applicant value, which indicated that the infiltration rate and operating load of the as-built system is smaller than the applicant value. The lower infiltration rate and operating load show that the as-built system performed better than predicted by the applicant and does not impact the infiltration rate and operating load of the baseline system.
8206773	Quantity	Total display area	+4%	**Increased savings –** The installed cases have a greater TDA than the value predicted by the applicant, which resulted in greater baseline measure consumption and greater savings.
8206773	Baseline	Baseline power	-1%	**Decreased savings –** The evaluated electrical demand of the baseline system was calculated using FECS. The calculated value was smaller than the applicant's value.

Ancillary Impacts

The evaluators calculated the ancillary impacts using the following formula:

$$heat\ savings = \frac{elec\ savings\ \times 3{,}412}{100{,}000 \times 0.8}$$

where:

$heat\ savings$ = ancillary heating savings, therms

$elec\ savings$ = evaluated project savings, kWh

3.412 = conversion factor from kWh to Btu

$100{,}000$ = conversion factor from Btu to therm

0.8 = estimated heating efficiency

The evaluators calculated the ancillary impacts to be 457 therms.

PY2019 SAMPLED SITES

RICE19C005

Report Date: May 17, 2021

Program Administrator	National Grid	
Application ID(s)	10048840	
Project Type	Retrofit Lighting & HVAC Controls	
Program Year	2019	
Evaluation Firm	DNV GL	
Evaluation Engineer	Ryan Brown	
Senior Engineer	Jeff Zynda	

Evaluated Site Summary and Results

This project is for a chain retail box store and consisted of installing two measures: (1) retrofit lighting and (2) HVAC temperature setback controls. The application claimed savings are derived from the reduction in wattage when replacing pre-retrofit fixtures with LEDs. Savings are also claimed for installing dimming controls to all fixtures which are set to 70% max output, and occupancy controls to most of the back of house areas. HVAC interactive impacts were not considered for either lighting application in the tracked savings. The HVAC temperature setback measure consists of installing supply temperature setpoint controls to pull the thermostat temperature back during un-occupied periods. Applicant savings are derived from the reduced cooling load with a higher setpoint. However, the evaluator determined the on-site baseline condition for this measure was a similar control scheme, which did not match the applicant reported baseline of the HVAC system operating without controls. Therefore, evaluated savings were zero for the HVAC controls measure as there was no added efficiency to the equipment.

The evaluation for this site consists of full scope M&V which included operational impacts. In reference to the COVID-19 pandemic, the site has not seen any decrease in operation over the past year. The site has been consistent in store operation and measure use.

The site tracking estimated energy savings of 57,129 kWh, 2.49 on peak summer kW and 1.27 on peak winter kW. The evaluation kWh savings estimate is 65,218, yielding a 114% realization rate. Site results are compared to the tracking system estimates in

Table 5-53. Evaluation Results Summary below.

Table 5-190. 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)
10048840	Lighting Controls	**Tracked**	53,433	72%	2.03	2.03
		Evaluated	65,218	61%	13.68	10.16
		Realization Rate	122%	85%	674%	500%
10048840	HVAC Setback Controls	Tracked	3,696	46%	0.00	0.00
		Evaluated	0	0%	0.00	0.00
		Realization Rate	0%	0%	0%	0%
Totals		**Tracked**	**57,129**	**70%**	**2.03**	**2.03**
		Evaluated	**65,218**	**61%**	**13.68**	**10.16**
		Realization Rate	**114%**	**87%**	**674%**	**500%**

Explanation of Deviations from Tracking

The evaluated savings are 14% more than the applicant-reported savings primarily due to the addition of HVAC interactive cooling impacts for lighting, which is attributed to both fixtures as well as the controls. Further details regarding deviations from the tracked savings are presented in Section 3-4.

Recommendations for Program Designers & Implementers

It is recommended to conduct a full-scale pre-inspection for C&I projects to ensure the baseline event type and condition is properly reported.

Customer Alert

There are no customer alerts.

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 information available.

The project consisted of the installation of an interior lighting retrofit upgrade including dimming and occupancy controls, as well as setpoint setback controls for building HVAC.

Application Information and Applicant Savings Methodology

This section describes the application information, savings methodology provided by the applicant, and the evaluation assessment of the savings calculation algorithm used by the applicant. Both applicant and evaluated approaches calculated energy savings based on site findings and assumptions. Project savings were primarily based upon the fixture wattage reduction, as well as a reduction in annual operating hours attributed to controls.

Applicant Description of Baseline

The applicant measure type is Retrofit for both measures. The lighting retrofit installation was performed throughout the tenant space. The baseline condition for the 395 pre-existing fixtures were a mix of 2-4 lamp T8 fluorescents. Assumed annual operating hours were 4,693, which is a site-specific assumption. Applicant documentation does not state if lighting controls were present as a baseline condition. The baseline for the HVAC measure assumes the units were operating without controls at a lower cooling setpoint.

Applicant Description of Installed Equipment and Operation

The proposed condition for the lighting retrofit consisted of replacing all pre-existing fixtures with 443 LED fixtures. Hours of operation were 4,693 annually, equivalent with the baseline. Dimming controls were proposed for all areas where fixtures operating at 70% max output. Occupancy sensors were proposed to be installed for most of the auxiliary areas, where a 24% reduction was applied to the operating hours for those spaces.

The proposed condition for the HVAC controls applies a scheduled setback to the supply temperature for the space RTUs. The setback schedules are set and controlled via the site EMS.

Applicant Energy Savings Algorithm

The project documents include spreadsheet calculation files for both applications.

The applicant calculated the HVAC controls savings using a single algorithm to assume the reduction on building load. The algorithms are as follows:

$$Cooling\ savings_{kW} = Cooling\ savings_{btu} * \frac{0.000293071\ kWh}{1\ btu}$$

$$Cooling\ savings_{btu/hr} = Building\ load * Save_{factor}$$

$$Building\ load = EFLH_{cooling} * \frac{12{,}000\frac{btu}{hr}}{ton} * Tons\ needed$$

$$Tons\ needed = \frac{Building\ SF}{400\ SF/ton}$$

Where,

$EFLH_{cooling} = 935\ (eTRM)$

$Save_{factor} = 1\%$

$Building\ SF = 44{,}960$

The applicant calculated the lighting retrofit savings using a custom lighting analysis spreadsheet provided by the Program Administrator using the findings from the lighting audit as inputs. The tool determines energy savings by using the following formulas.

Baseline Fixture kWh = $\frac{Quantity_B * Wattage_B}{1000} * Applicant\ Operating\ Hours$

Proposed Fixture kWh = $\frac{Quantity_P * Wattage_P}{1000} * Applicant\ Operating\ Hours$

Fixture kWh Savings = $Baseline\ Fixture\ kWh - Proposed\ Fixture\ kWh$

Dimming kWh Savings = $(Proposed\ Fixture\ kW * (1 - Dim\%) * Applicant\ Operating\ Hours)$

Occupancy kWh Savings = $(Proposed\ Fixture\ kW * (1 - Dim\%) * (Applicant\ Operating\ Hours - (1 - Hours\%) * Applicant\ Operating\ Hours))$

Total kWh Savings = $Fixture\ kWh\ Savings + Dimming\ kWh\ Saving + Occupancy\ kWh\ Savings$

Where,

Dim% = 70% max output due to high end trim

Hours % = 24% reduction due to occupancy sensors

Table 5-56. Tracking System Fixture Inputs and kWh Savings below shows the tracking system inputs and savings calculations for the lighting retrofit. Additional details on the applicant algorithm could be found in the project files.

Table 5-191. Tracking System Lighting Inputs and kWh Savings

	A	B	C	D	E	F=A*B*E /1000	G=C*D*E/1000	H	I=F-G	J=H+I
Space Type	**Baseline Quantity**	**Baseline Watts per Fixture**	**Installed Quantity**	**Installed Watts per Fixture**	**Annual Hours**	**Baseline kWh**	**Installed kWh**	**Control kWh Savings**	**kWh Fixture Savings**	**kWh Fixture Savings**
MSF[51]	150	94	265	75	4,693	66,171	93,273	27,982	-27,102	880
MSF[1]	4	48	3	40	4,693	901	563	169	338	507
MSF[1]	2	72	2	75	4,693	676	704	211	-28	183
MSF[1]	90	72	43	34	4,693	30,411	6,861	2,058	23,549	25,608
BOH/Stock/Mezz[52]	18	94	0	0	4,693	7,941	0	0	7,941	7,941
BOH/Stock/Mezz[2]	25	48	22	40	4,693	5,632	4,130	1,933	1,502	3,435
BOH/Stock/Mezz[2]	69	48	69	34	4,693	15,543	11,010	5,153	4,533	9,686
BOH/Stock/Mezz[2]	37	72	39	75	4,693	12,502	13,727	6,424	-1,225	5,199
Total	**395**		**443**			**139,776**	**130,268**	**43,930**	**9,508**	**53,438[53]**

51 Space includes dimming controls where all fixtures are trimmed to 70% max output.

52 Space includes dimming controls where all fixtures are trimmed to 70% max output as well as occupancy sensors where there is an assumed 24% reduction to annual operating hours.

53 The tracking savings shown here are different to the application (+5 kWh) due to a rounding difference when transferring applicant spreadsheet values into the evaluation tool. Since the application tool was locked, the evaluator had to recreate savings using hard values shown in the spreadsheet.

Evaluation Assessment of Applicant Methodology

The applicant correctly used the custom lighting tool and the eTRM algorithms, and the evaluator determined the application calculation methodology reasonable.

On-Site Inspection and Metering

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

Summary of On-site Findings

The evaluator conducted a site visit on March 8, 2021. During the site visit, the evaluator interviewed the store energy manager and verified the applicant inputs by performing a site audit and installing long term DENT time of use (TOU) meter, DENT lumen/temperature meter, and DENT power meters to capture dimmed operation. All areas were confirmed to operate under the same programmed schedule and same trimmed level (max output 70%) for all hours of operation. Currently the lighting operates on a fixed schedule for the store. Considering there are opportunities where managers come in early or there is late stocking, the site decided to adjust the morning/evening settings to work based on the security settings when the store is occupied or unoccupied. Therefore, if the security is shut down, the lights would come on, and vice versa. DENT TOU meters were installed to specify operating hours for both occupancy controlled and scheduled areas. DENT lumen and temperature loggers were also installed in some areas for additional verification of dimmed use. DENT power meters collected dimmed operation for a handful of circuits to confirm the reduction in output due to dimming. During the walkthrough, the evaluator found occupancy-based controls to the back of house areas per the application such as conference and office spaces, the electrical room, upstairs storage, etc. The sales floor did not have occupancy controls.

Regarding the HVAC measure, the evaluator took photos of equipment and nameplate information from the rooftop units. It was confirmed that there are two units which control the front half and back half of the building. Both operate under the same conditions and setpoint schedules. The evaluator installed a kW meter to one of the RTUs directly from the panel to capture all 3 phases. Temperature loggers were installed in different areas to capture space temperature to see if they match the setpoint. The site contact mentioned setpoint remains at a fixed 70 °F for both heating and cooling. Depending on the season, the store overrides the overnight setting to heating or cooling mode so the units to not expend energy conditioning air when the building is unoccupied.

The evaluator also discovered that prior to the efficiency project, the store had an existing EMS that controlled setpoints for the RTUs. The site contact confirmed that the RTU baseline setpoints was 70 °F (which is what it is now) for both heating and cooling seasons. When installing the lighting retrofit a new EMS was also installed for the lighting controls. Rather than having two separate EMS systems, the site decided to shut down the original to consolidate and include the RTU controls within the lighting system EMS, and the pre-existing thermostats were replaced one for one. Based on this information, there is no change in efficiency due to the newly installed RTU controls as the same setup was in place for the baseline, and is not in line with the applicant reported baseline that assumed controls were not in place. Therefore, the evaluation negates all savings associated with this measure as the site had the capabilities for setpoint control in the baseline and there is no change to the post case.

Measured and Logged Data

The evaluator deployed twelve data loggers to characterize the operating profile for the lighting fixtures in different areas and one power logger to characterize the RTU use from March 8, 2021, to April 27, 2021. Table 5-93. Evaluation Data Collection – Installed Equipment presents the logger deployment details.

Table 5-192. Evaluation Data Collection – Installed Equipment

Parameter	M&V Equipment Brand and Model	Metering Start/Stop Dates	Metering Interval
Interior lighting operating schedules	11 Dent lighting logger TOU	3/8/2021-4/27/2021	On/off
Interior lighting operating schedules	1 Dent ELITEpro XC power logger (4 individual circuits)	3/8/2021-4/27/2021	1 minute
RTU-2 power	1 DENT ELITEpro XC power logger	3/8/2021-4/27/2021	1 minute

Table 5-193. Evaluation Data Collection – Data Received

Source	Parameter	Interval	Duration
Lighting loggers	Time of use	On/off	7 weeks
Power logger - lighting	Dimming wattage reduction	1 minute	7 weeks
Power logger – RTU	V, kW, PF, A	1 minute	7 weeks

On the return trip the evaluator was unable to have the site contact override the lighting circuits to 100% output. This was requested and the site contact obliged, but the project manager for the store read the override as an error in the system and cancelled the request. The site contact forwarded site settings to show the command sequence that interior fixtures are turned down to 70% max output for all fixtures and for all hours of operation. The evaluator used this information while observing the metered data and noticed that "on" trends in the power data were consistently operating at the 95-100% output range when comparing the hourly interval to the max observed kW in the data set. Assuming the observed max in the data set is the circuit operating at 70% to match the command sequence, the evaluator manually adjusted the max kW to show what operation would be at 100% output by dividing the max kW by 0.7. The max kW calculated using this method matched closely with what the evaluator counted on one of the circuits multiplied by the rated wattage of the fixture. This process was used to determine the dimmed operating profiles for the remaining controlled circuits, as all fixtures operated under these conditions.

The evaluator used the metered lighting TOU data to calculate an operating profile to show when the fixtures were being in use. Metered hourly data was expanded to fit a weekly profile. The profiles depict an hourly percent on value that shows the percent of the hourly interval where the fixture was in operation. An example of a logged operating schedule is shown below in

Figure 5-38. Logged Operating Data – developed from one of the power loggers monitoring the sales area.

Figure 5-58. Logged Operating Data – Sales dimming 1

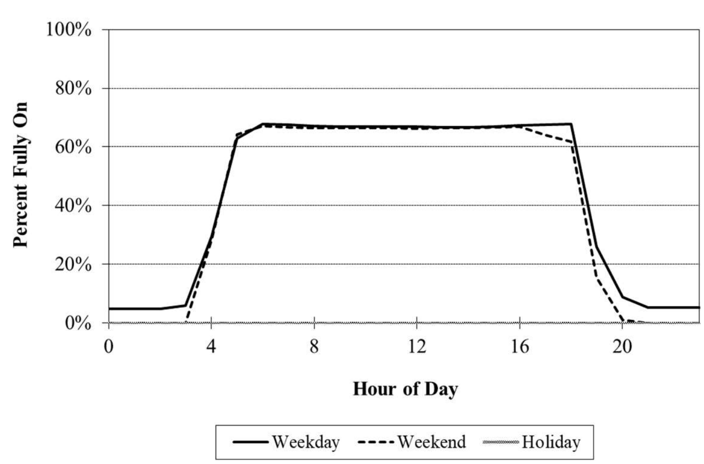
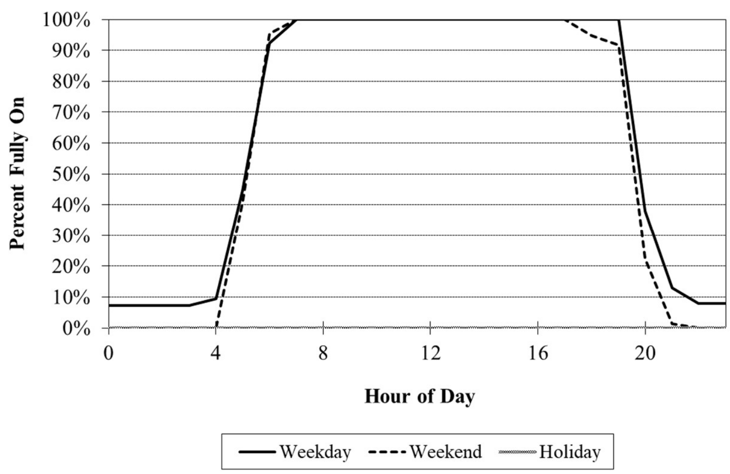


Figure 5-59. Logged Operating Data – Sales baseline 1



The figures above depict the operating profile developed from the metered data, as well as an assumed baseline non-controlled schedule for the same space. The process for developing the baseline schedules will be discussed in the following section. The weekly expanded schedules corroborate with the schedules provided by the site contact. For the analysis, the evaluator expanded the logger data set to an 8,760-operating profile. Table 5-95. Logged Data Schedules below lists the expanded operating profiles for all metered data sets. All "XC" mentions under the "Logger #" column reference circuits captured by the power logger, and baseline schedules developed from the metered data.

Table 5-194. Logged Data Schedules

Schedule ID	Logger #	Description	Annual Hours	On-Peak Hours
1	LL08050636	Checkout area	5,487	3,199
2	LL08050690	Upstairs office - closed office	518	423
3	LL08100823	Sales	5,495	3,205
4	LL08100887	Upstairs office - common space	5,488	3,201
5	LL08102240	Sales	5,488	3,202
6	LL08102819	Men RR	5,488	3,201
7	LL10120057	Restroom hall	5,469	3,201
8	LL10120321	Break room	417	381
9	LL11010132	Electrical room	5,488	3,201
10	LL08040675	Storage BOH upstairs	367	280
11	Sales XC 1	Sales XC 1	3,711	2,133
12	Sales XC 2	Sales XC 2	3,680	2,119
13	Sales XC 3	Sales XC 3	3,619	2,075
14	Back area XC	Back area XC	3,615	2,073
15	Sales XC 1 BL	Sales XC 1 BL	5,531	3,411

16	Sales XC 2 BL	Sales XC 2 BL	5,613	3,212
17	Sales XC 3 BL	Sales XC 3 BL	5,317	3,068
18	Back area XC BL	Back area XC BL	5,497	3,193
19	Break room BL	Break room BL	440	401
20	Office BL	Office BL	714	572
21	Storage upstairs BL	Storage upstairs BL	527	424
22	Control Avg[54]	Control Avg	3,656	2,100
23	BL Dim Avg[55]	BL Dim Avg	5,487	3,209
24	Bl occ avg[56]	Bl occ avg	560	466
25	Occ avg[57]	Occ avg	434	362

Evaluation Methods and Findings

This section describes the evaluator methods and findings.

Evaluation Description of Baseline

The evaluator reviewed the project files and interviewed the site contact to gather information on the baseline. The evaluator determined the lighting measure is a retrofit with a single baseline, where the baseline would be the pre-existing fixtures identified in the lighting audit.

Baseline schedules for controlled fixtures were developed from metered data for both occupancy and dimming controlled fixtures. For both control types, conditional formats were applied to the metered data to check for continuous hours of operation. For occupancy controls, if there were consecutive operational hours, the baseline schedule would recognize the non-shoulder hours and assume the baseline lights would have been left on during those hours before controls were installed. Shoulder hours were assumed to be the same between baseline and metered schedules to represent the partial hour (if the occupancy sensor turns the fixture on at half past or quarter of the hour). A visual example can be seen in Table 5-195. Baseline Schedule Example below where shoulder hours include hours 1, 4, and 6 while continuous hours include 2, 3, and 7. For dimming, the same method was used where EFLHs were converted from metered kW data. The same method as the occupancy controls theory applies showing that for consecutive non-zero hours, fixtures would have been operating at maximum output, which is equal to being on 100% for that hour. The shoulder hours are still equivalent between baseline and controlled schedules to represent the partial hour the fixture comes operates. If a fixture was installed with both occupancy and dimming controls, this method would still apply as the shoulder hour would represent the occupied schedule, and the consecutive non zero hours would represent continuous operation at 100% output.

Table 5-195. Baseline Schedule Example

Hour	Controlled Schedule	Baseline Schedule
1	25%	25%
2	45%	100%

54 Average of schedules 11-14
55 Average of schedules 1, 3-7, 9, 15-18
56 Average of schedules 19-21
57 Average of schedules 2, 8, 10

3	50%	100%
4	25%	25%
5	0%	0%
6	25%	25%
7	50%	100%

As for the RTU controls measure, discussion with the site contact led to the discovery that prior to the retrofit, the site already had an EMS system in place with capability of setpoint control. The baseline setpoints were 70 °F (which is what it is now) for both heating and cooling and remained fixed. From the information provided, there was no change in efficiency as the site retrofitted an EMS with a different EMS having the same capabilities.

Evaluation Calculation Method

The evaluator calculated the savings using a similar approach to the applicant. TOU data was used to determine the operations schedules and effective full load hours for all metered groups. Data was drawn from the loggers and expanded to fit an 8,760-model based on trends in the data. The custom savings equations are presented below.

Baseline Fixture kWh = $\frac{Quantity_B * Wattage_B}{1000} * Evaluated\ Operating\ Hours\ without\ controls$

Proposed Fixture kWh = $\frac{Quantity_P * Wattage_P}{1000} * Evaluated\ Operating\ Hours\ without\ controls$

Fixture kWh Savings = $Baseline\ Fixture\ kWh\ - Proposed\ Fixture\ kWh$

Control kWh Savings = $Proposed\ Fixture\ kW\ * (Evaluated\ Operating\ Hours\ without\ controls - Evaluated\ EFL\ Operating\ Hours\ with\ controls)$

HVAC Interactive Fixture Savings = $(pre\ conn\ kW - post\ conn\ kW) * Coincident\ Occupied\ Cooling\ Hours * \frac{0.8}{Cooling\ COP}$

HVAC Interactive Controls Savings = $(post\ conn\ kW\ * \ (pre\ coincident\ occupied\ cooling\ hours - post\ coincident\ cooling\ hours)\ * 0.8)/(Cooling\ COP)$

Total kWh Savings = $Fixture\ kWh\ Savings + Control\ kWh\ Savings + HVAC\ Interactive\ Fixture\ \ and\ HVAC\ Interactive\ Control\ Saving$

All spreadsheets used in the estimation of evaluation savings will be made available to the PAs for review at their request. For site cooling hours, the evaluator assumed cooling would only take place between the months of April and October. For each hourly interval within that range of months in the 8760 model, if dry bulb temperature taken from local TMY3 data was greater than or equal to the setpoint of 55°F, then that hour was determined to be a cooling hour. Cooling hours that coincided with the lighting hours were used to determine total annual cooling savings. The cooling COP is assumed to be 2.9 for the packaged DX unit that served the space.

Final Results

The evaluated savings for the lighting project were larger than the applicant reported savings primarily due to the addition of HVAC interactive impacts for both lighting and controls. Detailed values are shown in Table 5-196. Summary of Key Parameters comparing changes in the baseline and proposed conditions for both the application and evaluation hours of use for each area.

Table 5-196. Summary of Key Parameters

Applicant Space Description	Evaluator **Space Description**	Applicant **Baseline Hours**	**Proposed Hours**	Evaluation **Baseline Hours**	**Proposed Hours**
MSF	Sales	4,693	4,693	5,487	3,656
MSF	Sales	4,693	4,693	5,487	3,656
MSF	Sales	4,693	4,693	5,487	3,656
MSF	Sales	4,693	4,693	5,487	3,656
BOH/Stock/Mezz	Back area bottom	4,693	4,693	5,487	3,656
BOH/Stock/Mezz	Electrical	4,693	4,693	5,488	3,656
BOH/Stock/Mezz	Back area top (occ)	4,693	4,693	560	434
BOH/Stock/Mezz	Office, breakroom (occ)	4,693	4,693	560	434
BOH/Stock/Mezz	Remaining BOH	4,693	4,693	5,487	3,656
BOH/Stock/Mezz	Upstairs breakroom	4,693	4,693	5,487	3,656
BOH/Stock/Mezz	BOH/Stock/Mezz	4,693	4,693	5,487	3,656

Table 5-61. and Table 5-198. Evaluation Controls Inputs and kWh Savings below shows the evaluation inputs and savings calculations for the lighting fixtures and controls respectively.

Table 5-197. Evaluation Fixture Inputs and kWh Savings

	A	B	C	D	E	F	G=A*B*E /1000	H=C*D*E/1000	I=G-H	J	K	L	M=F*J*K*0.8/L	N=I+M
Space Type	Baseline Quantity	Baseline Watts per Fixture	Installed Quantity	Installed Watts per Fixture	Annual Hours	Connected kW Savings	Baseline kWh	Installed kWh	kWh Fixture Savings	Percent of Space Cooled	Annual Cooling Hours	Cooling COP	Interactive Cooling Savings	Total kWh Fixture Savings
BOH/Stock/Mezz	18	94	0	0	5,487	1.692	9,284	0	9,284	100%	2,509	2.9	1,159	10,443
sales	151	94	267	75	5,487	-5.831	77,886	109,882	-31,996	100%	2,509	2.9	-3,994	-35,990
sales	4	48	3	40	5,487	0.072	1,054	658	395	100%	2,509	2.9	49	444
sales	0	72	0	75	5,487	0.000	0	0	0	100%	2,509	2.9	0	0
sales	90	72	43	34	5,487	5.018	35,557	8,022	27,535	100%	2,509	2.9	3,437	30,972
back area bottom	37	72	39	75	5,487	-0.261	14,618	16,050	-1,432	100%	2,509	2.9	-179	-1,611
electrical	14	48	8	40	5,488	0.352	3,688	1,756	1,932	100%	2,510	2.9	241	2,173
back area top (occ)	11	48	14	40	560	-0.032	296	314	-18	100%	272	2.9	-2	-20
office, breakroom (o	22	48	22	34	560	0.308	591	419	172	100%	272	2.9	23	195
Remaining BOH	42	48	42	34	5,487	0.588	11,062	7,836	3,226	100%	2,509	2.9	403	3,629
Upstairs breakroom	4	48	4	34	5,487	0.056	1,054	746	307	100%	2,509	2.9	38	346
Total	**393**		**442**			**1.692**	**9284.39358**	**0**	**9284.39358**				**1,175**	**10,581**

Table 5-198. Evaluation Controls Inputs and kWh Savings

	A	B	C	D=A*B/1000	E=C*D	F	G	H	I=D*F*G*0.8/H	J=E+X
Space Type	Installed Quantity	Installed Watts per Fixture	Annual Hours Reduction	Connected kW	kWh Controls Savings	Percent of Space Cooled	Annual Cooling Hours Reduction	Cooling COP	Interactive Cooling Savings	Total kWh Controls Savings
sales	267	75	1,831	20.03	36,667	100%	820	2.9	4,610	41,277
sales	3	40	1,831	0.12	220	100%	820	2.9	28	247
sales	0	75	1,831	0.00	0	100%	820	2.9	0	0
sales	43	34	1,831	1.46	2,677	100%	820	2.9	337	3,014
back area bottom	39	75	1,831	2.93	5,356	100%	820	2.9	673	6,029
electrical	8	40	1,832	0.32	586	100%	821	2.9	74	660
back area top (occ)	14	40	126	0.56	70	100%	60	2.9	9	80
office, breakroom (occ)	22	34	126	0.75	94	100%	60	2.9	12	106
Remaining BOH	42	34	1,831	1.43	2,615	100%	820	2.9	329	2,944
Upstairs breakroom	4	34	1,831	0.14	249	100%	820	2.9	31	280
Total	**442**			**27.72**	**48,534**				**6,103**	**54,637**

Explanation of Differences

The evaluation savings are 14% higher than the applicant reported savings.Table 5-51 provides a summary of the primary differences between tracking and evaluated values.

Table 5-199. Summary of Deviations

End use	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
Lighting Fixtures & Controls	Interactive	HVAC Cooling Impacts	+12%	**Increased savings –** due to the addition of cooling HVAC impacts.
Lighting Controls	Operational	Annual Operating Hours	+8%	**Increased savings** – due to a difference in annual operating hours reductions for controls.
Lighting Fixtures	Operational	Annual Operating Hours	+<1%	**Increased savings** – due to the difference in annual operating hours for fixtures.
Lighting Fixtures	Quantity	Fixture Quantity	-<1%	**Decreased savings** – due to a change in installed fixture quantity.
HVAC Controls	Baseline	Measure Baseline	-6%	**Decreased savings –** due to the change in measure baseline. Savings were negated as the evaluator discovered the site had the same control sequence prior to the retrofit measure.

Ancillary impacts

For this measure, electric HVAC interaction savings occur in retrofitting the fluorescent fixtures to LED. The tracking estimate did not include HVAC interactive effects. The areas where all fixture retrofits took place are served by a packaged DX (cooling COP: 2.9). Adding this effect accounts for a 12% increase in savings compared to the tracking system application

RICE19C007

Report Date: June 4th, 2021

Program Administrator	National Grid
Application ID(s)	9926319, 9808400
Project Type	Retrofit
Program Year	2019
Evaluation Firm	DNV
Evaluation Approach	Non-Ops Lighting; Full M&V Non-Lighting
Evaluation Engineer	Laeng Khoun, Shaobo Feng
Senior Engineer	Stephen Carlson, Chad Telarico

1.1 Evaluated Site Summary and Results

The evaluated project was implemented at a dorm and dining hall in Providence, RI, and consists of non-lighting and lighting measures. The non-lighting measures includes the installation of electrically commutated motors and controls for the dining hall refrigeration.

Due to the impacts of the COVID-19 pandemic, the campus is still in a considerably lower occupancy and operation level. However, the site contact reported that the operation of the refrigeration for the dining hall was not affected by the pandemic. The contact reported that the coolers and freezers operated as normal throughout the pandemic.

Non-Lighting Part in Table 1-1:

Table 5-200. ECM Summary for Non-Lighting Measures

ECM Number	Application ID	Measure Description	Tracking Savings kWh
1	9808400	ECMs and Refrigeration Controls	12,580

Electrically commutated (EC) motors were installed to replace the existing seven (7) evaporator fan motors. Energy savings result from the improved efficiency of EC motors. Refrigeration controls were installed on 2 coolers and a freezer in the dining hall portion of the building. Three types of controls were implemented including fan-cycling, door heater controls, and defrost run-time reduction. The savings comes from the reduction in refrigeration load and run-time for the fans, door heaters, and defrost components of the coolers / freezers.[58] The controls system monitors the refrigeration system and stores run-time data on a cloud server. The data tracks operating time, amp, and temperature historically since the implementation of the controls. The tracking savings claims 12,580 kWh annually for all the refrigeration measures. Given there were no impact from the pandemic according to the site contact, the evaluators conducted a full-scope M&V using the tracked operation data provided by the Controls vendor.

Lighting Part in Table 5-201:

Table 5-202. ECM Summary for Lighting Measures

ECM Number	Application ID	Building (Type)	Measure Description	Tracking Savings kWh
2	9926319	Dorm / Dining Hall	Lighting Retrofit	108,642

766 lighting fixtures were proposed to be replaced with LEDs. The fixtures are located throughout the buildings and exterior. Savings from occupancy sensors were claimed on some interior lights. No savings from HVAC interactivity were claimed. The tracking savings claims 108,642 kWh annually. The site contact reported that the occupancy for the building has been significantly reduced due to COVID-19 restrictions on campus occupancy. The evaluators conducted a non-operational site visit to confirm the installation of the lights.

The evaluated savings are more than the tracking reported savings due to HVAC interactivity in lighting measures. The primary source of discrepancies in non-lighting is attributed to discrepancies in reduced run-hours associated with the fan cycling, ECMs, defrost, and door heater controls. A discrepancy in baseline operating hours was also found between the applicant and evaluator savings calculation approaches. The evaluation results are presented in Table 5-2.

[58] Only the freezer evaporators had defrost cycles.

Table 5-203. 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)
9808400	ECMs and Refrigeration Controls	Tracked	12,580	54%	1.58	1.58
		Evaluated	12,618	54%	4.62	3.1
		Realization Rate	100.3%	100%	292%	196%
9926319	Lighting Retrofit	Tracked	108,642	62%	26.0	7.4
		Evaluated	112,984	53%	27.2	7.4
		Realization Rate	104.0%	85%	105%	100%
Totals		**Tracked**	**121,222**	**61%**	**7.2**	**6.0**
		Evaluated	**125,602**	**54%**	**31.7**	**10.5**
		Realization Rate	**103.6%**	**86%**	**442%**	**175%**

RR = Realization rate

N.R = Not reported by program; N/A = Not applicable

1.1.1 Explanation of Deviations from Tracking

The reason for the discrepancy in non-lighting measures is a difference in reduced run-time hours between the applicant estimation and evaluator findings. The evaluator also identified lower baseline operating hours compared to the applicant baseline operating hours. The evaluators determined the baseline run-time hours for refrigeration equipment to be 8,232 hours annually whereas the applicant assumed 8,760 hours annually. The evaluator also included the interactive savings effect from installing the door heater controls. The primary reason causing discrepancy in lighting savings is attributed to additional savings from HVAC interactivity. The evaluator attributes the difference in summer and winter on-peak demand values to be an administrative tracking error. Further details regarding the project are presented in the following sections.

1.1.2 Recommendations for Program Designers & Implementers

The evaluators recommend the implementers to consider holiday and campus shutdown periods in the baseline assumptions.

1.1.3 Customer Alert

The customer requested to redact site-sensitive information in the site report.

1.2 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.

1.2.1 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.

1.2.2 Applicant Description of Baseline

Non-Lighting

The applicant classified this measure as a retrofit with the baseline as the existing condition. Evaporator fans with shaded-pole (SP) or permanent split capacitor (PSC) motors that run continuously. Anti-condensate door heaters operated at constant nameplate wattage. The defrost heaters operated on a fixed schedule of 4 defrost cycles per day, with 40-minute cycles. Baseline annual operating hours is claimed to be 8,760 hours per year.

Lighting

The applicant classified the measure as a retrofit with the baseline as the existing condition. The baseline condition for the 767 fixtures was a mix of compact fluorescents, incandescent, T5, T8 and T12 fixtures. Annual operating hours were split into usage groups of 2007, 2086, and 8760 hours. The applicant documentation does not state whether controls were present as a baseline condition.

1.2.3 Applicant Description of Installed Equipment and Operation

Non-Lighting

Electrically commutated (EC) motors were installed to replace the existing seven (7) evaporator fan motors Energy savings result from the improved efficiency of EC motors. Refrigeration controls were installed on 2 coolers and a freezer in the dining hall portion of the building. Three types of controls were implemented including fan-cycling, door heater controls, and defrost run-time reduction.

Lighting

The applicant proposed installing 766 LED lighting fixtures to replace the existing fixtures. Annual operating hours were consistent with the baseline assumed hours for fixture usage groups. Occupancy controls savings were claimed for some offices, stairwells, storage areas and mechanical rooms.

1.2.4 Applicant Energy Savings Algorithm

Non-Lighting

The applicant calculated the savings using custom spreadsheets. The applicant calculator assumes a 65% reduction in motor load from replacing the SP/PSC motors with ECMs. A 46% reduction in evaporator run-time is claimed for implementing fan-cycling controls. Anti-condensate heater control savings are based on a reduction in runtime of 65% for the freezer and 60% for the coolers. Savings from the electric defrost controls are based off a run-time reduction of 25%. The applicant includes a 5% reduction in evaporator fan and compressor run-times for direct digital controls. The formulas and reductions used in the applicant calculator are consistent with the RI TRM. The formulas below show the applicant calculation methodology:

Evaporator Fan kWh Reduction = $Evaporator\ Fan\ kW\ Load \times Evaporator\ Fan\ Off\ Hours$

Evaporator Fan Cooling Load Reduction (kWh) = $\text{Evaporator Fan kWh Reduction} \times \frac{3413\frac{Btuhr}{kW}}{12000\frac{Btuhr}{ton}} \times$

$Compressor\ Performance\ Factor\ (\frac{kW}{ton})$

Fan Cycling Savings (kWh) = $\text{Evaporator Fan kWh Reduction} + \text{Evaporator Fan Cooling Load Reduction}$

DDC Savings = $(\text{Compressor Annual Energy Use} * \text{Controller Reduced Run Time}) +$
$[(8760 - Evaporator\ Fan\ Off\ Hours) \times Evaporator\ Fan\ kW\ Load\ \times\ Controller\ Reduced\ Run\ Time]$

Total Evaporator Fan Savings= $\text{Fan Cycling Savings} + \text{DDC Savings}$

ECM Motor Savings = $\text{Evaporator Fan Run Hours} \times \text{Evaporator Fan kW Load} \times \text{Motor Load Reduction}$

ECM Cooling Load Reduction = $\text{ECM Motor Savings} \times \frac{3413\frac{Btuhr}{kW}}{12000\frac{Btuhr}{ton}} \times Compressor\ Performance\ Factor$

Total ECM Savings= $\text{ECM Motor Savings} + \text{ECM Cooling Load Reduction}$

Defrost Off Hours = $365 \times \text{Daily Defrost Cycles} \times \frac{40\ Minutes}{Hour} \times Defrost\ Hours\ Reduction$

Electric Defrost Reduction Savings = $\text{Electric Defrost kW Load} \times \text{Defrost Off Hours}$

Electric Defrost Cooling Load Reduction = $\text{Electric Defrost Reduction Savings} \times \frac{3413\frac{Btuhr}{kW}}{12000\frac{Btuhr}{ton}} \times$
$Compressor\ Performance\ Factor\ (\frac{kW}{ton})$

Total Defrost Savings = $\text{Electric Defrost Reduction Savings} + \text{Electric Defrost Cooling Load Reduction}$

Baseline Door Heater Energy Use = $\text{Baseline DH Hours} \times \text{DH kW Load}$

DH Energy Use with Humidity Sensor = $\text{Estimated DH Run Hours} \times \text{DH Power Level} \times \text{DH kW Load}$

Total Door Heater Savings = $\text{Baseline Door Heater Energy Use} - \text{DH Energy Use with Humidity Sensor}$

Total Controls Savings = $\text{Total Evaporator Fan Savings} + \text{Total ECM Savings} + \text{Total Defrost Savings} +$
$\text{Total Door Heater Savings}$

Where,

Compressor Performance Factor = 1.6 kW/ton

Controller Reduced Run Time = 5%

Motor Load Reduction = 65% for ECMs

Daily Defrost Cycles = 4 cycles each day

Defrost Hours Reduction = 25%

Baseline DH Hours = 8,760

DH Power Level = Power Level to maintain 5 deg above dew point, assumed to be 60%

Lighting

The applicant used the National Grid Lighting tool to estimate the tracking savings. No savings from HVAC interactivity were claimed as part of this application. The savings are calculated using the formulas shown below:

Baseline Fixture kWh = $\frac{Quantity_B * Wattage_B}{1000} * Applicant\ Operating\ Hours$

Proposed Fixture kWh = $\frac{Quantity_P * Wattage_P}{1000} * Applicant\ Operating\ Hours$

Fixture kWh Savings = $Baseline\ Fixture\ kWh\ - Proposed\ Fixture\ kWh$

Control kWh Savings = $(Proposed\ controlled\ Fixture\ kW) * Applicant\ Operating\ Hours * Hours\%$

Total kWh Savings = $Fixture\ kWh\ Savings + Control\ kWh\ Saving$

Where,

Hours % = 24% reduction due to occupancy sensors

Table 2-1 shows the tracking system fixture inputs and savings calculations for the fixtures.

Table 5-1. Tracking System Fixture Inputs and kWh Savings

	A	B	C	D	E	F=A*B*E /1000	G=C*D*E/1000	H	I=F-G	J=H+I
Space Type	**Baseline Quantity**	**Baseline Watts per Fixture**	**Installed Quantity**	**Installed Watts per Fixture**	**Annual Hours**	**Baseline kWh**	**Installed kWh**	**Control kWh Savings**	**kWh Fixture Savings**	**kWh Fixture and Control Savings**
Hallways/Stairwells	3	112	3	40	8,760	2,943	1,051	252	1,892	2,144
Hallways/Stairwells	1	60	1	16	8,760	526	140	0	385	385
Hallways/Stairwells	40	60	40	40	8,760	21,023	14,015	3,364	7,008	10,371
Hallways/Stairwells	2	60	2	10	8,760	1,051	175	42	876	918
Hallways/Stairwells	2	88	2	40	8,760	1,542	701	168	841	1,009
Hallways/Stairwells	3	65	3	10	8,760	1,708	263	63	1,445	1,508
Hallways/Stairwells	6	100	6	10	8,760	5,256	526	126	4,730	4,856
Hallways/Stairwells	76	32	76	20	8,760	21,303	13,314	0	7,989	7,989
Hallways/Stairwells	35	48	35	19	8,760	14,716	5,825	0	8,891	8,891
Hallways/Stairwells	3	48	2	29	8,760	1,261	508	0	753	753
Hallways/Stairwells	22	54	22	10	8,760	10,406	1,927	463	8,479	8,942
Hallways/Stairwells	56	54	56	13	8,760	26,489	6,377	0	20,112	20,112
Hallways/Stairwells	5	72	5	40	8,760	3,153	1,752	420	1,402	1,822
Dorm Rooms	130	63	130	19	2,086	17,081	5,151	0	11,930	11,930
Dorm Rooms	130	32	130	20	2,086	8,676	5,423	0	3,254	3,254
Dorm Rooms	50	54	50	13	2,086	5,631	1,356	0	4,275	4,275
Lobby/Offices/Low Hour Common	16	112	16	20	2,086	3,737	667	0	3,070	3,070
Lobby/Offices/Low Hour Common	26	60	26	16	2,086	3,254	868	0	2,386	2,386
Lobby/Offices/Low Hour Common	16	60	16	20	2,086	2,002	667	0	1,335	1,335
Lobby/Offices/Low Hour Common	2	60	2	40	2,086	250	167	40	83	123
Lobby/Offices/Low Hour Common	8	30	8	10	2,086	501	167	0	334	334
Lobby/Offices/Low Hour Common	5	65	5	10	2,086	678	104	25	574	599
Lobby/Offices/Low Hour Common	15	54	15	16	2,086	1,689	501	0	1,189	1,189
Miscellaneous Areas	12	112	12	40	2,007	2,698	964	231	1,734	1,966
Miscellaneous Areas	12	60	12	40	2,007	1,445	964	231	482	713

Miscellaneous Areas	2	88	2	40	2,007	353	161	39	193	231
Miscellaneous Areas	85	54	85	13	2,007	9,214	2,218	0	6,996	6,996
Miscellaneous Areas	4	75	4	10	2,007	602	80	19	522	541
Total	**767**		**766**			**169,189**	**66,031**	**5,484**	**103,158**	**108,642**

1.3 Evaluation Assessment of Applicant Methodology

The applicant's overall method for calculating the savings is appropriate and of sufficient rigor for both measures. The evaluator reviewed the application files with respect to baseline, methodology, trend and administrative errors.

Non-Lighting

The evaluator reviewed the applicant savings calculation methodology and deemed the approach to be reasonable. However, the evaluator notes that the approach relies on the vendor's standard percent reductions for certain measures based on RI TRM. The evaluator approach uses the trend data monitored by the refrigeration controls system to determine reduced hours in place of the percent reductions. The evaluator also notes that the applicant methodology assumes the pre-install operating hours to be 8,760 whereas the evaluator confirmed that there is a yearly shutdown period for winter break. The evaluator noted that interactive refrigeration savings aren't included in the applicant analysis. The evaluator approach includes the interactive effects.

Lighting

The evaluator deemed the applicant savings calculation methodology and assumptions to be reasonable. However, the evaluator notes that the applicant methodology does not include savings from HVAC interactivity.

1.3.1 On-Site Inspection and Metering

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

Summary of On-site Findings

The evaluators conducted a site visit on March 24, 2021 verifying the installation and operation on the lighting measures and non-lighting measures. During the site visit, the evaluators interviewed the facilities director and verified the lighting and non-lighting measures were installed and operated as proposed. The evaluators took a walk through the building with the site contact to understand the lighting with controls and refrigeration with controls.

During the site audit, the evaluators were able to collect the information below:

Non-Lighting

- Evaluators confirmed the controllers for two coolers and a freezer in use at the dining hall. Photos of the controller and nameplate information for the refrigeration equipment including evaporator fans were taken. The nameplate information matched the applicant documentation.
- Evaluators confirmed the different components such as evaporator fan, door heater, and defrost and matched nameplate information to the applicant information including kW loads.
- Evaluators visually confirmed the cloud-based monitoring system as shown on the site contact's computer system.
- Evaluators were able to request run-time data for the refrigeration controls spanning back to the installation of the controls system.
- Evaluators noted that a gap in data transmission occurred between the months of March 2020 and September 2020. The site contact confirmed that the refrigerators were taken offline during this period due to building closure related to the pandemic. The facilities director confirmed that in a typical year, the refrigerators are intended to run year-round and are only shutdown during winter break. The applicant baseline assumes the refrigeration runs through winter break.

Lighting

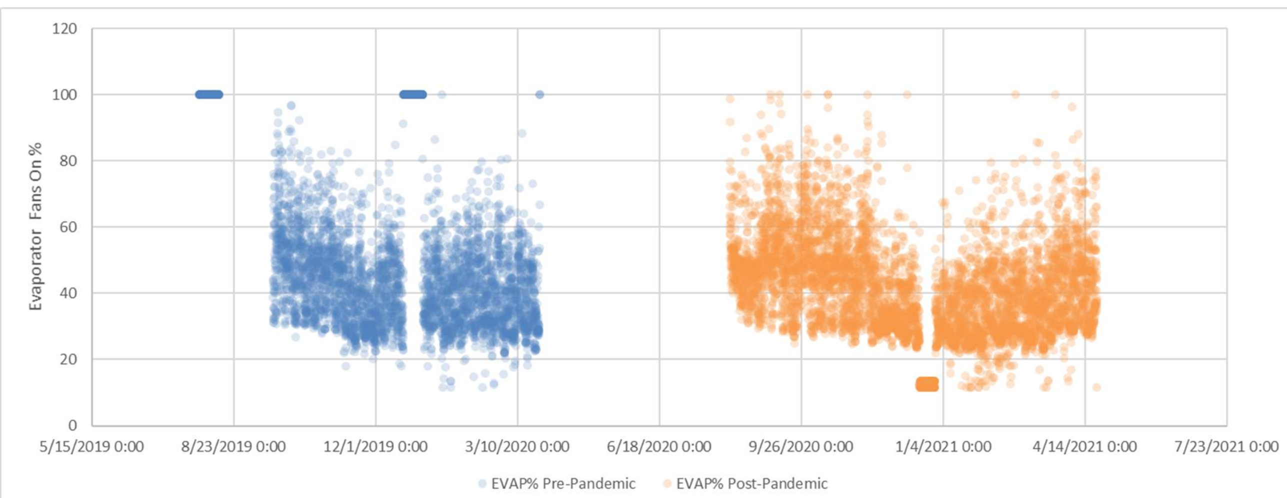
- Evaluators were able to inspect lighting for all fixture locations, operating hour groups, and confirmed the fixtures to match the proposed fixture description shown in the documentation. The evaluators were able to meet the 50% target sample of fixtures in the accessible spaces.
- The site contact informed the evaluators that the lights in the one building could not be accessed. That building was shut down due to restrictions related to the pandemic.
- Evaluators confirmed occupancy sensors to be present in the relevant areas claimed in the application. The evaluators visually confirmed the occupancy sensors and observed areas where the lights turned on upon entering the space.

Measured and Logged Data

The evaluators requested run-time data for the refrigeration controls spanning back to the installation of the controls system. The data includes post-install run-time data for the evaporator fans, door heaters, and defrost. The provided data shows hourly percentage on for each measured factor. The data is presented in the figures shown below. The evaluators used the run time data to create 7 day x 24 hour schedules for each month of the year. The schedules were applied to an 8,760 analysis to determine average annual run-hours for the evaporator fan, door heater, and defrost.

Evaluators noted that a gap in data transmission occurred between the months of March 2020 and September 2020. The site contact confirmed that the refrigerators were taken offline during this period due to building closure related to the pandemic. The facilities director confirmed that in a typical year, the refrigerators are intended to run year-round and are only shutdown during winter break. An example of the data is shown in Figure 2-1 below showing post installation hourly evaporator fan run percentage.

Figure 5-60. Cooler A Hourly Evaporator Fan Run Time Percentage



The evaluator noted that during the winter break periods, the evaporator fan readings were stalled at a fixed percentage. The facilities director informed the evaluator that the intention during winter break is to shut down the refrigeration system. In either case, because the refrigeration system is shutdown during winter break, there are no savings during that period. Figures 2-2 and 2-3 below shows the hourly door heater output percentage for the Freezer and Cooler C, respectively.

Figure 5-2. Freezer Hourly Door Heater Percentage Output

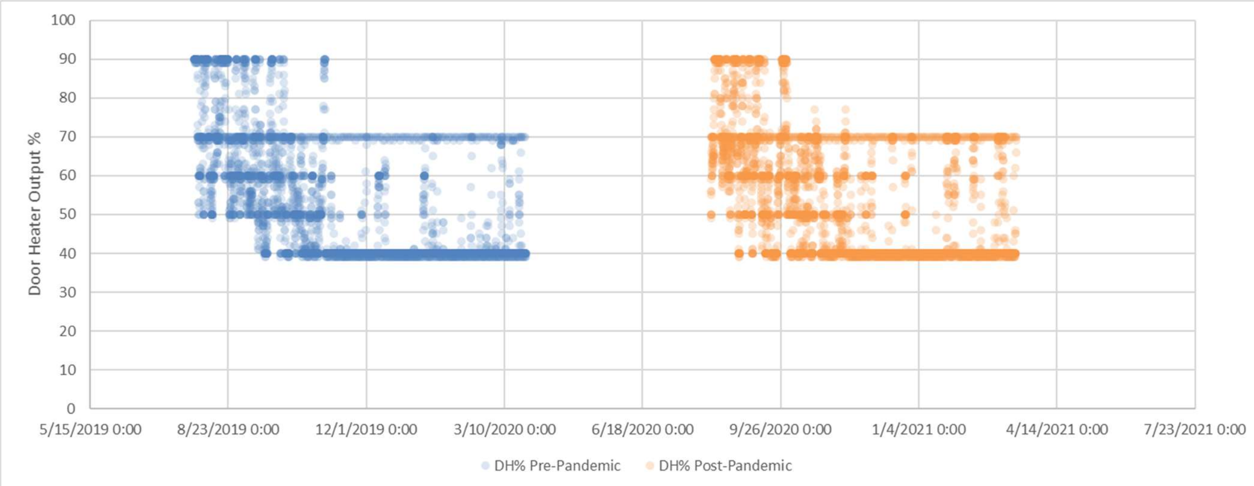
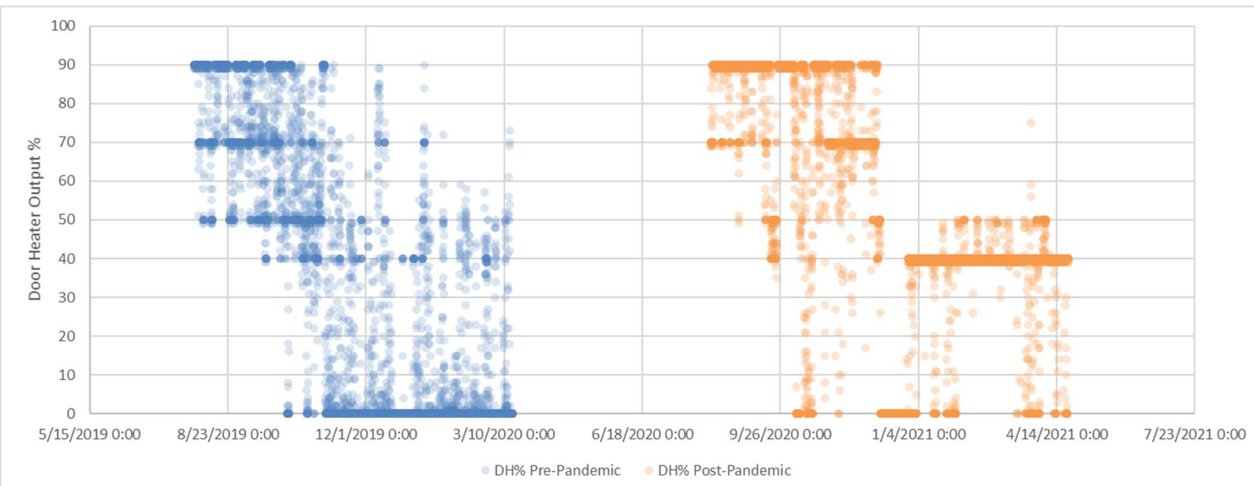
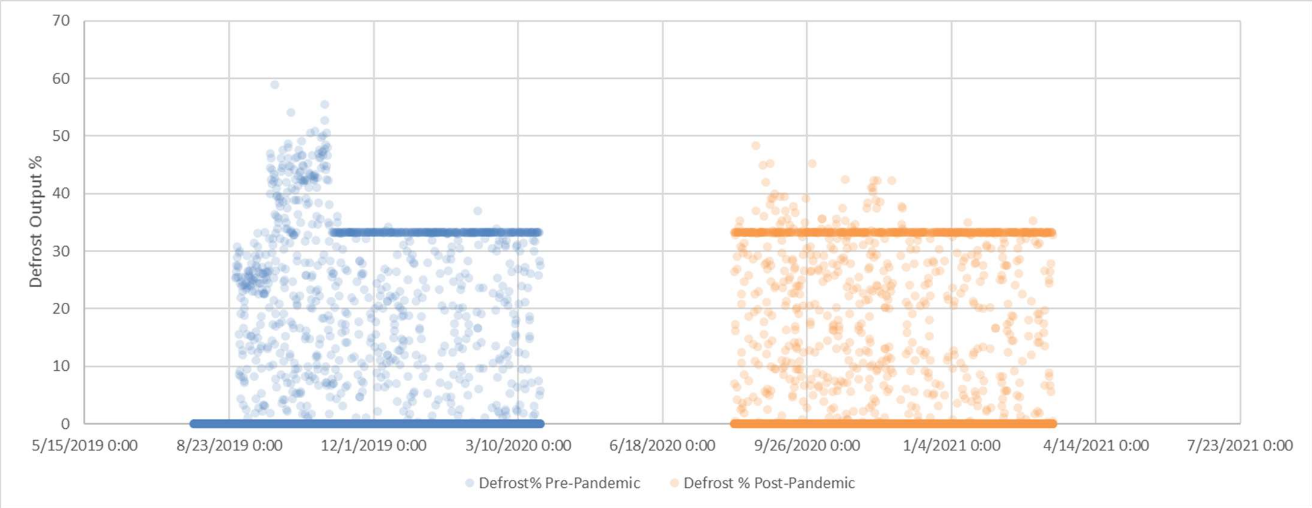


Figure 5-3. Cooler C Hourly Door Heater Percentage Output



The monitored data included hourly percent output for the defrost measure for the freezer. The evaluator also created 7 day x 24 hour schedules for each month. Figure 2-4 below shows the hourly defrost output percentage for the Freezer.

Figure 5-4. Freezer Hourly Defrost Output Percentage



Evaluation Methods and Findings

This section describes the evaluator methods and findings.

1.3.2 Evaluation Description of Baseline

Non-Lighting

The applicant classified this measure as a retrofit with the baseline as the existing condition. Evaporator fans with shaded-pole (SP) or permanent split capacitor (PSC) motors that run continuously. The existing condition assumes the fans were running continuously. Anti-condensate door heaters operated at constant nameplate wattage. The defrost heaters operated on a fixed schedule of 4 defrost cycles per day, with 40-minute cycles. The applicant assumes the refrigeration runs year-round and claims baseline annual operating hours to be 8,760 however, the evaluator determined that the baseline operating hours are 8,232.

Lighting

The evaluator determined the lighting measure is a retrofit with a dual baseline measure, where the baseline would be the pre-existing fixtures identified in the lighting audit. The dual baseline for the analysis of lifetime savings follows the model where 1/3 lifetime is attributed to a baseline of the existing fixtures, and 2/3 will be assumed using a 60% of the baseline fixture wattage for that remaining period regardless of existing fixture age or reported condition.

1.3.3 Evaluation Calculation Method

Non-Lighting

The evaluators used run-time data from the cloud-based monitoring system to create twelve monthly 7 day x 24 hour schedules for use in conjunction with an 8,760 analysis. The evaluators used evaporator fan, door heater, and electric defrost run-time data from the controls vendor to create schedules for each sub-measure. The evaluator deems the applicant formulas to be reasonable and did not update the formulas in the evaluated case. The site contact reported a shutdown period for winter break and the evaluator confirmed this period in the run-time data to determine the pre-retrofit hours of 8,232. The evaluator also included interactive refrigeration savings for the door heater controls. The formulas below show the evaluator savings approach:

Hourly Evaporator Fan kWh Usage= $Evaluated\ Evap\ Fan\ Operating\ Hours\ \times Evap\ Fan\ kW\ Load$

Evaporator Fan kWh Reduction = $\sum Hourly\ Baseline\ Evaporator\ Fan\ kWh\ Usage\ -$
$\sum Hourly\ Evaluated\ Evaporator\ Fan\ kWh\ Usage$

Evaporator Fan Cooling Load Reduction (kWh) = $\text{Evaporator Fan kWh Reduction} \times \frac{3413\frac{Btuhr}{kW}}{12000\frac{Btuhr}{ton}} \times$

$Compressor\ Performance\ Factor\ (\frac{kW}{ton})$

Fan Cycling Savings (kWh) = $\text{Evaporator Fan kWh Reduction} + \text{Evaporator Fan Cooling Load Reduction}$

DDC Savings = $(\text{Compressor Annual Energy Use} * \text{Controller Reduced Run Time}) +$

$[(8232 - Eval.Evap\ Fan\ Off\ Hours) \times Evaporator\ Fan\ kW\ Load\ \times\ Controller\ Reduced\ Run\ Time]$

Total Evaporator Fan Savings= $\text{Fan Cycling Savings} + \text{DDC Savings}$

ECM Motor Savings = $Eval.\text{Evap Fan Run Hours} \times \text{Evaporator Fan kW Load} \times \text{Motor Load Reduction}$

ECM Cooling Load Reduction = $\text{ECM Motor Savings} \times \frac{3413\frac{Btuhr}{kW}}{12000\frac{Btuhr}{ton}} \times Compressor\ Performance\ Factor$

Total ECM Savings= $\text{ECM Motor Savings} + \text{ECM Cooling Load Reduction}$

Electric Defrost Reduction Savings = $\text{Electric Defrost kW Load} \times \text{Evaluated Defrost Off Hours}$

Electric Defrost Cooling Load Reduction = $\text{Electric Defrost Reduction Savings} \times \frac{3413\frac{Btuhr}{kW}}{12000\frac{Btuhr}{ton}} \times$

$Compressor\ Performance\ Factor\ (\frac{kW}{ton})$

Total Defrost Savings = $\text{Electric Defrost Reduction Savings} + \text{Electric Defrost Cooling Load Reduction}$

Baseline Door Heater Energy Use = $\text{Evaluated Baseline DH Hours} \times \text{DH kW Load}$

DH Energy Use with Humidity Sensor = $\text{Evaluated DH Run Hours} \times \text{DH kW Load}$

DH Savings = $\text{Baseline Door Heater Energy Use} - \text{DH Energy Use with Humidity Sensor}$

DH Interactive Savings = $\text{DH Savings} \times \frac{35\%\ Of\ Load\ From\ Heater}{ACOP}$

Total Door Heater Savings = $\text{Door Heater Savings} + \text{DH Interactive Savings}$

Total Controls Savings = $\text{Total Evaporator Fan Savings} + \text{Total ECM Savings} + \text{Total Defrost Savings} +$

$\text{Total Door Heater Savings}$

Where,

Compressor Performance Factor = 1.6

Controller Reduced Run Time = 5%

Motor Load Reduction = 65% for ECMs

35% of the load from the heater ends up as load on case[59]

ACOP = 2.03 for Freezers and 2.69 for Coolers[60]

The evaluators developed hourly-run time schedules based on the monitored evaporator run percentage data and applied the schedules to the 8,760 analysis to determine the annual sum of run hours for Cooler A, Freezer, and Cooler C. Table 2-2 below shows the annual run hours for the coolers and freezers.

Table 2-2. Evaluated Evaporator Fan Run Hours

[59] From SDG&E workpaper https://www.sdge.com/sites/default/files/WPSDGENRRN0009%2520Rev%25200%2520Anti-Sweat%2520Heat%2520%2528ASH%2529%2520Controls%2520_0.doc

[60] From CT PSD

Equipment	Run Hours
Cooler A Evaporator Fan	1877
Freezer Evaporator Fan	1309
Cooler C Evaporator Fan	1877
Total Evaporator Fan Operating Hours	5063

The evaluators developed hourly-run time schedules based on the monitored door heater output percentage data and applied the schedules to the 8,760 analysis to determine the hourly output percentage for the Freezer and Cooler C door heaters. Figures 2-5 and 2-6 below show the hourly annual run hours based on the developed schedules for the Freezer and Cooler C, respectively.

Figure 5-5. Freezer Door Heater Annual Run Hours

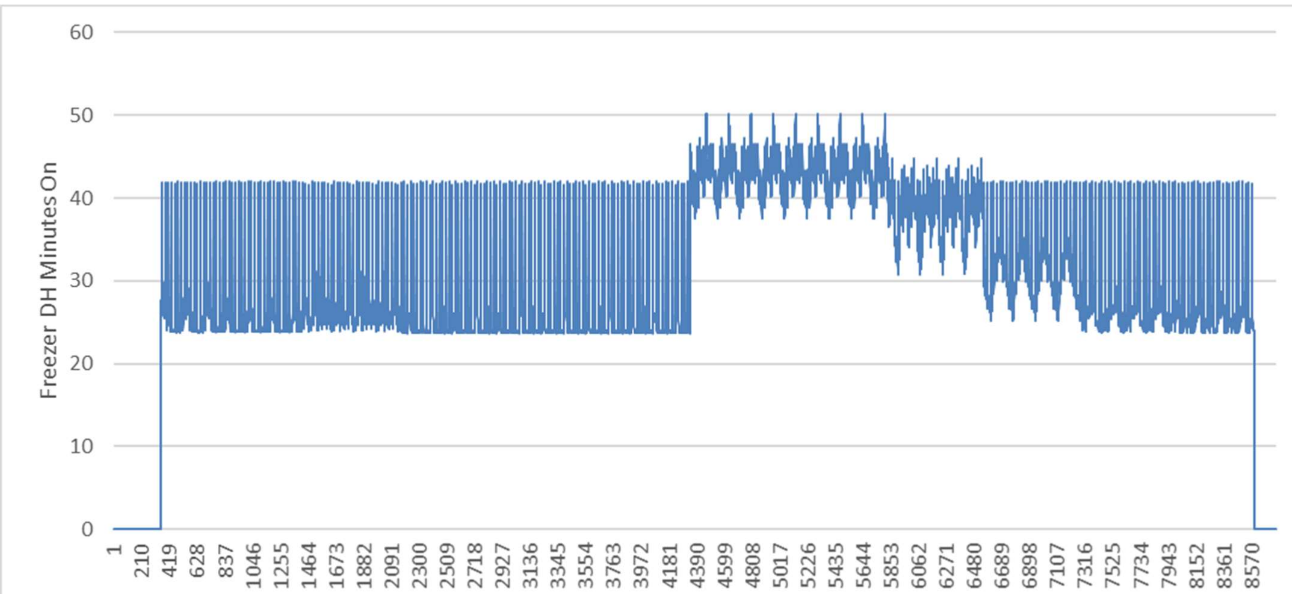
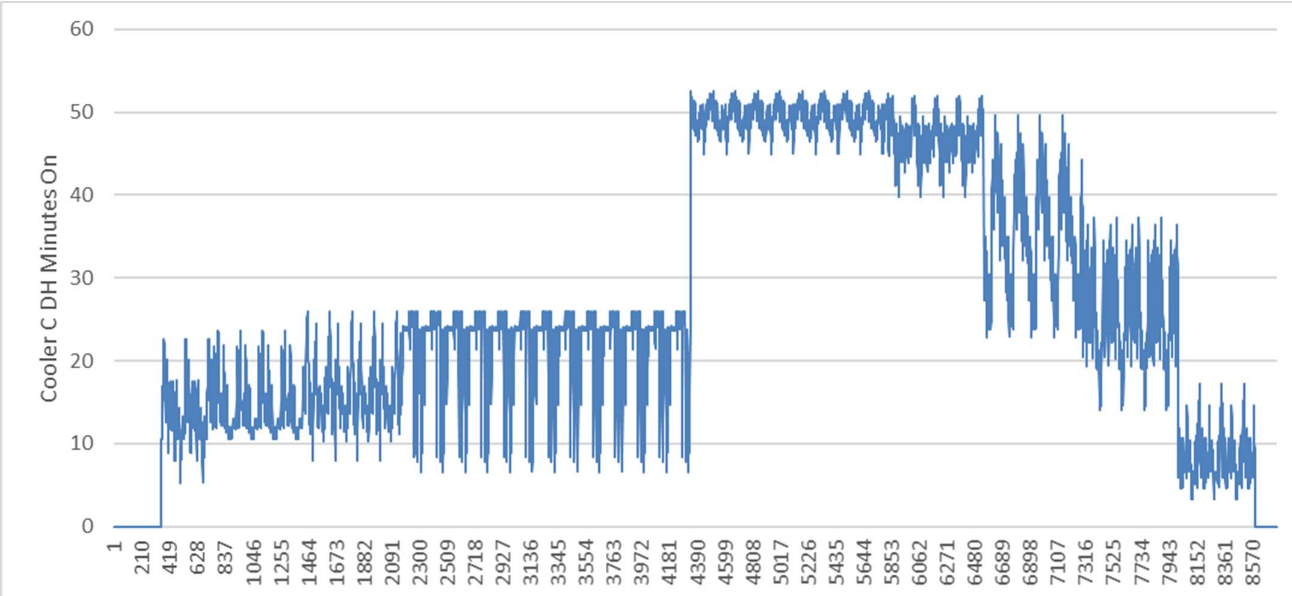


Figure 5-6. Cooler C Door Heater Annual Run Hours



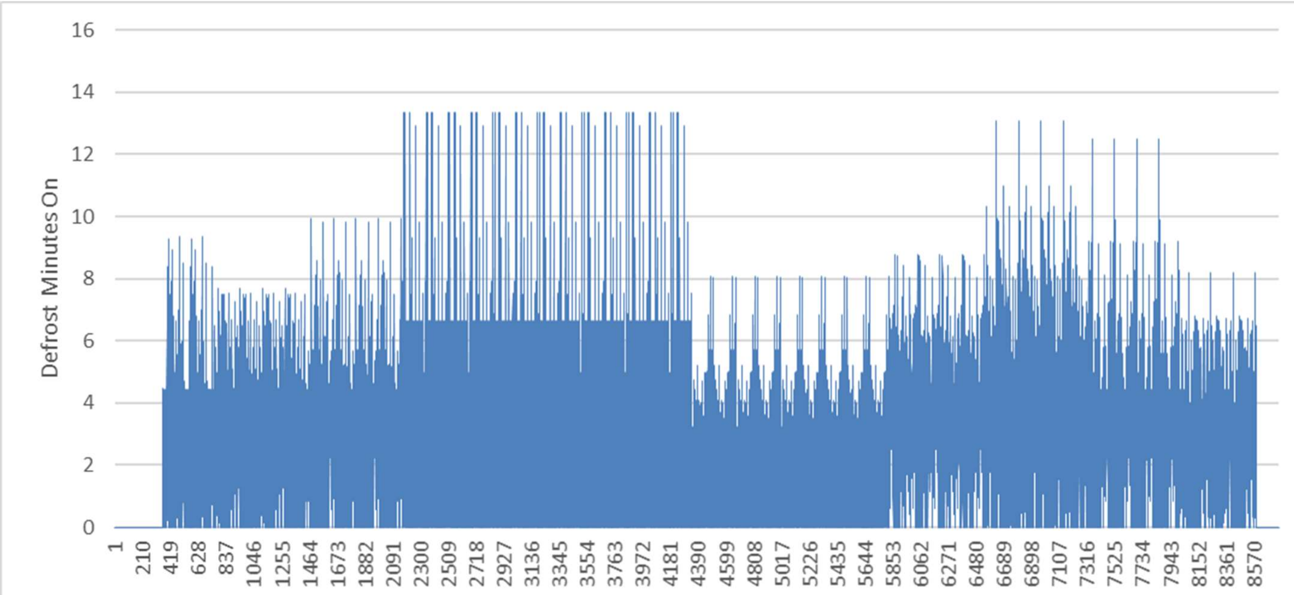
The Table 2-3 below shows the summed annual run hours for the coolers and freezers based on hourly output percentage.

Table 2-3. Evaluated Door Heater Run Hours

Equipment	Run Hours
Cooler C Door Heater	3,850
Freezer Door Heater	4,165

The evaluators developed hourly-run time schedules based on the monitored defrost output percentage data and applied the schedules to the 8,760 analysis to determine the hourly output percentage for the Freezer defrost. The evaluators determined the defrost to run for 383 hours annually based on the monitored data. Figure 2-7 below show the hourly annual run hours based on the developed schedules for the Freezer.

Figure 5-7. Freezer Defrost Annual Run Hours



Lighting

The evaluator calculated the savings using a similar approach to the applicant. The evaluator used the National Grid Custom Lighting tool to determine the evaluated savings. The savings algorithms used in the tool are as follows:

$$\text{Baseline Fixture kWh} = \frac{Quantity_B * Wattage_{\boldsymbol{B}}}{1000} * Evaluated\ Operating\ Hours\ without\ controls$$

$$\text{Proposed Fixture kWh} = \frac{Quantity_P * Wattage_{\boldsymbol{P}}}{1000} * Evaluated\ Operating\ Hours\ without\ controls$$

$$\text{Fixture kWh Savings} = Baseline\ Fixture\ kWh\ - Proposed\ Fixture\ kWh$$

$$\text{HVAC Interactive Fixture Savings} = (pre\ connected\ kW - post\ connected\ kW) * Coincident\ Occupied\ Cooling\ Hours * \frac{0.8}{Cooling\ COP}$$

$$\text{Control kWh Savings} = Proposed\ Fixture\ kW\ * (Evaluated\ Operating\ Hours\ without\ controls - Evaluated\ EFL\ Operating\ Hours\ with\ controls)$$

$$\text{Total kWh Savings} = Fixture\ kWh\ Savings + HVAC\ Interactive\ Fixture\ Savings + Control\ kWh\ Savings$$

All spreadsheets used to estimate evaluation savings will be made available to the PAs for review at their request. For site cooling hours, the evaluator confirmed with the site contact that cooling typically occurs between May and October. For each hourly interval within that range of months in the 8760 model, if dry bulb temperature taken from local TMY3 data was greater than or equal to the cooling balance point of 65°F, then that hour was determined to be a cooling hour. Cooling hours that coincided with the lighting hours were used to determine total annual cooling savings. The cooling COP is assumed to be 5.5 for the chillers that serve the facility. Table 2-4 and Table 2-5 shows the evaluation inputs and savings calculations for the fixtures and controls, respectively.

Table 5-4. Evaluation Fixture Inputs and kWh Savings

	A	B	C	D	E	F	G=A*B*E/1000	H=C*D*E/1000	I=G-H	J	K	L	M=F*J*K*0.8/L	N=I+M
Space Type	**Baseline Quantity**	**Baseline Watts per Fixture**	**Installed Quantity**	**Installed Watts per Fixture**	**Annual Pre Hours**	**Connected kW Savings**	**Baseline kWh**	**Installed kWh**	**kWh Fixture Savings**	**% of Space Cooled**	**Annual Cooling Hours**	**Cooling COP**	**Interactive Cooling Savings**	**Total kWh Fixture Savings**
Hallways/Stairwells	3	112	3	40	8,760	0.216	2,943	1,051	1,892	100%	2,238	5.5	70	1,962
Hallways/Stairwells	1	60	1	16	8,760	0.044	526	140	385	100%	2,238	5.5	14	400
Hallways/Stairwells	40	60	40	40	8,760	0.800	21,023	14,015	7,008	100%	2,238	5.5	259	7,267
Hallways/Stairwells	2	60	2	10	8,760	0.100	1,051	175	876	100%	2,238	5.5	32	908
Hallways/Stairwells	2	88	2	40	8,760	0.096	1,542	701	841	100%	2,238	5.5	31	872
Hallways/Stairwells	3	65	3	10	8,760	0.165	1,708	263	1,445	100%	2,238	5.5	53	1,499
Hallways/Stairwells	6	100	6	10	8,760	0.540	5,256	526	4,730	100%	2,238	5.5	175	4,905
Hallways/Stairwells	76	32	76	20	8,760	0.912	21,303	13,314	7,989	100%	2,238	5.5	295	8,284
Hallways/Stairwells	35	48	35	19	8,760	1.015	14,716	5,825	8,891	100%	2,238	5.5	329	9,220
Hallways/Stairwells	3	48	2	29	8,760	0.086	1,261	508	753	100%	2,238	5.5	28	781
Hallways/Stairwells	22	54	22	10	8,760	0.968	10,406	1,927	8,479	100%	2,238	5.5	314	8,793
Hallways/Stairwells	56	54	56	13	8,760	2.296	26,489	6,377	20,112	100%	2,238	5.5	744	20,856
Hallways/Stairwells	5	72	5	40	8,760	0.160	3,153	1,752	1,402	100%	2,238	5.5	52	1,453
Dorm Rooms	130	63	130	19	2,086	5.720	17,081	5,151	11,930	100%	679	5.5	562	12,492
Dorm Rooms	130	32	130	20	2,086	1.560	8,676	5,423	3,254	100%	679	5.5	153	3,407
Dorm Rooms	50	54	50	13	2,086	2.050	5,631	1,356	4,275	100%	679	5.5	202	4,477

Lobby/Offices/Low Hour Common	16	112	16	20	2,086	1.472	3,737	667	3,070	100%	679	5.5	145	3,215
Lobby/Offices/Low Hour Common	26	60	26	16	2,086	1.144	3,254	868	2,386	100%	679	5.5	112	2,498
Lobby/Offices/Low Hour Common	16	60	16	20	2,086	0.640	2,002	667	1,335	100%	679	5.5	63	1,398
Lobby/Offices/Low Hour Common	2	60	2	40	2,086	0.040	250	167	83	100%	679	5.5	4	87
Lobby/Offices/Low Hour Common	8	30	8	10	2,086	0.160	501	167	334	100%	679	5.5	16	349
Lobby/Offices/Low Hour Common	5	65	5	10	2,086	0.275	678	104	574	100%	679	5.5	27	601
Lobby/Offices/Low Hour Common	15	54	15	16	2,086	0.570	1,689	501	1,189	100%	679	5.5	56	1,245
Miscellaneous Areas	12	112	12	40	2,007	0.864	2,698	964	1,734	100%	653	5.5	82	1,816
Miscellaneous Areas	12	60	12	40	2,007	0.240	1,445	964	482	100%	653	5.5	23	504
Miscellaneous Areas	2	88	2	40	2,007	0.096	353	161	193	100%	653	5.5	9	202
Miscellaneous Areas	85	54	85	13	2,007	3.485	9,214	2,218	6,996	100%	653	5.5	329	7,325
Miscellaneous Areas	4	75	4	10	2,007	0.260	602	80	522	100%	653	5.5	25	546
Total	**767**		**766**			**25.97**	**169,189**	**66,031**	**103,158**				**4,204**	**107,362**

Table 5-5. Evaluation Control Inputs and kWh Savings

	A	B	C	D=A*B/1000	E=C*D	F	G	H	I=D*F*G*0.8/H	J=E+X
Space Type	Installed Quantity	Installed Watts per Fixture	Annual Hours Reduction	Connected kW	kWh Controls Savings	Percent of Space Cooled	Annual Cooling Hours Reduction	Cooling COP	Interactive Cooling Savings	Total kWh Controls Savings
Hallways/Stairwells	6	10	2,102	0.06	126	100%	323	5.5	3	129
Hallways/Stairwells	40	40	2,102	1.60	3,364	100%	323	5.5	75	3,438
Hallways/Stairwells	2	10	2,102	0.02	42	100%	323	5.5	1	43
Hallways/Stairwells	3	40	2,102	0.12	252	100%	323	5.5	6	258
Hallways/Stairwells	22	10	2,102	0.22	463	100%	323	5.5	10	473
Hallways/Stairwells	2	40	2,102	0.08	168	100%	323	5.5	4	172
Hallways/Stairwells	5	40	2,102	0.20	420	100%	323	5.5	9	430
Hallways/Stairwells	3	10	2,102	0.03	63	100%	323	5.5	1	64
Lobby/Offices/Low Hour Common	2	40	501	0.08	40	100%	174	5.5	2	42
Lobby/Offices/Low Hour Common	5	10	501	0.05	25	100%	174	5.5	1	26
Miscellaneous Areas	12	40	482	0.48	231	100%	167	5.5	12	243
Miscellaneous Areas	12	40	482	0.48	231	100%	167	5.5	12	243
Miscellaneous Areas	2	40	482	0.08	39	100%	167	5.5	2	40
Miscellaneous Areas	4	10	482	0.04	19	100%	167	5.5	1	20
Total	**766**			**14.73**	**5,484**				**138**	**5,622**

1.4 Final Results

Overall, the evaluated kWh savings for the non-lighting measure is 0.3% more than tracking due to inclusion of interactive savings and discrepancies in evaluated operating hour reductions for the door heater, defrost, and door heaters. A discrepancy was also found in the baseline operating hours for the refrigeration system. The applicant assumed the refrigeration system operated 8,760 hours annually. The evaluator determined the baseline operating hours to be 8,232 hours annually. The applicant did not include interactive effects of installing door heater controls. The evaluator method includes the savings from less sensible heat from door heaters in the refrigeration case. The parameters impacting the analysis are summarized in Table 3-1 below.

The evaluated kWh savings for the lighting retrofit are 4% higher due to the inclusion of HVAC interactivity. A summary of the key parameters in the non-lighting and lighting analysis are shown in Table 3-1 below.

Table 5-204. Summary of Key Parameters

Parameter	Applicant	Evaluator
Baseline Operating Hours (Non-lighting)	8,760	8,232
Post-Install Evaporator Fan Run Hours	4,688	5,063
Post-Install Evaporator Fan Run Hour Reduction	46%	39%
Post-Install Defrost Off Hours	243	383
Post-Install Cooler C Door Heater Run Hours	2,256	3,850
Post-Install Freezer Door Heater Run Hours	5,694	4,165
Door Heater Controls Interactive Savings	Not Included	Included interactive refrigeration savings for Cooler C and Freezer door heater controls
Baseline Fixture Quantity	767	767
Installed Fixture Quantity	766	766
HVAC	Not Included	Heating: Steam Boiler Cooling: Chiller (COP 5.5)

1.4.1 Explanation of Differences

Non-Lighting

The evaluation found discrepancies in post-install operating hours and baseline operating hours for the non-lighting measure. A 46% reduction in evaporator run-time is claimed for implementing fan-cycling controls. Anti-condensate heater control savings are based on a reduction in runtime of 65% for the freezer and 60% for the coolers. Savings from the electric defrost controls are based off a run-time a reduction of 25%. The evaluators use run-time data spanning back to the install date of the refrigeration controls to determine the run-time reductions for evaporator run time, door heaters, and electric defrost. The evaluator noted that the evaluated run time hours for the defrost and Freezer C door heater were less than the applicant estimated run time hours however, this was outweighed by the greater run-time hours for the evaporator fans and Cooler C door heater. A minor increase in savings resulted from including interactive savings for door heater controls. The Table 5-205. Summary of Deviations provides a summary of the primary differences between tracking and evaluated values.

Lighting

The evaluated savings for the lighting project were slightly greater than the applicant-reported savings primarily due to a discrepancy stemming from heating and cooling interaction. Table 3-2 provides a summary of the primary differences between tracking and evaluated values. The percent impact of deviations shown in the table are separate for the lighting and non-lighting applications.

Table 5-205. Summary of Deviations

End-use	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
9808400 - Refrigeration Controls	Operating Hours	Baseline Operating Hours	-0.7%	**Negative** – due to the shutoff period for winter break
9808400 - Refrigeration Controls	Operational	Operating Hours	-1.2%	**Negative** – due to lesser reduction in operating hours for evaporator fans, and Cooler C door heater
9808400 - Refrigeration Controls	Interactive	Door Heater Controls Interactivity	+2.2%	**Positive –** due to lesser sensible heat from installing door heater controls in the freezer and Cooler C and less refrigeration load
9926319 - Lighting	Interactive	HVAC Interactivity	+4%	**Positive –** a difference of 4,342 kWh was determined by the inclusion of HVAC interactivity in the evaluator's savings algorithms.

1.4.2 Ancillary Impacts

For the lighting measures, electric HVAC interaction savings occur in retrofitting the fluorescent fixtures to LED. The tracking estimate did not include HVAC interactive effects.

RICE19C036 Lighting

Report Date: 05/28/2021

Program	RICE2019	
Application ID(s)	9494449, 9209205, & 8116694 (lighting only)	
Project Type	Existing Building Retrofit	
Program Year	2019	
Evaluation Firm	DNV	DNV
Evaluation Engineer	Shravan Iyer/Khusbu Modi	
Senior Engineer	Jeffrey Zynda/Srikar Kaligotla	

Evaluated Site Summary and Results

This University Campus retrofitted multiple lighting and non-lighting measures at 41 different buildings using National Grid's custom electric program incentives under three applications (9494449, 9209205, & 8116694) with a total energy savings of 2,278,505 kWh. In some cases, both lighting and non-lighting measures were completed at a single building. To reduce the customer burden and to be cost effective, the evaluator disaggregated the savings at the building level and sampled within those buildings using Model Based Statistical Sampling (MBSS) technique. The sample included 2 buildings with lighting measures and 5 buildings with non-lighting measures.

To reduce the complexity and to streamline reporting, lighting and non-lighting reports are separated. This site report will include lighting sites only. The total claimed lighting savings from the project is 1,415,130 kWh per year. The total tracking savings from the two sub sampled buildings is 397,771 annual kWh, which accounts for nearly 28% of the lighting savings.

In total, 3,292 fixtures were retrofitted with 3,355 LED fixtures at the two sub-sampled buildings. Occupancy sensors were installed on 30 fixtures in the office, conference room, and lounge areas at one of the buildings and were assumed to reduce operating hours by 24% for a total savings of 559 kWh.

The applicant's project savings calculation for the two sub-sampled buildings resulted in an annual energy savings of 397,771 kWh. Summer On-peak demand savings was 44.7 kW, and winter was 48.2 kW. The evaluator calculated the annual energy savings to be 421,840 kWh, summer on-peak demand savings to be 51.1 kW, and winter on-peak demand savings to be 48.1 kW; due mostly to the inclusion of interactive savings.

Metering was not performed at this site due to the atypical operating conditions caused by the pandemic (lower occupancy and lighting usage due to remote/virtual learning). As such, the operational assumptions in the applicant savings calculations were assumed in the evaluation savings calculations. See Section 2.3 for further details. Building specific weights will be developed for this site-level sample and population (buildings with measures) and then expanded to the population using ratio estimation method.

The evaluation results are presented in Table 1-1.

Table 5-206: Evaluation Results Summary

Building #	Measure Name		Annual Electric Energy (kWh)	Summer On-Peak Demand (kW)	Winter On-Peak Demand (kW)
Building 1	Lighting Retrofit	Tracked	392,630	44.1	47.6
		Evaluated	416,373	50.4	47.6
		Realization Rate	106.0%	114.2%	100.0%
Building 2	Lighting Retrofit	Tracked	4,582	0.52	0.55
		Evaluated	4,780	0.60	0.52
		Realization Rate	104.3%	116.6%	94.2%
Building 2	Lighting Controls	Tracked	559	0.06	0.068
		Evaluated	688	0.09	0.075
		Realization Rate	123.0%	140.0%	110.4%
Evaluation Totals		**Tracked**	**397,771**	**44.7**	**48.18**
		Evaluated	**421,840**	**51.1**	**48.15**
		Realization Rate	**106.1%**	**114.3%**	**99.9%**

Explanation of Deviations from Tracking

The 5.8% increase in savings in Building 1 is due entirely to the inclusion of interactive savings which were not accounted for in the applicant savings calculations. No changes in technology or quantity were observed for this application and only a very small documentation error was found (a 2 kWh increase in savings)

In Building 2, a 5.6% decrease in fixture savings was calculated due to differences found in the installed wattage of 35 of the fixtures[61]. A 9.5% increase in fixture savings was attributed to this application due to the inclusion of interactive savings. Twenty-seven of the 35 fixtures[62] where differences in wattage were found also had occupancy sensors installed on them through the program causing a 10.4% increase in controls savings. An additional 12.2% increase in controls savings was attributed to this application due to the inclusion of interactive savings.

Recommendations for Program Designers & Implementers

There are no recommendations currently.

Customer Alert

There are no customer alerts for this site.

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 interior and exterior LED fixtures and controls in the two sub-sampled buildings.

Application Information and Applicant Savings Methodology

This section describes the applicant's application information, savings methodology, and evaluation assessment of the applicant's savings calculation algorithm. Project savings were generated from a reduction in fixture wattage and a reduction in hours of use caused by occupancy sensors installed on some of the installed program fixtures.

Applicant Description of Baseline

The two sub-sampled sites in this project is classified as a lighting retrofit project in the application. The majority (97.8%) of the baseline fixtures/lamps are categorized as T8 fluorescents (53.7%), CFLs (26.0%), and T5 fluorescents (18.1%). The remaining baseline fixtures/lamps were categorized as incandescents. The site documentation reported that the baseline consisted of 3,292 fixtures with varying wattages from 15 to 270 watts. Application baseline usage hours ranged from 760 to 8,760 annual hours. These fixtures had no advanced controls and were manually operated. The key applicant baseline parameters are summarized in Table 2-1.

Table 5-207: Applicant baseline key parameters

		BASELINE		
Measure	Parameter	Value(s)	Source of Parameter Value	Note
Lighting Retrofit	Fixture Wattage	Varies from 15-270 watts	Project Files	None
Lighting Retrofit	Fixture Quantity	3,292	Project Files	None
Lighting Retrofit	Operating Hours	Varies from 760-8,760 annual hours	Project Files	None

Applicant Description of Installed Equipment and Operation

The facility upgraded its lighting system by retrofitting 3,292 older fixtures with 3,355 LED fixtures with varying wattages from 5 to 123 watts. Except for the 30 fixtures that also had occupancy sensors installed, operating schedules observed in the baseline description are maintained for the installed fixtures. For the fixtures with occupancy sensors installed, a 24% reduction in operating hours was assumed. Project savings were generated from a reduction in fixture wattage and a reduction in hours of use caused by the occupancy sensors installed on some of the installed program fixtures. The key applicant proposed parameters are summarized in Table 2-2.

Table 5-2: Application proposed key parameters

		PROPOSED

[61] Two fixtures were reported to be 10 watts but were found to be 9.8 watts, two fixtures were reported to be 11 watts but were found to be 10 watts, one fixture was reported to be 16 watts but was found to be 15 watts, 23 fixtures were reported to be 24 watts but were found to be 26 watts, and seven fixtures were reported to be 45 watts but were found to be 52 watts.

[62] One was reported to be 10 watts but was found to be 9.8 watts, one was reported to be 11 watts but was found to be 10 watts, 18 were reported to be 24 watts but were found to be 26 watts, and seven were reported to be 45 watts but were found to be 52 watts.

Measure	Parameter	Value(s)	Source of Parameter Value	Note
Lighting Retrofit	Fixture Wattage	Varies from 5-123 watts	Project Files	None
Lighting Retrofit	Fixture Quantity	3,355	Project Files	None
Lighting Retrofit	Operating Hours	Varies from 760-8,760 annual hours	Project Files	None
Lighting Controls	Operating Hours	24% reduction from assumed baseline hours	Project Files	None

Applicant Energy Savings Algorithm

Savings were calculated using a custom lighting savings excel workbook using the following equations. The primary driver for this measure's energy savings is a reduction in fixture/lamp wattage. Energy savings algorithms are as follows:

Total kWh Savings = $Fixture\ kWh\ Savings + Control\ kWh\ Savings$

Baseline Fixture kWh = $\frac{Quantity_B * Wattage_B}{1000} * Existing\ Operating\ Hours$ without Controls

Proposed Fixture kWh = $\frac{Quantity_P * Wattage_P}{1000} * ProposedOperatingHours \frac{Quantity_B * Wattage_B}{1000} * Existing\ Operating\ Hours$ without Controls

Fixture kWh Savings = $Baseline\ Fixture\ kWh - Proposed\ Fixture\ kWh$

Control kWh Savings = $Proposed\ Fixture\ kW * Existing\ Operating\ Hours\ without\ Controls * 24\%$

Table 5-3: Building 1 baseline key parameters

Building 1	A	B	C	D	E	F=A*B*E /1000	G=C*D*E/1000	H	H=F-G
Space Type	Baseline Quantity	Baseline Watts per Fixture	Installed Quantity	Installed Watts per Fixture	Annual Hours	Baseline kWh	Installed kWh	Control kWh Savings	kWh Fixture Savings
Mechanical / Storage	224	47	224	25	4,000	42,112	22,400	0	19,712
Mechanical / Storage	1	60	1	28	4,000	240	112	0	128
Mechanical / Storage	7	34	7	15	7,000	1,666	735	0	931
Mechanical / Storage	3	47	3	25	8,760	1,235	657	0	578
Mechanical / Storage	4	34	4	15	8,760	1,191	526	0	666
Mechanical / Storage	1	150	1	16	8,760	1,314	140	0	1,174
Mechanical / Storage	6	47	6	25	1,520	429	228	0	201
Mechanical / Storage	16	47	16	25	1,140	857	456	0	401
Mechanical / Storage	2	135	2	25	1,140	308	57	0	251
Mechanical / Storage	17	95	17	50	1,140	1,841	969	0	872
Mechanical / Storage	2	270	2	50	1,140	616	114	0	502
Mechanical / Storage	8	47	8	25	1,500	564	300	0	264
Mechanical / Storage	6	47	6	25	3,800	1,072	570	0	502
Mechanical / Storage	2	32	2	14	3,000	192	84	0	108
Mechanical / Storage	1	60	1	28	3,000	180	84	0	96
Mechanical / Storage	2	72	2	39	3,000	432	234	0	198
Mechanical / Storage	1	32	1	14	2,000	64	28	0	36
Mechanical / Storage	6	47	6	25	1,900	536	285	0	251
Mechanical / Storage	2	60	2	25	760	91	38	0	53
Mechanical / Storage	1	32	1	14	1,825	58	26	0	33
Hallway / Lobby	4	47	4	25	7,000	1,316	700	0	616
Hallway / Lobby	379	34	379	15	7,000	90,202	39,795	0	50,407
Hallway / Lobby	13	60	13	28	7,000	5,460	2,548	0	2,912
Hallway / Lobby	48	47	48	25	8,760	19,763	10,512	0	9,251
Hallway / Lobby	233	34	233	15	8,760	69,397	30,616	0	38,781
Hallway / Lobby	4	50	4	8	8,760	1,752	280	0	1,472
Hallway / Lobby	9	60	9	25	8,760	4,730	1,971	0	2,759
Hallway / Lobby	9	60	9	28	8,760	4,730	2,208	0	2,523
Hallway / Lobby	4	50	4	8	6,580	1,316	211	0	1,105
Hallway / Lobby	11	34	11	15	5,000	1,870	825	0	1,045
Laboratory	2	47	2	25	4,000	376	200	0	176
Laboratory	438	32	438	14	4,000	56,064	24,528	0	31,536
Laboratory	10	16	10	12	4,000	640	480	0	160
Laboratory	30	24	30	13	4,000	2,880	1,560	0	1,320
Laboratory	2	15	2	5	4,000	120	40	0	80

Building 1 cont.	A	B	C	D	E	F=A*B*E /1000	G=C*D*E/1000	H	H=F-G
Space Type	Baseline Quantity	Baseline Watts per Fixture	Installed Quantity	Installed Watts per Fixture	Annual Hours	Baseline kWh	Installed kWh	Control kWh Savings	kWh Fixture Savings
Laboratory	6	47	6	25	8,760	2,470	1,314	0	1,156
Laboratory	44	34	44	15	8,760	13,105	5,782	0	7,323
Laboratory	3	60	3	28	8,760	1,577	736	0	841
Laboratory	6	28	6	12.5	8,760	1,472	657	0	815
Laboratory	53	47	53	25	6,000	14,946	7,950	0	6,996
Laboratory	43	34	43	15	6,000	8,772	3,870	0	4,902
Laboratory	15	150	15	16	6,000	13,500	1,440	0	12,060
Laboratory	9	60	9	28	6,000	3,240	1,512	0	1,728
Laboratory	2	72	2	42	6,000	864	504	0	360
Laboratory	8	54	8	25	6,000	2,592	1,200	0	1,392
Laboratory	13	28	13	12.5	6,000	2,184	975	0	1,209
Laboratory	46	47	46	25	5,000	10,810	5,750	0	5,060
Laboratory	6	34	6	15	5,000	1,020	450	0	570
Laboratory	29	150	29	16	5,000	21,750	2,320	0	19,430
Laboratory	1	60	1	28	5,000	300	140	0	160
Laboratory	1	200	1	16	5,000	1,000	80	0	920
Laboratory	18	72	18	39	5,000	6,480	3,510	0	2,970
Laboratory	384	47	384	25	3,800	68,582	36,480	0	32,102
Laboratory	2	34	2	15	3,800	258	114	0	144
Laboratory	10	47	10	25	3,000	1,410	750	0	660
Laboratory	1	15	1	5	3,000	45	15	0	30
Laboratory	5	16	5	12	3,040	243	182	0	61
Laboratory	654	47	654	25	4,560	140,165	74,556	0	65,609
Laboratory	1	60	1	28	4,560	274	128	0	146
Laboratory	1	200	1	16	2,000	400	32	0	368
Laboratory	2	47	2	25	2,280	214	114	0	100
Laboratory	8	150	8	16	4,700	5,640	602	0	5,038
Laboratory	4	72	4	39	4,700	1,354	733	0	620
Laboratory	12	47	12	25	4,400	2,482	1,320	0	1,162
Laboratory	3	234	6	62	4,080	2,864	1,518	0	1,346
Laboratory	8	150	8	16	3,760	4,512	481	0	4,031
Bathroom	16	34	16	15	8,760	4,765	2,102	0	2,663
Bathroom	82	47	82	25	3,192	12,302	6,544	0	5,758
Bathroom	32	34	32	15	3,192	3,473	1,532	0	1,941
Bathroom	5	60	5	25	3,192	958	399	0	559
Bathroom	1	47	1	25	4,200	197	105	0	92
Bathroom	2	34	2	15	6,658	453	200	0	253
Office	6	47	6	25	4,000	1,128	600	0	528

Building 1 cont.	A	B	C	D	E	F=A*B*E /1000	G=C*D*E/1000	H	H=F-G
Space Type	Baseline Quantity	Baseline Watts per Fixture	Installed Quantity	Installed Watts per Fixture	Annual Hours	Baseline kWh	Installed kWh	Control kWh Savings	kWh Fixture Savings
Office	22	34	22	15	4,000	2,992	1,320	0	1,672
Office	1	32	1	14	4,000	128	56	0	72
Office	15	16	15	12	4,000	960	720	0	240
Office	9	60	9	28	4,000	2,160	1,008	0	1,152
Office	4	234	8	123	4,000	3,744	3,936	0	-192
Office	2	34	2	15	8,760	596	263	0	333
Office	6	95	6	50	6,000	3,420	1,800	0	1,620
Office	10	34	10	15	5,000	1,700	750	0	950
Office	4	47	4	25	3,000	564	300	0	264
Office	19	47	19	25	3,040	2,715	1,444	0	1,271
Office	4	34	4	15	3,040	413	182	0	231
Office	26	117	26	62	3,040	9,248	4,900	0	4,347
Office	12	95	12	50	3,040	3,466	1,824	0	1,642
Office	56	234	112	62	2,720	35,643	18,888	0	16,755
Office	1	32	1	14	2,000	64	28	0	36
Office	2	32	2	14	1,000	64	28	0	36
Total	**3,243**	**-**	**3,306**		**-**	**741,291**	**348,660**	**0**	**392,632**

Table 5-4: Building 2 baseline key parameters

Building 2	A	B	C	D	E	F=A*B*E /1000	G=C*D*E/1000	H	H=F-G
Space Type	**Baseline Quantity**	**Baseline Watts per Fixture**	**Installed Quantity**	**Installed Watts per Fixture**	**Annual Hours**	**Baseline kWh**	**Installed kWh**	**Control kWh Savings**	**kWh Fixture Savings**
Stairwell	1	24	1	10	2,500	60	25	0	35
Stairwell	1	30	1	11	5,000	150	55	0	95
Storage	3	60	3	24	1,500	270	108	0	162
Storage	4	15	4	5	1,500	90	30	0	60
Lobby	3	30	3	13	5,000	450	195	0	255
Lobby	1	15	1	5	5,000	75	25	0	50
Office	1	24	1	10	2,800	67	28	7	39
Office	3	30	3	13	2,800	252	109	26	143
Office	18	60	18	24	2,800	3,024	1,210	258	1,814
Office	3	112	3	45	2,800	941	378	91	563
Office	1	28	1	11	2,800	78	31	7	48
Conf room	4	112	4	45	3,000	1,344	540	130	804
Kitchen	1	45	1	16	2,500	113	40	0	73
Bathroom	1	15	1	5	2,000	30	10	0	20
Hallway	2	30	2	13	5,000	300	130	0	170
Lounge	2	60	2	24	3,500	420	168	40	252
Total	**49**		**49**			**7,664**	**3,082**	**559**	**4,582**

Evaluation Assessment of Applicant Methodology

The evaluator agrees with the analysis approach used by the applicant.

Onsite Inspection

The evaluators conducted a site visit after confirming the following criteria:

- The site was safe to visit and the site contact with knowledge of the project was available to assist with the evaluation site visit.
- COVID-19 impacted the site's operations so metering equipment was not installed.

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

Summary of Site Visit Findings and Metering

With the facility manager's assistance, the site visit was completed on April 29, 2021. While visiting the customer's facility, the evaluator confirmed the lighting control types being utilized, fixture counts, wattages, and HVAC information.

While onsite, the evaluators did not observe any differences in the fixture wattages or counts found in Building 1. In Building 2 differences were found in the wattage of 35 of the installed fixtures[63]. Twenty-seven of these fixtures[64] also had occupancy sensors installed on them through the program.

The table below provides a quick summary of the evaluator's findings.

Table 5-5: Measure Verification

Measure Name	Verification Method	Verification Result
Lighting Retrofit	Verify fixture quantity, control, and wattage.	Changes were observed with the wattage of 35 of the installed fixtures. Fixture control and quantity are consistent with what's seen in the tracking documentation.
Lighting Controls	Verify fixture quantity, control, and wattage.	Changes were observed with the wattage of 27 of the controlled fixtures. Fixture control and quantity are consistent with what's seen in the tracking documentation.

2.3.2 Measured and Logged Data

Metering was not performed at this site due to the atypical operating conditions caused by the COVID-19 pandemic (lower occupancy and lighting usage due to remote/virtual learning) as the evaluator's felt that any metering data collected would not be representative of normal operations. As such, the operation in the applicant savings calculations was assumed in the evaluation savings calculations.

Evaluation Methods and Findings

This section describes the evaluator methods and findings.

Evaluation Description of Baseline

Baseline conditions for the two sub-sampled sites in this project consisted mostly of T8 fluorescents (53.7%), CFLs (26.0%), and T5 fluorescents (18.1%). The remaining baseline fixtures/lamps were categorized as incandescents. The site documentation reported that the baseline consisted of 3,292 fixtures with varying wattages from 15 to 270 watts.

---

[63] Two fixtures were reported to be 10 watts but were found to be 9.8 watts, two fixtures were reported to be 11 watts but were found to be 10 watts, one fixture was reported to be 16 watts but was found to be 15 watts, 23 fixtures were reported to be 24 watts but were found to be 26 watts, and seven fixtures were reported to be 45 watts but were found to be 52 watts.

[64] One was reported to be 10 watts but was found to be 9.8 watts, one was reported to be 11 watts but was found to be 10 watts, 18 were reported to be 24 watts but were found to be 26 watts, and seven were reported to be 45 watts but were found to be 52 watts.

Application baseline usage hours ranged from 760 to 8,760 annual hours. These fixtures had no advanced controls and were manually operated.

The application documentation does not include pre-existing lighting controls. The evaluator reviewed the project files and interviewed the site contact, and conducted a site visit to confirm the baseline information provided in the application.

Evaluation Metered Data and Analysis Methodology

The evaluators conducted a site visit to verify equipment technology, quantities, and gather HVAC information. As mentioned above, metering was not performed at this site due to the atypical operating conditions caused by the COVID-19 pandemic.

The evaluator used the equations highlighted below to calculate the energy savings associated with the measure installed through the program.

Baseline Fixture kWh = $\frac{Quantity_B * Wattage_B}{1000} * Existing\ Operating\ Hours$

Proposed Fixture kWh = $\frac{Quantity_B * Wattage_B}{1000} * Existing\ Operating\ Hours \frac{Quantity_P * Wattage_P}{1000} * ProposedOperatingHours$

Fixture kWh Savings = $Baseline\ Fixture\ kWh - Proposed\ Fixture\ kWh$

Control kWh Savings = *Proposed Fixture kW * Existing Operating Hours without Controls * 24%*

HVAC Interactive Fixture Savings = $pre\ connected\ kW - post\ connected\ kW) * Coincident\ Occupied\ Cooling\ Hours * \frac{0.8}{Cooling\ COP}$

HVAC Interactive Controls Savings = *(post conn kW * (pre coincident occupied cooling hours-post coincident cooling hours) *0.8)/(Cooling COP)*

Total kWh Savings = $Fixture\ kWh\ Savings + Control\ kWh\ Savings\ + HVAC\ Interactive\ Fixture\ Savings\ +$
$HVAC\ Interactive\ Control\ SavingsFixturekWhSavings + ControlkWhSavings$
$ProposedFixturekW * (ExistingOperatingHourswithoutcontrols - EstimatedEFLOperatingHourswithcontrols)$

Final Results

This section will summarize the evaluation results determined in the analysis above. The evaluators' estimated savings values result from observed changes to the applicant's pre and post-cases.

Table 3-2 below shows the evaluation inputs and savings calculations.

Table 3-2: Building 1 Evaluation Fixture Inputs and kWh Savings

Building 1	A	B	C	D	E	F=A*B*E /1000	G=C*D*E /1000	H=F-G	I	J	K	L=(A*B-C*D)*I*J*0.8/K	M=H+L
Space Type	Baseline Quantity	Baseline Watts per Fixture	Installed Quantity	Installed Watts per Fixture	Annual Hours	Baseline kWh	Installed kWh	kWh Fixture Savings	% of Space Cooled	Annual Cooling Hours	Cooling COP	HVAC Savings	Total Fixture Savings
Mechanical / Storage	224	47	224	25	4,000	42,112	22,400	19,712	100%	1,630	5.5	1,205	20,917
Mechanical / Storage	1	60	1	28	4,000	240	112	128	100%	1,630	5.5	8	136
Mechanical / Storage	7	34	7	15	7,000	1,666	735	931	100%	2,775	5.5	55	986
Mechanical / Storage	3	47	3	25	8,760	1,235	657	578	100%	3,447	5.5	34	612
Mechanical / Storage	4	34	4	15	8,760	1,191	526	666	100%	3,447	5.5	39	705
Mechanical / Storage	1	150	1	16	8,760	1,314	140	1,174	100%	3,447	5.5	69	1,243
Mechanical / Storage	6	47	6	25	1,520	429	228	201	100%	684	5.5	14	214
Mechanical / Storage	16	47	16	25	1,140	857	456	401	100%	539	5.5	28	430
Mechanical / Storage	2	135	2	25	1,140	308	57	251	100%	539	5.5	18	269
Mechanical / Storage	17	95	17	50	1,140	1,841	969	872	100%	539	5.5	62	934
Mechanical / Storage	2	270	2	50	1,140	616	114	502	100%	539	5.5	35	537
Mechanical / Storage	8	47	8	25	1,500	564	300	264	100%	676	5.5	18	282
Mechanical / Storage	6	47	6	25	3,800	1,072	570	502	100%	1,554	5.5	31	532
Mechanical / Storage	2	32	2	14	3,000	192	84	108	100%	1,249	5.5	7	115
Mechanical / Storage	1	60	1	28	3,000	180	84	96	100%	1,249	5.5	6	102
Mechanical / Storage	2	72	2	39	3,000	432	234	198	100%	1,249	5.5	12	210
Mechanical / Storage	1	32	1	14	2,000	64	28	36	100%	867	5.5	2	38
Mechanical / Storage	6	47	6	25	1,900	536	285	251	100%	829	5.5	16	267

Building 1 cont'	A	B	C	D	E	F=A*B*E /1000	G=C*D*E /1000	H=F-G	I	J	K	L=(A*B-C*D)*I*J*0.8/K	M=H+L
Space Type	Baseline Quantity	Baseline Watts per Fixture	Installed Quantity	Installed Watts per Fixture	Annual Hours	Baseline kWh	Installed kWh	kWh Fixture Savings	% of Space Cooled	Annual Cooling Hours	Cooling COP	HVAC Savings	Total Fixture Savings
Mechanical / Storage	2	60	2	25	760	91	38	53	100%	394	5.5	4	57
Mechanical / Storage	1	32	1	14	1,825	58	26	33	100%	800	5.5	2	35
Hallway / Lobby	4	47	4	25	7,000	1,316	700	616	100%	2,775	5.5	37	653
Hallway / Lobby	379	34	379	15	7,000	90,202	39,795	50,407	100%	2,775	5.5	2,997	53,404
Hallway / Lobby	13	60	13	28	7,000	5,460	2,548	2,912	100%	2,775	5.5	173	3,085
Hallway / Lobby	48	47	48	25	8,760	19,763	10,512	9,251	100%	3,447	5.5	546	9,797
Hallway / Lobby	233	34	233	15	8,760	69,397	30,616	38,781	100%	3,447	5.5	2,289	41,069
Hallway / Lobby	4	50	4	8	8,760	1,752	280	1,472	100%	3,447	5.5	87	1,559
Hallway / Lobby	9	60	9	25	8,760	4,730	1,971	2,759	100%	3,447	5.5	163	2,922
Hallway / Lobby	9	60	9	28	8,760	4,730	2,208	2,523	100%	3,447	5.5	149	2,672
Hallway / Lobby	4	50	4	8	6,580	1,316	211	1,105	100%	2,615	5.5	66	1,171
Hallway / Lobby	11	34	11	15	5,000	1,870	825	1,045	100%	2,012	5.5	63	1,108
Laboratory	2	47	2	25	4,000	376	200	176	100%	1,630	5.5	11	187
Laboratory	438	32	438	14	4,000	56,064	24,528	31,536	100%	1,630	5.5	1,927	33,463
Laboratory	10	16	10	12	4,000	640	480	160	100%	1,630	5.5	10	170
Laboratory	30	24	30	13	4,000	2,880	1,560	1,320	100%	1,630	5.5	81	1,401
Laboratory	2	15	2	5	4,000	120	40	80	100%	1,630	5.5	5	85
Laboratory	6	47	6	25	8,760	2,470	1,314	1,156	100%	3,447	5.5	68	1,225
Laboratory	44	34	44	15	8,760	13,105	5,782	7,323	100%	3,447	5.5	432	7,756
Laboratory	3	60	3	28	8,760	1,577	736	841	100%	3,447	5.5	50	891
Laboratory	6	28	6	12.5	8,760	1,472	657	815	100%	3,447	5.5	48	863
Laboratory	53	47	53	25	6,000	14,946	7,950	6,996	100%	2,394	5.5	419	7,415
Laboratory	43	34	43	15	6,000	8,772	3,870	4,902	100%	2,394	5.5	293	5,195

Building 1 cont.	A	B	C	D	E	F=A*B*E /1000	G=C*D*E /1000	H=F-G	I	J	K	L=(A*B-C*D)*I*J*0 .8/K	M=H+L
Space Type	Baseline Quantity	Baseline Watts per Fixture	Installed Quantity	Installed Watts per Fixture	Annual Hours	Baseline kWh	Installed kWh	kWh Fixture Savings	% of Space Coole d	Annual Cooling Hours	Cooling COP	HVAC Savings	Total Fixture Savings
Laboratory	15	150	15	16	6,000	13,500	1,440	12,060	100%	2,394	5.5	722	12,782
Laboratory	9	60	9	28	6,000	3,240	1,512	1,728	100%	2,394	5.5	103	1,831
Laboratory	2	72	2	42	6,000	864	504	360	100%	2,394	5.5	22	382
Laboratory	8	54	8	25	6,000	2,592	1,200	1,392	100%	2,394	5.5	83	1,475
Laboratory	13	28	13	12.5	6,000	2,184	975	1,209	100%	2,394	5.5	72	1,281
Laboratory	46	47	46	25	5,000	10,810	5,750	5,060	100%	2,012	5.5	305	5,365
Laboratory	6	34	6	15	5,000	1,020	450	570	100%	2,012	5.5	34	604
Laboratory	29	150	29	16	5,000	21,750	2,320	19,430	100%	2,012	5.5	1,172	20,602
Laboratory	1	60	1	28	5,000	300	140	160	100%	2,012	5.5	10	170
Laboratory	1	200	1	16	5,000	1,000	80	920	100%	2,012	5.5	56	976
Laboratory	18	72	18	39	5,000	6,480	3,510	2,970	100%	2,012	5.5	179	3,149
Laboratory	384	47	384	25	3,800	68,582	36,480	32,102	100%	1,554	5.5	1,968	34,071
Laboratory	2	34	2	15	3,800	258	114	144	100%	1,554	5.5	9	153
Laboratory	10	47	10	25	3,000	1,410	750	660	100%	1,249	5.5	41	701
Laboratory	1	15	1	5	3,000	45	15	30	100%	1,249	5.5	2	32
Laboratory	5	16	5	12	3,040	243	182	61	100%	1,264	5.5	4	65
Laboratory	654	47	654	25	4,560	140,165	74,556	65,609	100%	1,844	5.5	3,978	69,588
Laboratory	1	60	1	28	4,560	274	128	146	100%	1,844	5.5	9	155
Laboratory	1	200	1	16	2,000	400	32	368	100%	867	5.5	24	392
Laboratory	2	47	2	25	2,280	214	114	100	100%	974	5.5	6	107
Laboratory	8	150	8	16	4,700	5,640	602	5,038	100%	1,898	5.5	305	5,343
Laboratory	4	72	4	39	4,700	1,354	733	620	100%	1,898	5.5	38	658
Laboratory	12	47	12	25	4,400	2,482	1,320	1,162	100%	1,783	5.5	71	1,232
Laboratory	3	234	6	62	4,080	2,864	1,518	1,346	100%	1,661	5.5	82	1,429
Laboratory	8	150	8	16	3,760	4,512	481	4,031	100%	1,539	5.5	247	4,278
Bathroom	16	34	16	15	8,760	4,765	2,102	2,663	100%	3,447	5.5	157	2,820
Bathroom	82	47	82	25	3,192	12,302	6,544	5,758	100%	1,322	5.5	358	6,116
Bathroom	32	34	32	15	3,192	3,473	1,532	1,941	100%	1,322	5.5	120	2,061
Bathroom	5	60	5	25	3,192	958	399	559	100%	1,322	5.5	35	593
Bathroom	1	47	1	25	4,200	197	105	92	100%	1,707	5.5	6	98
Bathroom	2	34	2	15	6,658	453	200	253	100%	2,645	5.5	15	268
Office	6	47	6	25	4,000	1,128	600	528	100%	1,630	5.5	32	560

Building 1 cont.	A	B	C	D	E	F=A*B*E /1000	G=C*D*E /1000	H=F-G	I	J	K	L=(A*B-C*D)*I*J*0 .8/K	M=H+L
Space Type	Baseline Quantity	Baseline Watts per Fixture	Installed Quantity	Installed Watts per Fixture	Annual Hours	Baseline kWh	Installed kWh	kWh Fixture Savings	% of Space Coole d	Annual Cooling Hours	Cooling COP	HVAC Savings	Total Fixture Savings
Office	22	34	22	15	4,000	2,992	1,320	1,672	100%	1,630	5.5	102	1,774
Office	1	32	1	14	4,000	128	56	72	100%	1,630	5.5	4	76
Office	15	16	15	12	4,000	960	720	240	100%	1,630	5.5	15	255
Office	9	60	9	28	4,000	2,160	1,008	1,152	100%	1,630	5.5	70	1,222
Office	4	234	8	123	4,000	3,744	3,936	-192	100%	1,630	5.5	-12	-204
Office	2	34	2	15	8,760	596	263	333	100%	3,447	5.5	20	353
Office	6	95	6	50	6,000	3,420	1,800	1,620	100%	2,394	5.5	97	1,717
Office	10	34	10	15	5,000	1,700	750	950	100%	2,012	5.5	57	1,007
Office	4	47	4	25	3,000	564	300	264	100%	1,249	5.5	16	280
Office	19	47	19	25	3,040	2,715	1,444	1,271	100%	1,264	5.5	79	1,350
Office	4	34	4	15	3,040	413	182	231	100%	1,264	5.5	14	245
Office	26	117	26	62	3,040	9,248	4,900	4,347	100%	1,264	5.5	271	4,618
Office	12	95	12	50	3,040	3,466	1,824	1,642	100%	1,264	5.5	102	1,744
Office	56	234	112	62	2,720	35,643	18,888	16,755	100%	1,142	5.5	1,054	17,809
Office	1	32	1	14	2,000	64	28	36	100%	867	5.5	2	38
Office	2	32	2	14	1,000	64	28	36	100%	486	5.5	3	39
Total	**3,243**	-	**3,306**	-	-	**741,291**	**348,660**	**392,632**	-	-	-	**23,741**	**416,373**

Table 3-3: Building 2 Evaluation Fixture Inputs and kWh Savings

Building 2 cont.	A	B	C	D	E	F=A*B*E /1000	G=C*D*E /1000	H=F-G	I	J	K	L=(A*B-C*D)*I*J*0 .8/K	M=H+L
Space Type	**Baseline Quantity**	**Baseline Watts per Fixture**	**Installed Quantity**	**Installed Watts per Fixture**	**Annual Hours**	**Baseline kWh**	**Installed kWh**	**kWh Fixture Savings**	**% of Space Cooled**	**Annual Cooling Hours**	**Cooling COP**	**HVAC Savings**	**Total Fixture Savings**
Stairwell	1	24	1	9.8	2,500	60	25	36	0%	N/A	N/A	0	36
Stairwell	1	30	1	10	5,000	150	50	100	0%	N/A	N/A	0	100
Storage	3	60	3	26	1,500	270	117	153	0%	N/A	N/A	0	153
Storage	4	15	4	5	1,500	90	30	60	0%	N/A	N/A	0	60
Lobby	3	30	3	13	5,000	450	195	255	100%	1,970	2.9	28	283
Lobby	1	15	1	5	5,000	75	25	50	100%	1,970	2.9	6	56
Office	1	24	1	9.8	2,800	67	27	40	100%	1,131	2.9	5	44
Office	3	30	3	13	2,800	252	109	143	100%	1,131	2.9	16	159
Office	18	60	18	26	2,800	3,024	1,310	1,714	100%	1,131	2.9	196	1,909
Office	3	112	3	52	2,800	941	437	504	100%	1,131	2.9	58	562
Office	1	28	1	10	2,800	78	28	50	100%	1,131	2.9	6	56
Conf room	4	112	4	52	3,000	1,344	624	720	100%	1,207	2.9	82	802
Kitchen	1	45	1	15	2,500	113	38	75	100%	1,017	2.9	9	84
Bathroom	1	15	1	5	2,000	30	10	20	100%	826	2.9	2	22
Hallway	2	30	2	13	5,000	300	130	170	100%	1,970	2.9	19	189
Lounge	2	60	2	26	3,500	420	182	238	100%	1,398	2.9	27	265
Total	**49**	**-**	**49**	**-**	**-**	**7,664**	**3,337**	**4,327**	**-**	**-**	**-**	**453**	**4,780**

Table 3-4: Building 2 Evaluation Controls Inputs and kWh Savings

Building 2	A	B	C	D=A*B /1000	E=C*D	F	G	H	I=D*F*G* 0.8/H	J=E+I
Space Type	**Installed Quantity**	**Installed Watts per Fixture**	**Annual Hours Reduction**	**Connected kW**	**kWh Controls Savings**	**Percent of Space Cooled**	**Annual Cooling Hours Reduction**	**Cooling COP**	**Interactive Cooling Savings**	**Total kWh Controls Savings**
Office	1	10	672	0.01	7	100%	271	2.9	1	7
Office	16	26	672	0.42	280	100%	271	2.9	32	311
Office	1	9.8	672	0.01	7	100%	271	2.9	1	7
Office	3	13	672	0.04	26	100%	271	2.9	3	29
Office	3	52	672	0.16	105	100%	271	2.9	12	117
Conf room	4	52	720	0.21	150	100%	290	2.9	17	167
Lounge	2	26	840	0.05	44	100%	336	2.9	5	49
Total	**30**	**-**	**-**	**0.89**	**617**	**-**	**-**	**-**	**70**	**688**

Explanation of Differences

The significant factors that affect this project's energy-saving are changes observed in the fixture wattage and operating hours. The table below highlights the values used to calculate both the applicant's and evaluator's energy saving values.

Table 3-5 and Table 3-6 provides a summary of the differences between tracking and evaluated values. Table 3-5 summarizes the installed fixture wattages differences that were found, while Table 3-6 summarizes the impact of the discrepancies between the application and evaluation savings.

Table 3-5: Summary of Key Parameters

	Applicant				Evaluation			
Space Description	Fixture Annual Hours	Controls Annual Hours	Fixture Quantity	Proposed Watts per Fixture	Fixture Annual Hours	Controls Annual Hours	Fixture Quantity	Proposed Watts per Fixture
Office	2800	2128	1	45	2800	2128	1	52
Conf room	3000	2280	4	45	3000	2280	4	52
Office	2800	2128	6	24	2800	2128	6	26
Office	2800	2128	1	10	2800	2128	1	9.8
Office	2800	2128	1	24	2800	2128	1	26
Office	2800	2128	4	24	2800	2128	4	26
Office	2800	2128	1	11	2800	2128	1	10
Office	2800	2128	1	45	2800	2128	1	52
Office	2800	2128	1	24	2800	2128	1	26
Office	2800	2128	1	45	2800	2128	1	52
Office	2800	2128	2	24	2800	2128	2	26
Office	2800	2128	1	24	2800	2128	1	26
Office	2800	2128	1	24	2800	2128	1	26
Lounge	3500	2660	2	24	3500	2660	2	26
Stairwell	2500	N/A	1	10	2500	N/A	1	9.8
Stairwell	5000	N/A	1	11	5000	N/A	1	10
Storage	1500	N/A	3	24	1500	N/A	3	26
Kitchen	2500	N/A	1	16	2500	N/A	1	15
Office	2800	N/A	2	24	2800	N/A	2	26
Total	**-**	**-**	**35**	**-**	**-**	**-**	**35**	**-**

Table 5-6: Summary of Deviations

Building #	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
Building 1	HVAC Interaction	Electric Cooling	+6.0%	Increased savings –Inclusion of HVAC interactive cooling savings.
Building 2	Technology	Wattage	-0.05%	Decreased savings – Changes to the installed fixture wattages for 35 of the fixtures installed; including 27 that also received occupancy sensors through the program.
Building 2	HVAC Interaction	Electric Cooling	+0.1%	Increased savings –Inclusion of HVAC interactive cooling savings.

Ancillary Impacts

There are no fuel-based ancillary impacts associated with this project.

RICE19C036 Non-Lighting

Report Date: 6/2/21

Application ID(s)	9494449, 9209205, 8116694, 8116694

Project Type	C&I Retrofit	
Program Year	2019	
Evaluation Firm	DNV	
Evaluation Analysis Type	Full Evaluation Measurement & Verification (EM&V)	
Evaluation Engineer	Joe St. John	
Senior Engineer	Olav Hegland	

Evaluated Site Summary and Results

This evaluation report describes findings from evaluating 10 sampled non-lighting custom electric measures across 5 buildings at a university campus. These 10 sampled measures were drawn from a list of 40 energy efficiency measures installed across 30 buildings at this university campus that were claimed by the utility program in 2019. The projects were completed between 2017-2018.

DNV reviewed available data for these 10 sampled measures and determined that coupled with on-site spot measurements and verification, that sufficient post installation data existed from before the pandemic to justify full EM&V analysis. For some of the measures, the evaluators collected data through short-term meters including spot measurements to further support the longer-term data found in the supporting documentation that was associated with the tracking estimates.

The evaluation results are presented in Table 1-1. The overall realization rate for these 10 measures was found to be 93.8%.

Table 5-208. Evaluation Results Summary

Measure Number	PA Application ID	Measure Name		Annual Electric Energy (kWh)	% of Energy Savings On-Peak	Summer On-Peak Demand (kW)	Winter On-Peak Demand (kW)
1	9494449 , 9209205, 8116694, 8116694	Building 1, Recreational Building - Add Scheduling Controls to HV-1	Tracked	51,222	45.00%	11.14	2.96
			Evaluated - ops	12,834	3.15%	0.02	0.01
			Realization Rate	25%	7%	0%	0%
2	9494449 , 9209205, 8116694, 8116694	Building 1, Recreational Building - Add Scheduling Controls to HV-4	Tracked	10,069	45.00%	2.19	0.58
			Evaluated - ops	27,298	2.85%	2.95	1.75
			Realization Rate	271%	6%	135%	302%
3	9494449 , 9209205, 8116694, 8116694	Building 1, Recreational Building - Add Scheduling Controls to HV-2	Tracked	17,823	45.00%	3.87	1.03
			Evaluated - ops	10,622	-0.18%	0.00	-0.05
			Realization Rate	60%	0%	0%	-5%
4	9494449 , 9209205, 8116694, 8116694	Building 1, Recreational Building - Add Scheduling Controls to AC-3	Tracked	23,224	45.00%	5.05	1.34
			Evaluated - ops	8,912	11.72%	0.00	0.00
			Realization Rate	38%	26%	0%	0%

Measure Number	PA Application ID	Measure Name		Annual Electric Energy (kWh)	% of Energy Savings On-Peak	Summer On-Peak Demand (kW)	Winter On-Peak Demand (kW)
5	9494449 , 9209205, 8116694, 8116694	Building 2, Laboratory - Lab Ventilation Reduction	Tracked	77,377	45.00%	16.82	4.46
			Evaluated - ops	125,113	5.69%	0.00	0.00
			Realization Rate	162%	13%	0%	0%
6	9494449 , 9209205, 8116694, 8116694	Building 2, Laboratory - Modifications to MRI Chilled Water Supply	Tracked	30,397	45.00%	6.61	1.75
			Evaluated - ops	18,845	50.37%	2.15	3.31
			Realization Rate	62%	112%	33%	189%
7	9494449 , 9209205, 8116694, 8116694	Building 2, Laboratory - Thermostat Cover	Tracked	391	8.52%	0.02	91.82
			Evaluated - ops	92	59.19%	0.01	0.05
			Realization Rate	23 %	695%	55%	0%
8	9494449 , 9209205, 8116694, 8116694	Building 3, Research Office Building - Add Scheduling Controls to FCUs	Tracked	26,011	45.00%	5.65	1.50
			Evaluated - ops	18,195	63.19%	3.14	3.26
			Realization Rate	70%	140%	56%	217%
9	9494449 , 9209205, 8116694, 8116694	Building 4, Administrative/Office - Add Scheduling Controls to AHU-1, AHU-2, AHU-3	Tracked	8,231	45.00%	1.79	0.47
			Evaluated - ops	7,328	35.10%	0.50	0.51
			Realization Rate	89%	78%	28%	108%
10	9494449 , 9209205, 8116694, 8116694	Building 5, Administrative/Office - Add Scheduling Controls to 1 HP FCU	Tracked	3,251	45.00%	0.71	0.19
			Evaluated - ops	3,286	36.17%	0.34	0.34
			Realization Rate	101%	80%	49%	180%
	Totals Evaluated		**Tracked**	247,996		53.85	106.11

Measure Number	PA Application ID	Measure Name		Annual Electric Energy (kWh)	% of Energy Savings On-Peak	Summer On-Peak Demand (kW)	Winter On-Peak Demand (kW)
			Evaluated - ops	232,524		9.12	9.18
			Realization Rate	93.8%		16.9%	8.7%

Explanation of Deviations from Tracking

The measure which contributed most significantly to the low realization rate is measure 1 which had a low realization rate because the motor load factor of the motor on this fan scheduling measure was 56%, whereas the tracking calculations assumed a 100% motor load factor. Largely offsetting this reduction was the high realization rate of measure 5, which is a measure that involves reducing the air changes per hour (ACH) rate from 6 ACH to 4 ACH when no occupants are in the space. The reason for the discrepancy is that the tracking calculations assumed that the fan power reduction was linearly correllated to the CFM reduction, whereas the evaluator used the affinity law with 2.7 as the exponent. The other measure which contributed significantly to the realitively high realization rate was measure 2, which involved scheduling a 10 HP fan so that it would run fewer hours in the post-case than it did in the base case. The main reason for the discrepancy for this measure was due to an administrative error. For this measure, the tracking savings in the database were 10,069 kWh, but the supporting tracking calculations indicated 34,456 kWh of savings. The evaluator found 27,298 kWh worth of savings. Additional details on differences can be found in Section 0.

Recommendations for Program Designers & Implementers

There are no recommendations.

Customer Alert

There were no customer alerts. During the evaluation a motor metered in Building 1 for measure 1 was found to be operating on 2 phases. The customer put in a work order to repair the issue, but the customer service representative may want to follow-up.

Evaluated Measures

The measures evaluated as part of this report are described below:

6. **Building 1, Recreational Building - Add Scheduling Controls to HV-1**

   Reduce the operating hours from 168 hours per week (24/7) to 123 hours per week on a 15 HP supply fan named HV-1 which provides 21,000 cfm of air. Fan savings and cooling savings were claimed in the tracking calculations.

7. **Building 1, Recreational Building - Add Scheduling Controls to HV-4**

   Reduce the runtime of a 10 HP fan named HV-4 from 8,536 hours to 3,916 hours per year by adding scheduling controls. Only fan savings were claimed in the tracking calculations, not cooling savings.

8. **Building 1, Recreational Building - Add Scheduling Controls to HV-2**

   Reduce the runtime of 8 HP (includes supply and return fan) fans named HV-2 from 8,760 hours/year to 5,787 hours per year. Only fan savings were claimed in the tracking calculations, not cooling savings.

9. **Building 1, Recreational Building - Add Scheduling Controls to AC-3**

   Reduce operating hours of 5 HP, 3,700 CFM air handler named AC-3 from 168 hours per week (24/7) to 72 hours per week (9/7). Fan savings and cooling savings were claimed in the tracking calculations.

10. **Building 2, Laboratory - Lab Ventilation Reduction**

    Reduce minimum air changes in selected labs from 6 to 4 ACH when no occupants are in the space.

11. **Building 2, Laboratory - Modifications to MRI Chilled Water Supply**

    Replace 10-ton chiller serving MRI with a plate and frame heat exchanger which uses building chilled water. The 10-ton chiller will remain as a backup.

12. **Building 2, Laboratory - Thermostat Cover**

Install two thermostat face covers serving two unit heaters in the loading dock. Set the thermostats to 65 and lock the thermostat boxes to prevent any future adjustments.

13. **Building 3, Research Office Building - Add Scheduling Controls to FCUs**

    Reduce operating hours on 131 fractional HP fan coil units in 118 rooms from 16.5 hours/day x 365 days/year = 6,023 hrs/year to 4,552 hours per year. The tracking documentation indicates that fans will be reprogrammed to cycle off when satisfied during occupied hours, whereas previously, the fans would run 100% of the time during occupied hours. The total HP of the units is 12.796 HP. The calculations assume that motors are running at full load, which likely overestimates savings.

14. **Building 4, Administrative/Office - Add Scheduling Controls to AHU-1, AHU-2, AHU-3**

    Reduce fan runtime on (3) 0.75 HP supply fans from 8,760 hours per year to 6,161 hours per year by integrating this equipment into the BAS and cycling the fans off during unoccupied hours and during occupied hours when the setpoint is satisfied. There appears to be one fan per floor.

15. **Building 5, Administrative/Office - Add Scheduling Controls to 1 HP FCU**

    Install a programmable thermostat and BAS automation to control the boiler and FCU fan to operate on a time of day schedule/ temperature setpoint, rather than letting the fan run 8,760 hours per year. The FCU fan is a 1 HP, 3,400 CFM unit that operated 24/7 in the baseline, and operates approximately 16/7 in the post-case.

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.

Applicant Baseline and Installed Key Parameters

The applicant classified all the measures as a retrofit with a single baseline.

Table 5-209 shows the key baseline and post-case parameters used in the applicant's calculations.

Table 5-209. Applicant baseline and post-case key parameters

Measure Number	Measure Name	Baseline key Parameters	Post Key Parameters
1	Building 1, Recreational Building - Add Scheduling Controls to HV-1	15 HP 8,760 hrs/yr 100% Motor Load Factor	15 HP 6,396 hrs/yr 100% Motor Load Factor Cooling Savings = 29% of Fan Savings
2	Building 1, Recreational Building - Add Scheduling Controls to HV-4	10 HP 8,536 hrs/yr 100% Motor Load Factor	10 HP 3,916 hrs/yr 100% Motor Load Factor Cooling Savings = 0% of Fan Savings
3	Building 1, Recreational Building - Add Scheduling Controls to HV-2	8 HP 8,760 hrs/yr 100% Motor Load Factor	8 HP 5,787 hrs/yr 100% Motor Load Factor Cooling Savings = 0% of Fan Savings

Measure Number	Measure Name	Baseline key Parameters	Post Key Parameters
4	Building 1, Recreational Building - Add Scheduling Controls to AC-3	5 HP 8,760 hrs/yr 100% Motor Load Factor	5 HP 3,744 hrs/yr 100% Motor Load Factor Cooling Savings = 6% of Fan Savings
5	Building 2, Laboratory - Lab Ventilation Reduction	23,391 Supply Fan Occupied CFM 28,499 Exhaust Fan Occupied CFM 0.00120 Supply Fan kW/Supply Fan CFM 8,760 Occupied Hrs/Yr 0 Unoccupied Hrs/Yr 0.00090 Exhaust Fan kW/Exhaust Fan CFM 0.00061 Cooling kW/Supply Fan CFM	23,391 Supply Fan Occupied CFM 17,174 Supply Fan Unoccupied CFM 28,499 Exhaust Fan Occupied CFM 25,196 Exhaust Fan Unoccupied CFM 4,112 Occupied Hrs/Yr 4,648 Unoccupied Hrs/Yr 0.00120 Supply Fan kW/Supply Fan CFM 0.00090 Exhaust Fan kW/Exhaust Fan CFM 0.00061 Cooling kW/Supply Fan CFM
6	Building 2, Laboratory - Modifications to MRI Chilled Water Supply	14.5 GPM Flow Rate 9.0 ΔT Temperature Difference 688 MMBtu Chiller Load	10.3 GPM Flow Rate 10.3 ΔT Temperature Difference 383 MMBtu Chiller Load
7	Building 2, Laboratory - Thermostat Cover	3 Fan Coil Units 0.25 HP per Fan Coil 100% Motor Load Factor 1,783 Hrs/Yr	3 Fan Coil Units 0.25 HP per Fan Coil 100% Motor Load Factor 1,084 Hrs/Yr
8	Building 3, Research Office Building - Add Scheduling Controls to FCUs	131 Fan Coil Units 12.796 HP Total 100% Load Factor 6,023 Hrs/Yr	131 Fan Coil Units 12.796 HP Total 100% Load Factor 4,552 Hrs/Yr
9	Building 4, Administrative/Office - Add Scheduling Controls to AHU-1, AHU-2, AHU-3	3 indoor units of split system AHUs 0.75 HP per AHU 100% Motor Load Factor 8,760 Hrs/Yr	3 indoor units of split system AHUs 0.75 HP per AHU 100% Motor Load Factor 6,161 Hrs/Yr
10	Building 5, Administrative/Office - Add Scheduling Controls to 1 HP FCU	1 Fan Coil Unit 1 HP 100% Motor Load Factor 8,760 Hrs/Yr	1 Fan Coil Unit 1 HP 100% Motor Load Factor 5,840 Hrs/Yr

Applicant Energy Savings Algorithm

This section provides algorithms used in the applicant savings analysis files.

1 Building 1, Recreational Building - Add Scheduling Controls to HV-1

The applicant claimed both fan and cooling savings for this measure. An 8,760 approach was used by the applicant. The fan savings are due exclusively to reducing the fan operating hours from the baseline to the post period. The applicant cooling savings only account for the sensible ventilation cooling load reduction from no longer drawing in and needing to cool outdoor air during unoccupied hours.

$$Total\ Savings = Fan\ Savings + Cooling\ Savings$$

$$Fan\ Savings = Baseline\ Fan\ Energy - Post\ Fan\ Energy$$

$$Baseline\ Fan\ Energy = Motor\ HP\ \times 100\%\ Motor\ Load\ Factor\ \times 0.746 \frac{kW}{HP} \times Baseline\ Annual\ Operating\ Hours$$

$$Post\ Fan\ Energy = Motor\ HP\ \times 100\%\ Motor\ Load\ Factor\ \times 0.746 \frac{kW}{HP} \times Post\ Annual\ Operating\ Hours$$

$$Cooling\ Savings = Baseline\ Cooling\ Energy - Post\ Cooling\ Energy$$

$$Baseline\ Cooling\ Energy = \frac{Total\ CFM\ \times 0.075 \frac{lb}{ft^3} \times \frac{0.24Btu}{lb\ °F} \times 60 \frac{min}{hr} \times 1.2 \frac{kW}{ton}}{12{,}000 \frac{Btu}{ton \cdot hr}} \times \sum_{hour=}^{8{,}760} Outdoor\ Air\ \%\ \times (Outdoor\ Air\ Temp - Supply\ Air\ Temp)\ °F$$

$$Post\ Cooling\ Energy = \frac{Total\ CFM\ \times 0.075 \frac{lb}{ft^3} \times \frac{0.24Btu}{lb\ F} \times 60 \frac{min}{hr} \times 1.2 \frac{kW}{ton}}{12{,}000 \frac{Btu}{ton \cdot hr}} \times \sum_{hour=}^{8{,}760} Outdoor\ Air\ \%\ \times (Outdoor\ Air\ Temp - Supply\ Air\ Temp)\ °F$$

2 Building 1, Recreational Building - Add Scheduling Controls to HV-4

The applicant used the same calculation methodology described for measure 1 above but did not claim any cooling savings for this measure, only fan savings.

3 Building 1, Recreational Building - Add Scheduling Controls to HV-2

The applicant used the same calculation methodology described for measure 1 above but did not claim any cooling savings for this measure, only fan savings.

4 Building 1, Recreational Building - Add Scheduling Controls to AC-3

The applicant used the same calculation methodology described for measure 1 above. The applicant did claim cooling savings for this measure.

5 Building 2, Laboratory - Lab Ventilation Reduction

In the equations below, BL refers to baseline, and Pst refers to post-case.

$$Total\ Savings = Baseline\ Energy - Post\ Energy$$

$$Baseline\ Energy = BL\ Occ\ Energy\ + BL\ Unocc\ Energy$$

$$BL\ Occ\ Energy\ Use = BL\ Occ\ Supply\ Fan\ Energy + BL\ Occ\ Exhaust\ Fan\ Energy + BL\ Occ\ Cooling\ Energy$$

$$BL\ Unocc\ Energy\ Use = BL\ Unocc\ Supply\ Fan\ Energy + BL\ Unocc\ Exhaust\ Fan\ Energy + BL\ Unocc\ Cooling\ Energy$$

$$Post\ Energy = Pst\ Occ\ Energy\ + Pst\ Unocc\ Energy$$

$$Pst\ Occ\ Energy\ Use = Pst\ Occ\ Supply\ Fan\ Energy + Pst\ Occ\ Exhaust\ Fan\ Energy + Pst\ Occ\ Cooling\ Energy$$

$$Pst\ Unocc\ Energy\ Use = Pst\ Unocc\ Supply\ Fan\ Energy + Pst\ Unocc\ Exhaust\ Fan\ Energy + Pst\ Unocc\ Cooling\ Energy$$

$$BL\ Occ\ Supply\ Fan\ Energy = Supply\ Fan\ Occ\ CFM\ \times Supply\ Fan\ kW\ per\ Supply\ Fan\ CFM\ \times BL\ Occupied\ Hours$$

$$BL\ Unocc\ Supply\ Fan\ Energy = Supply\ Fan\ Unocc\ CFM\ \times Supply\ Fan\ kW\ per\ Supply\ Fan\ CFM\ \times BL\ Unoccupied\ Hours$$

$$BL\ Occ\ Exhaust\ Fan\ Energy = Exhaust\ Fan\ Occ\ CFM\ \times Exhaust\ Fan\ kW\ per\ Exhuast\ Fan\ CFM\ \times BL\ Occupied\ Hours$$

$$BL\ Unocc\ Exhaust\ Fan\ Energy = Exhaust\ Fan\ Unocc\ CFM\ \times Exhaust\ Fan\ kW\ per\ Exhaust\ Fan\ CFM \times BL\ Unoccupied\ Hours$$

$$BL\ Occ\ Cooling\ Energy = Supply\ Fan\ Occ\ CFM\ \times Cooling\ kW\ per\ Supply\ Fan\ CFM\ \times BL\ Occupied\ Hours$$

$$BL\ Unocc\ Cooling\ Energy = Supply\ Fan\ Unocc\ CFM\ \times Cooling\ kW\ per\ Supply\ Fan\ CFM\ \times BL\ Unoccupied\ Hours$$

$$Pst\ Occ\ Supply\ Fan\ Energy = Supply\ Fan\ Occ\ CFM\ \times Supply\ Fan\ kW\ per\ Supply\ Fan\ CFM\ \times Pst\ Occupied\ Hours$$

$$Pst\ Unocc\ Supply\ Fan\ Energy = Supply\ Fan\ Unocc\ CFM\ \times Supply\ Fan\ kW\ per\ Supply\ Fan\ CFM\ \times Pst\ Unoccupied\ Hours$$

$$Pst\ Occ\ Exhaust\ Fan\ Energy = Exhaust\ Fan\ Occ\ CFM\ \times Exhaust\ Fan\ kW\ per\ Exhuast\ Fan\ CFM\ \times Pst\ Occupied\ Hours$$

$$Pst\ Unocc\ Exhaust\ Fan\ Energy = Exhaust\ Fan\ Unocc\ CFM\ \times Exhaust\ Fan\ kW\ per\ Exhaust\ Fan\ CFM \times Pst\ Unoccupied\ Hours$$

$$Pst\ Occ\ Cooling\ Energy = Supply\ Fan\ Occ\ CFM\ \times Cooling\ kW\ per\ Supply\ Fan\ CFM\ \times Pst\ Occupied\ Hours$$

$$Pst\ Unocc\ Cooling\ Energy = Supply\ Fan\ Unocc\ CFM\ \times Cooling\ kW\ per\ Supply\ Fan\ CFM\ \times Pst\ Unoccupied\ Hours$$

$$Supply\ Fan\ kW\ per\ Supply\ Fan\ CFM = \frac{Supply\ Fan\ Full\ Flow\ CFM\ \times Supply\ Fan\ Full\ Flow\ Total\ Pressure \times 0.746\ kW/HP}{6{,}356 \frac{BHP}{CFM \cdot lb/in^2} \times 70\%\ Fan\ Efficiency \times 70\%\ Motor\ Efficiency}$$

$$Exhaust\ Fan\ kW\ per\ Exhaust\ Fan\ CFM = \frac{Exhaust\ Fan\ Full\ Flow\ CFM\ \times Exhaust\ Fan\ Full\ Flow\ Total\ Pressure \times 0.746\ kW/HP}{6{,}356 \frac{BHP}{CFM \cdot lb/in^2} \times 70\%\ Fan\ Efficiency \times 70\%\ Motor\ Efficiency}$$

The algorithms used by the applicant for this measure are shown below. The algorithms incorporate the ΔT and the flow rate (gpm) from the baseline and post-case, collected from the building automation system. The algorithm below is incorrect, because the source of savings from this measure comes from serving the MRI load by a more efficient cooling source. Rather than using the less efficient 10-ton air-cooled chiller, the facility is using the more efficient central chilled water plant. The equation should reflect a change to the chiller efficiency not the chiller load, which is what the tracking calculations show. The tracking calculation savings do not match (are 80% greater than) the database savings for this measure, so the tracking calculations shown below are not so important, since they do not actually produce the claimed savings for this measure.

$$Total\ Savings = Baseline\ Energy - Post\ Energy$$

$$Baseline\ Energy = \frac{0.13\frac{ft^3}{gallon} \times 62.4\frac{lb}{ft^3} \times 60\frac{min}{hr} \times 14.5\frac{gallon}{min} \times 9.0°F\Delta T \times 1.0\frac{Btu}{lb\cdot°F}}{3{,}412\frac{Btu}{hr}/kWh}$$

$$Post\ \ Energy = \frac{0.13\frac{ft^3}{gallon} \times 62.4\frac{lb}{ft^3} \times 60\frac{min}{hr} \times 10.3\frac{gallon}{min} \times 8.5°F\Delta T \times 1.0\frac{Btu}{lb\cdot°F}}{3{,}412\frac{Btu}{hr}/kWh}$$

7 Building 2, Laboratory - Thermostat Cover

$$Total\ Savings = Baseline\ Energy - Post\ Energy$$

$$Baseline\ Energy = Motor\ HP\ \times 100\%\ Motor\ Load\ Factor\ \times 0.746\frac{kW}{HP} \times Baseline\ Annual\ Operating\ Hours$$

$$Post\ Energy = Motor\ HP\ \times 100\%\ Motor\ Load\ Factor\ \times 0.746\frac{kW}{HP} \times Post\ Annual\ Operating\ Hours$$

8 Building 3, Research Office Building - Add Scheduling Controls to FCUs

The savings algorithms used in the tracking savings for this measure are the same algorithms shown in measure 7 above.

9 Building 4, Administrative/Office - Add Scheduling Controls to AHU-1, AHU-2, AHU-3

The savings algorithms used in the tracking savings for this measure are the same algorithms shown in measure 7 above.

10 Building 5, Administrative/Office - Add Scheduling Controls to 1 HP FCU

The savings algorithms used in the tracking savings for this measure are the same algorithms shown in measure 7 above.

Evaluation Assessment of Applicant Methodology

The evaluator assessment of the applicant methodology described below for each measure:

1. **Building 1, Recreational Building - Add Scheduling Controls to HV-1**

   The applicant calculations include cooling savings for this measure, but this unit provides heating only, furthermore, the unit's outside air damper is closed during unoccupied periods so the unit is strictly recycling air during unoccupied hours and not providing any cooling. Additionally, the applicant calculations overestimated fan savings by not including a motor load factor, implicitly assuming 100% load factor.

2. **Building 1, Recreational Building - Add Scheduling Controls to HV-4**

   The applicant calculations overestimated fan savings by not including a motor load factor, implicitly assuming 100% load factor. Besides this, the applicant calculation methodology is acceptable.

3. **Building 1, Recreational Building - Add Scheduling Controls to HV-2**

   The applicant calculations overestimated fan savings by not including a motor load factor, implicitly assuming 100% load factor. Besides this, the applicant calculation methodology is acceptable.

4. **Building 1, Recreational Building - Add Scheduling Controls to AC-3**

   The applicant calculations overestimated fan savings by not including a motor load factor, implicitly assuming 100% load factor. Besides this, the applicant calculation methodology is acceptable.

5. **Building 2, Laboratory - Lab Ventilation Reduction**

   The applicant calculations underestimated savings by assuming that fan energy use decreases linearly with a reduction in CFM, rather than following a relationship in accordance with the fan affinity laws.

6. **Building 2, Laboratory - Modifications to MRI Chilled Water Supply**

   The applicant calculations did not match the tracking database savings. The tracking calculations reviewed by the evaluators calculated the reduction in chiller load before and after the project, and converted that reduction in Btus directly to kWh, without using the baseline and/or post-case chiller's efficiency in kW/ton. The correct methodology for calculating the savings for this measure involve developing an estimated annual load profile (from a combination of baseline and post-case load data) and applying the baseline and post-case chiller efficiency values. The baseline chiller plant efficiency is of the 10-ton air-cooled chiller, and the post-case chiller plant efficiency is of the central, water cooled chillers, and auxiliary equipment.

7. **Building 2, Laboratory - Thermostat Cover**

   The applicant calculations overestimated fan savings by not including a motor load factor. Besides this, the applicant calculation methodology is acceptable.

8. **Building 3, Research Office Building - Add Scheduling Controls to FCUs**

   The applicant calculations overestimated fan savings by not including a motor load factor. Besides this, the applicant calculation methodology is acceptable.

9. **Building 4, Administrative/Office - Add Scheduling Controls to AHU-1, AHU-2, AHU-3**

   The applicant calculations overestimated fan savings by not including a motor load factor. Besides this, the applicant calculation methodology is acceptable.

10. **Building 5, Administrative/Office - Add Scheduling Controls to 1 HP FCU**

    The applicant calculations overestimated fan savings by not including a motor load factor. Besides this, the applicant calculation methodology is acceptable.

Onsite Metering

This section provides details on the tasks performed during the onsite visit. DNV installed meters and conducted an onsite verification of the system installed. The following section provides a summary of the findings.

Summary of Onsite Findings

DNV interviewed the facility staff and verified the equipment installed onsite. DNV completed an initial site visit on 4/8/21 to visually verify and collect data on select measures.

Table 5-34 shows the verification method and result for each of the ten measures evaluated within this report.

Table 5-210. Measure Verification

Measure Name	Verification Method	Verification Result
6) Building 1, Recreational	Take spot kW measurement of fan to gather motor load factor	Took a spot measurement, but phase 1 of the motor was not drawing any amps, which we confirmed

Measure Name	Verification Method	Verification Result
Building - Add Scheduling Controls to HV-1	on this constant volume fan. Review baseline and post runtime data available from BMS from before pandemic. Confirm motor horsepower.	with 2 different meters. Pre-COVID baseline and post runtime data confirmed that the unit was scheduled as intended by the measure. Motor was confirmed to be 15 HP as indicated in application.
7) Building 1, Recreational Building - Add Scheduling Controls to HV-4	Take spot kW measurement of fan to gather motor load factor on this constant volume fan. Review baseline and post runtime data available from BMS from before pandemic. Confirm motor horsepower.	During the site visit, we commanded this motor on to take a spot measurement (it was off when we arrived), but it would not come on. It appears that there may have been an issue with the starter. They called in a work-order to get this fixed. We did not factor this finding into the results, it appears to be a routine maintenance issue that they have put in a work order to address. This was confirmed to be a 10 HP motor. Pre-COVID baseline and post runtime data confirmed that the unit was scheduled as intended by the measure.
8) Building 1, Recreational Building - Add Scheduling Controls to HV-2	Take spot kW measurement of fan to gather motor load factor on this constant volume fan. Review baseline and post runtime data available from BMS from before pandemic. Confirm motor horsepower.	It was not possible to measure this motor safely according to the site contact and site electrician. This unit had no return fan, and the supply fan was 5 HP. There was an exhaust fan, but it was not running, even though the 5 HP supply fan for HV-2 was running. There was no nameplate available on the exhaust fan, and since the evaluator could not say one way or the other the 3 HP motor from the tracking calculations, the evaluator assumed that the 3 HP tracking value was correct. Pre-COVID baseline and post runtime data confirmed that the unit was scheduled as intended by the measure.
9) Building 1, Recreational Building - Add Scheduling Controls to AC-3	Take spot kW measurement of fan to gather motor load factor on this constant volume fan. Install amp meter for several weeks to confirm that data from BAS matches data from data collected by evaluators. Review baseline and post runtime data available from BMS from before pandemic. Confirm motor horsepower.	AC-3 was found to be a 3 HP motor, not a 5 HP motor as indicated in the tracking calculations. The site-contact confirmed that there were no return or exhaust fans for this units since the area being served was on the other side of the wall from the unit. During the spot measurement period, AC-3 drew an average of 1.77 kW, which corresponds to a mechanical output of 2.13 HP. This corresponds to a motor load factor of 2.13 output / 3 HP output nameplate = 71%. We left a logger to measure Amps on AC-3 for a longer period, to ensure that the trend data from the BAS matches data we collect with our own physical loggers, which we confirmed.
10) Building 2, Laboratory - Lab Ventilation Reduction	Install kW or amp loggers on supply and exhaust fans.	Not able to install any loggers for this measure, because the site contact stated it was too difficult to shut down the equipment at a lab building to install the meters, and it would be unsafe to do it without shutting them down. A review of the tracking documentation, and interview with the site-contact confirmed that the measure was installed and operating.
11) Building 2, Laboratory - Modifications to MRI Chilled Water Supply	Visual verification of new heat exchanger to send chilled water from the central chilled water plant to the MRI.	Evaluator visually verified the installation of the new heat exchanger and confirmed that the old 10-ton air-cooled chiller was not operating.
12) Building 2, Laboratory - Thermostat Cover	Visual verification of thermostat covers	Evaluator visually verified the installation of the thermostat covers.
13) Building 3, Research Office Building - Add Scheduling Controls to FCUs	Take spot measurements on a sample of the fan coil units to collect motor load factor information. Review baseline and post runtime data	None of the fan coil units were found to be running during the initial site visit, and we were unable to get any turned on then. However, we installed two kW loggers that we hoped would collect data when the fan coils did eventually turn on. When we

Measure Name	Verification Method	Verification Result
	available from BMS from before pandemic. Confirm motor horsepower.	returned, the fans still had not turned on – due to reduced operation during the COVID pandemic, but we were able to get them turned on. Data was collected on one of the fans, while the data collection failed on the other fan that was metered. Pre-COVID baseline and post runtime data confirmed that the unit was scheduled as intended by the measure. The motor HPs of the units we looked at matched the motor HP values indicated by the scope of work.
14) Building 4, Administrative/Office - Add Scheduling Controls to AHU-1, AHU-2, AHU-3	Take spot kW measurement of fans to gather motor load factor on this constant volume fan. Review baseline and post runtime data available from BMS from before pandemic. Confirm motor horsepower.	Took spot measurements on AHU-1's supply fan motor. Pre-COVID baseline and post runtime data confirmed that the units were scheduled as intended by the measure. The motor horsepower values were confirmed from the nameplate information collected.
15) Building 5, Administrative/Office - Add Scheduling Controls to 1 HP FCU	Review baseline and post runtime data available from BMS from before pandemic.	Pre-COVID baseline and post runtime data confirmed that the units were scheduled as intended by the measure. Spot measurements were not gathered on this measure because of limited time available during the site visit. Motor load factor information collected from other units was used to estimate the motor load factor for this measure.

Table 5-35 shows the loggers installed by the evaluators, the metering period, and the parameters they monitored.

Table 5-211. Evaluator Logger Information

Measure #	Data Logger Type	Parameter	Time Interval	Duration
1	DENT ELITEPro XC	Fan Motor kW	1-second	~2 minutes
4	DENT ELITEPro XC	Fan Motor kW	1-second	~2 minutes
4	HOBO Energy Logger Pro	Fan Motor Amps	5-minutes	4/8/21 – 5/13/21
8	DENT ELITEPro XC	Fan Motor kW	5-minutes	~30 minutes
9	DENT ELITEPro XC	Fan Motor kW	1-second	~2 minutes

Table 5-36 shows the trend data from the facility's BAS that was from before the COVID pandemic which were incorporated into the evaluator analyses and measure verifications.

Table 5-212. Trend Data Incorporated from Tracking Documentation

Measure #	Data Type	Parameter	Time Interval	Duration
1	BAS	Supply fan status, room temp, mixed air temp, discharge air temp.	15-mintute	Baseline data from 1/1/17 - 9/11/17 Post data from 9/13/17 -9/24/18
2	BAS	Supply fan status, room temp, mixed air temp, discharge air temp.	15-mintute	Baseline from 11/9/17 - 4/30/18 Post from 5/1/18 - 9/24/18
3	BAS	Supply fan status	15-mintute	Baseline from 5/1/17 – 9/20/17 Post from 9/21/17 – 12/27/17
4	BAS	Supply fan status, room temp, mixed air temp, discharge air temp.	15-mintute	Baseline from 1/1/17 – 8/31/17 Post from 9/1/17 – 12/31/17
5	BAS	Supply and exhaust airflow (CFM) for room 133A, 137A, 163A, 173A, 277A, 269A, 257A,	15-minute	Post data from 10/16/18-10/23/18

		337A ,373A, 281A, 365A, 435A, 445A, 459A, 465A, 471A, 477A		
6	BAS	Process CHWST, CHWRT, flow rate (gpm) to MRI Primary CHWST, CHWRT, flow rate (gpm) to building	15-minute	Baseline from 11/20/17 -12/20/17 Post from 12/23/18 - 2/10/19
8	BAS	Fan status/runtime data is available on 40 fan coil units	15-minute	Data from 1/1/16 to 8/27/18, which includes both pre and post data
9	BAS	Fan status/runtime data	15-minute	Post-case runtime data from 9/1/18 - 11/20/18
10	BAS	Fan status/runtime data	15-minute	Post-case runtime data from 10/15/18 - 11/13/18

1. **Building 1, Recreational Building - Add Scheduling Controls to HV-1**

Figure 5-61 shows the spot kW measurement taken on 4/8/21 on HV-1. It shows that phase 1 of the motor was drawing no amps. The two working phases of the motor drew a total of 5.01 kW, which corresponds to a motor load factor of 39%. As neither the fan speed nor its load had changed, we conclude that the motor power draw is representative despite the phasing issue. Had all three phases been working, they would each draw less current to deliver the same mechanical power.

Figure 5-61 HV-1 Spot Measured kW

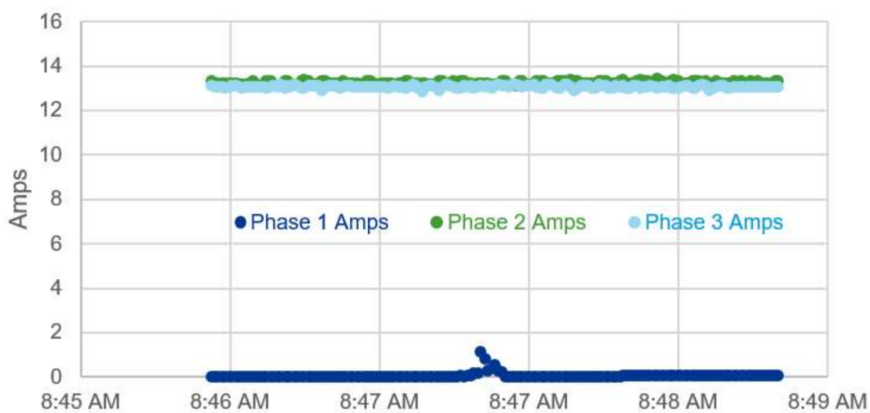


Figure 5-62 shows the baseline and post runtime profile data of HV-1 based on the data from the BAS.

Figure 5-62 HV-1 Baseline and Post Runtime Data by Day of Week and Hour of Day

Hour	Baseline Sun	Baseline Mon	Baseline Tue	Baseline Wed	Baseline Thu	Baseline Fri	Baseline Sat	Post Sun	Post Mon	Post Tue	Post Wed	Post Thu	Post Fri	Post Sat
0	1.00	1.00	0.98	1.00	1.00	1.00	1.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00
1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.02	0.00	0.00	0.01	0.04
2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.02	0.02	0.02	0.01	0.00	0.02	0.04
3	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.02	0.04	0.01	0.02	0.00	0.00	0.01
4	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.04	0.03	0.02	0.00	0.01	0.02	0.07
5	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.75	0.03	0.03	0.03	0.04	0.03	0.77
6	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	0.75	0.76	0.76	0.76	0.76	1.00
7	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	0.98	1.00	1.00	1.00	1.00	1.00
8	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	0.98	1.00	1.00	1.00	1.00	1.00
9	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	0.98	1.00	1.00	1.00	1.00	1.00
10	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	0.98	1.00	1.00	1.00	1.00	1.00
11	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	0.98	1.00	1.00	1.00	1.00	1.00
12	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	0.98	1.00	1.00	1.00	1.00	1.00
13	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	0.98	1.00	1.00	1.00	1.00	1.00
14	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	0.98	1.00	1.00	1.00	1.00	1.00
15	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	0.98	1.00	1.00	1.00	1.00	1.00
16	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	0.98	0.99	1.00	1.00	1.00	1.00
17	1.00	0.98	1.00	1.00	1.00	1.00	1.00	0.98	0.98	1.00	1.00	0.99	1.00	1.00
18	1.00	0.97	1.00	1.00	1.00	1.00	1.00	0.98	0.97	1.00	1.00	1.00	1.00	1.00
19	1.00	0.99	1.00	0.99	1.00	1.00	1.00	0.98	0.96	1.00	1.00	1.00	1.00	1.00
20	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	0.97	1.00	1.00	1.00	1.00	1.00
21	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	0.97	0.99	0.99	0.99	0.99	1.00
22	1.00	0.97	0.98	1.00	1.00	1.00	1.00	0.98	0.49	0.49	0.49	0.49	0.49	1.00
23	1.00	1.00	0.97	1.00	1.00	1.00	1.00	0.96	0.01	0.00	0.00	0.00	0.00	0.98

2. **Building 1, Recreational Building - Add Scheduling Controls to HV-4**

Figure 5-63 shows the baseline and post runtime profile data of HV-4 based on the data from the BAS.

Figure 5-63 HV-4 Baseline and Post Runtime Data by Day of Week and Hour of Day

Hour	Baseline Sun	Baseline Mon	Baseline Tue	Baseline Wed	Baseline Thu	Baseline Fri	Baseline Sat	Post Sun	Post Mon	Post Tue	Post Wed	Post Thu	Post Fri	Post Sat
0	0.84	0.90	0.86	0.74	0.78	0.74	0.79	0.07	0.17	0.29	0.26	0.23	0.20	0.12
1	0.89	0.97	0.97	0.79	0.85	0.83	0.89	0.08	0.19	0.18	0.10	0.05	0.10	0.10
2	0.89	0.97	0.94	0.81	0.94	0.85	0.91	0.12	0.19	0.24	0.14	0.10	0.10	0.14
3	0.90	0.97	0.94	0.88	0.95	0.87	0.95	0.15	0.19	0.24	0.14	0.10	0.12	0.14
4	0.92	0.96	0.98	0.86	0.97	0.87	0.94	0.17	0.23	0.32	0.17	0.11	0.14	0.14
5	0.97	1.00	1.00	0.97	1.00	0.98	0.98	0.26	0.39	0.54	0.38	0.39	0.29	0.18
6	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.38	0.44	0.61	0.52	0.50	0.40	0.19
7	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.36	0.51	0.60	0.63	0.65	0.62	0.39
8	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.38	0.63	0.70	0.63	0.75	0.70	0.40
9	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.46	0.88	0.87	0.81	0.80	0.83	0.50
10	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.40	0.74	0.75	0.73	0.73	0.63	0.55
11	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.33	0.74	0.69	0.62	0.69	0.62	0.50
12	1.00	0.99	1.00	1.00	1.00	1.00	1.00	0.33	0.63	0.60	0.60	0.63	0.68	0.49
13	1.00	0.96	1.00	1.00	1.00	1.00	1.00	0.33	0.51	0.48	0.49	0.62	0.63	0.56
14	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.35	0.50	0.43	0.50	0.49	0.58	0.58
15	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.31	0.53	0.42	0.60	0.40	0.37	0.58
16	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.36	0.46	0.43	0.69	0.44	0.45	0.54
17	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.40	0.65	0.61	0.92	0.68	0.56	0.39
18	1.00	0.98	1.00	1.00	1.00	1.00	1.00	0.44	0.71	0.69	0.81	0.68	0.71	0.38
19	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.43	0.70	0.74	0.80	0.67	0.68	0.33
20	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.35	0.64	0.54	0.58	0.64	0.61	0.30
21	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.33	0.43	0.39	0.37	0.44	0.36	0.14
22	1.00	1.00	1.00	1.00	1.00	0.98	1.00	0.35	0.34	0.32	0.27	0.38	0.23	0.14
23	0.92	1.00	1.00	1.00	0.97	0.96	0.94	0.36	0.78	0.81	0.62	0.80	0.19	0.12

3. **Building 1, Recreational Building - Add Scheduling Controls to HV-2**

Figure 5-64 shows the baseline and post runtime profile data of HV-2 based on the data from the BAS.

Figure 5-64 HV-2 Baseline and Post Runtime Data by Day of Week and Hour of Day

Hour	Baseline Sun	Baseline Mon	Baseline Tue	Baseline Wed	Baseline Thu	Baseline Fri	Baseline Sat	Post Sun	Post Mon	Post Tue	Post Wed	Post Thu	Post Fri	Post Sat
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.07	0.00	0.00	0.00	0.05	0.00
1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.05	0.07	0.00	0.00	0.00	0.00	0.00
2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.07	0.07	0.00	0.00	0.00	0.00	0.00
3	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.07	0.07	0.00	0.00	0.00	0.00	0.00
4	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.07	0.07	0.00	0.00	0.00	0.00	0.00
5	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.07	0.14	0.07	0.07	0.07	0.07	0.00
6	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.14	1.00	1.00	1.00	1.00	0.96	0.07
7	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
8	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
9	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
10	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
11	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
12	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
13	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
14	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
15	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
16	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
17	1.00	1.00	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
18	1.00	1.00	1.00	1.00	1.00	0.95	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
19	1.00	1.00	1.00	1.00	1.00	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
20	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
21	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
22	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.95	1.00	1.00	1.00
23	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.93	0.93	0.93	0.93	0.93	0.93	0.93

4. Building 1, Recreational Building - Add Scheduling Controls to AC-3

Figure 5-65 shows the spot measured kW collected by the evaluators for AC-3. During the spot measurement period, AC-3 drew an average of 1.77 kW, which corresponds to an input HP of 2.38 “electrical” HP, and a mechanical output HP of 2.38 HP x 89.5% efficiency = 2.13 HP. This corresponds to a motor load factor of 2.13 output HP / 3 HP nameplate = 71% on a 3 HP motor.

Figure 5-65 AC-3 Spot Measured kW

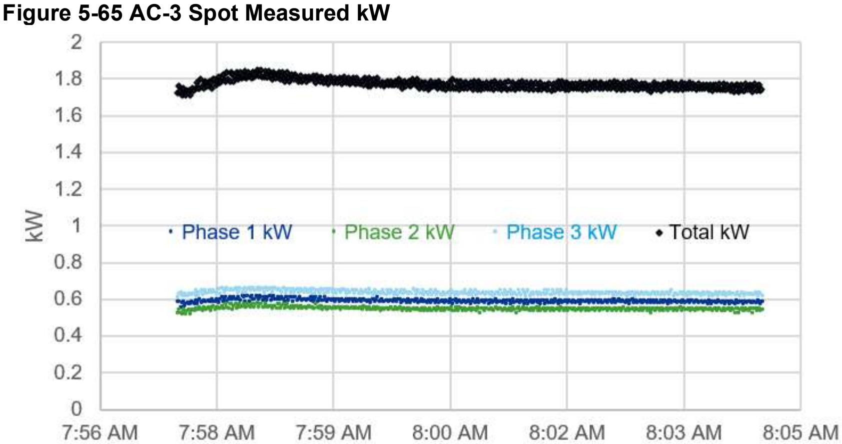


Figure 5-66 shows the evaluator collected amperage data which was used to verify that the BAS data lined up reasonably well with data collected using evaluator instrumentation.

Figure 5-66 AC-3 Evaluator Measured Amp Data

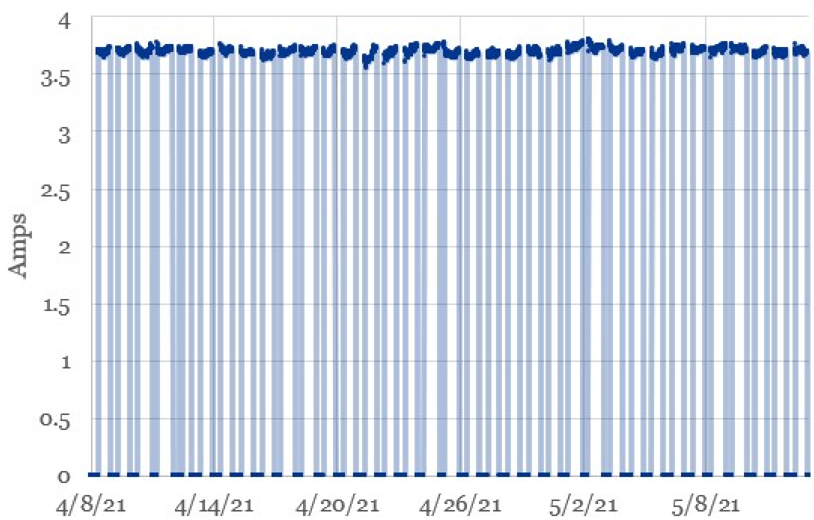


Figure 5-67 shows the baseline and post runtime profile data of AC-3 based on the data from the BAS (first two heat maps). The baseline fan status data from the BAS is from 1/1/17 – 8/31/17, and the post data on the fan status from the BAS is from 9/1/17 – 12/31/17. The third heat map shows amp data collected by the evaluators from 4/8/21-5/13/21. Figure 5-67 shows that the schedules have not changed significantly since the measure was implemented, and that the data from the BAS lines up with data collected by instrumentation used by the evaluators very closely. There appears to be a shift of one hour, which might be due to daylight savings time.

Figure 5-67 AC-3 Baseline and Post Runtime Data by Day of Week and Hour of Day from BAS, with Evaluator Collected Amp Data

	Baseline Fan Status							Post Fan Status							Post Amps 4/8/21 - 5/13/21						
Hour	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat
0	0.47	0.52	0.47	0.46	0.45	0.49	0.48	0.06	0.00	0.01	0.03	0.06	0.06	0.07	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.55	0.47	0.48	0.49	0.44	0.43	0.49	0.01	0.00	0.01	0.03	0.03	0.07	0.06	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.54	0.51	0.48	0.48	0.51	0.49	0.44	0.00	0.00	0.00	0.04	0.03	0.06	0.04	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.51	0.53	0.49	0.48	0.48	0.50	0.49	0.03	0.00	0.00	0.04	0.07	0.04	0.04	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.51	0.52	0.51	0.46	0.47	0.48	0.48	0.07	0.00	0.00	0.03	0.06	0.06	0.10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.52	0.47	0.51	0.47	0.49	0.49	0.43	0.53	0.00	0.00	0.03	0.07	0.06	0.53	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.54	0.52	0.53	0.47	0.46	0.49	0.48	0.51	0.04	0.00	0.12	0.13	0.13	0.54	2.6	0.0	0.0	0.0	0.0	0.0	2.6
7	0.45	0.55	0.51	0.45	0.53	0.47	0.49	0.44	0.54	0.62	0.63	0.56	0.56	0.54	3.1	0.0	0.0	0.0	0.0	0.0	3.1
8	0.53	0.51	0.45	0.46	0.47	0.49	0.54	0.44	0.71	0.62	0.57	0.62	0.53	0.51	3.1	3.1	3.1	2.8	2.8	2.6	3.1
9	0.49	0.57	0.55	0.51	0.50	0.57	0.52	0.40	0.57	0.69	0.50	0.54	0.63	0.57	3.1	3.7	3.7	3.1	3.2	3.1	3.1
10	0.55	0.56	0.65	0.56	0.46	0.65	0.50	0.46	0.53	0.66	0.63	0.54	0.54	0.53	3.1	3.7	3.7	3.1	3.1	3.1	3.1
11	0.46	0.54	0.66	0.61	0.52	0.63	0.55	0.47	0.50	0.72	0.57	0.65	0.60	0.51	3.4	3.4	3.7	3.1	3.1	3.1	3.1
12	0.54	0.61	0.64	0.59	0.52	0.56	0.52	0.38	0.47	0.74	0.60	0.60	0.58	0.47	3.7	3.7	3.7	3.1	3.1	3.1	3.1
13	0.46	0.61	0.57	0.55	0.54	0.63	0.58	0.43	0.47	0.59	0.63	0.59	0.65	0.38	3.7	3.7	3.7	3.1	3.1	3.1	3.1
14	0.46	0.55	0.54	0.67	0.55	0.54	0.56	0.35	0.50	0.46	0.74	0.49	0.43	0.28	3.7	3.7	3.7	3.1	3.1	3.1	3.1
15	0.51	0.67	0.60	0.69	0.51	0.59	0.59	0.32	0.81	0.60	0.87	0.49	0.79	0.28	3.7	3.7	3.7	3.1	3.1	3.1	3.1
16	0.52	0.78	0.63	0.73	0.47	0.57	0.54	0.43	0.78	0.82	0.91	0.49	0.79	0.36	3.7	3.7	3.7	3.1	3.1	3.1	3.1
17	0.50	0.76	0.58	0.72	0.44	0.54	0.58	0.32	0.74	0.81	0.91	0.49	0.79	0.39	3.7	3.7	3.7	3.1	3.1	3.1	3.1
18	0.52	0.68	0.59	0.71	0.46	0.41	0.54	0.35	0.74	0.62	0.87	0.44	0.56	0.38	3.7	3.7	3.7	3.1	3.1	3.1	3.1
19	0.50	0.69	0.46	0.71	0.44	0.46	0.51	0.38	0.63	0.41	0.90	0.38	0.40	0.36	3.7	3.7	3.7	3.1	3.1	3.1	3.1
20	0.54	0.63	0.44	0.71	0.46	0.48	0.58	0.46	0.65	0.38	0.85	0.38	0.39	0.39	3.7	3.7	3.7	3.1	3.1	3.1	3.1
21	0.53	0.50	0.45	0.51	0.51	0.47	0.54	0.35	0.19	0.15	0.34	0.24	0.15	0.35	3.7	3.7	3.7	3.1	3.1	3.1	3.1
22	0.51	0.46	0.47	0.44	0.46	0.42	0.54	0.40	0.00	0.04	0.04	0.03	0.00	0.28	3.7	0.6	0.6	0.5	0.5	0.5	3.1
23	0.53	0.49	0.51	0.46	0.44	0.53	0.57	0.07	0.00	0.06	0.03	0.01	0.07	0.06	3.4	0.0	0.0	0.0	0.0	0.0	2.9

Figure 5-68 shows the mixed air temperature data plotted against the outdoor air temperature data for AC-3, along with the linear correlation relationship between the two variables. This correlation was used by the evaluators to estimate the cooling savings for this measure.

Figure 5-68 AC-3 Mixed Air Temperature vs. Outdoor Air Temperature, Using Baseline and Post Data from BAS

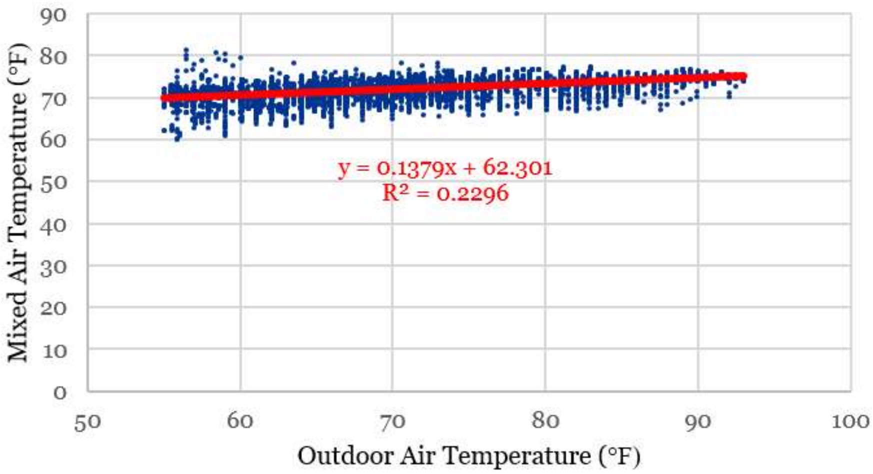
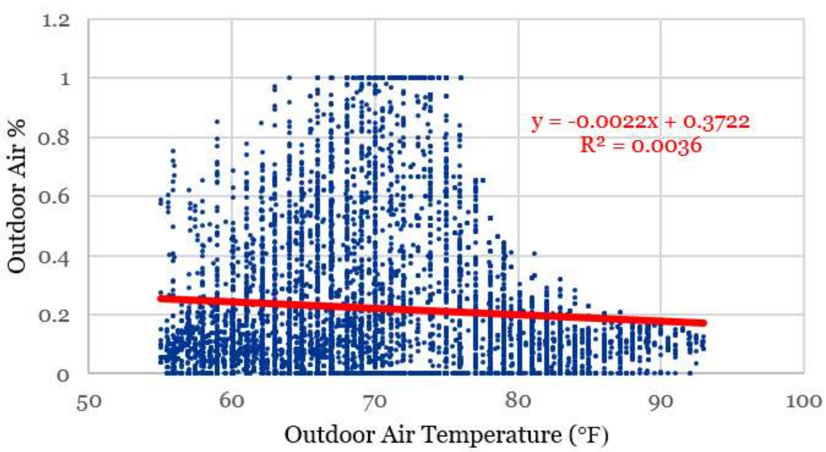


Figure 5-68 Figure 5-69 shows the outdoor air % data plotted against the outdoor air temperature data for AC-3, along with the linear correlation relationship between the two variables. This correlation was used by the evaluators to estimate the cooling savings for this measure.

Figure 5-69 AC-3 Outdoor Air % vs. Outdoor Air Temperature, Using Baseline and Post Data from BAS



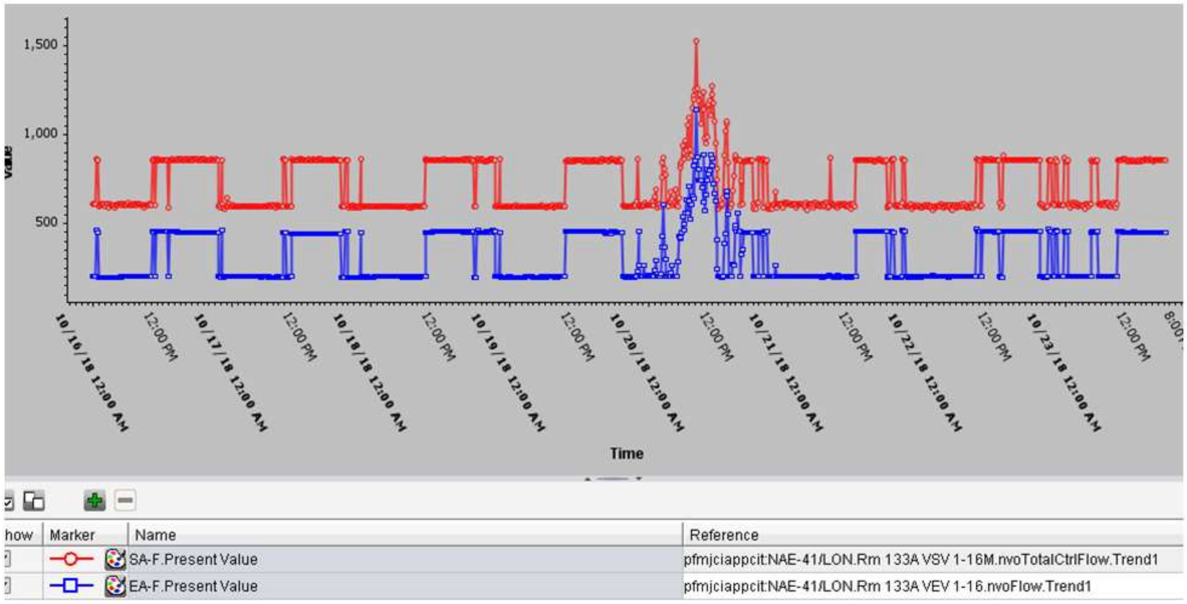
The outdoor air % was calculated from the BAS trend data from the following equation:

$$OA\% = Max\left[Min\left[\left(1 - \frac{Mixed\ Air\ Temp - Outdoor\ Air\ Temp}{Return\ Air\ Temp - Outdoor\ Air\ Temp}\right), 1\right], 0\right]$$

5. **Building 2, Laboratory - Lab Ventilation Reduction**

Figure 5-70 shows one week of post data for one of the labs that was involved in this project where the air changes per hour was reduced during unoccupied hours. This is an example of one of the 18 charts that the evaluators used to verify the installation and operation of this measure and was included in the tracking documentation.

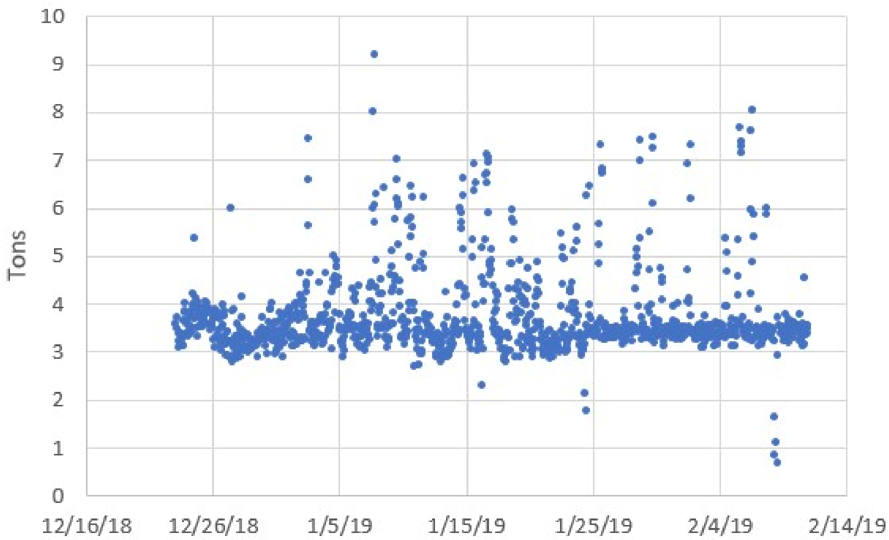
Figure 5-70 Supply and Exhaust Air Flow for Room 133A



6. Building 2, Laboratory - Modifications to MRI Chilled Water Supply

Figure 5-71 shows the MRI chiller load in tons collected from the BAS between 12/23/18 and 2/10/19. This data was collected from BAS measurements of the flow rates and temperature differences on either side of the heat exchanger, the process side, and chiller side. The loads on either side of the heat exchanger should have been approximately equal, but they were not, and it was not possible to determine which measurement may have been inaccurate. For this reason, the average load, from each side of the heat exchanger was calculated, and is what is shown in Figure 5-71. This is the load that was used in the evaluator calculations.

Figure 5-71 MRI Chiller Load



7. **Building 2, Laboratory - Thermostat Cover**

Figure 5-72 shows a photo of a thermostat cover that was taken as part of the verification for this measure. This thermostat cover was installed to prevent occupants from changing the thermostat, even if the garage doors were opened.

Figure 5-72 Photo of Thermostat Cover

8. **Building 3, Research Office Building - Add Scheduling Controls to FCUs**

Figure 5-73 shows the kW measurement that was collected on one of the FCU motors during the return visit on 5/13/21. This data was collected on a 1/6 HP motor that powered the fan coil. The data shows that the average kW was 0.0915 kW, which corresponds to a motor load factor of 55% (assuming a 75% motor efficiency for a 1/6 HP motor), compared to the tracking calculations which assumed a 100% motor load factor.

Figure 5-73 Room 205 FCU kW Measurement

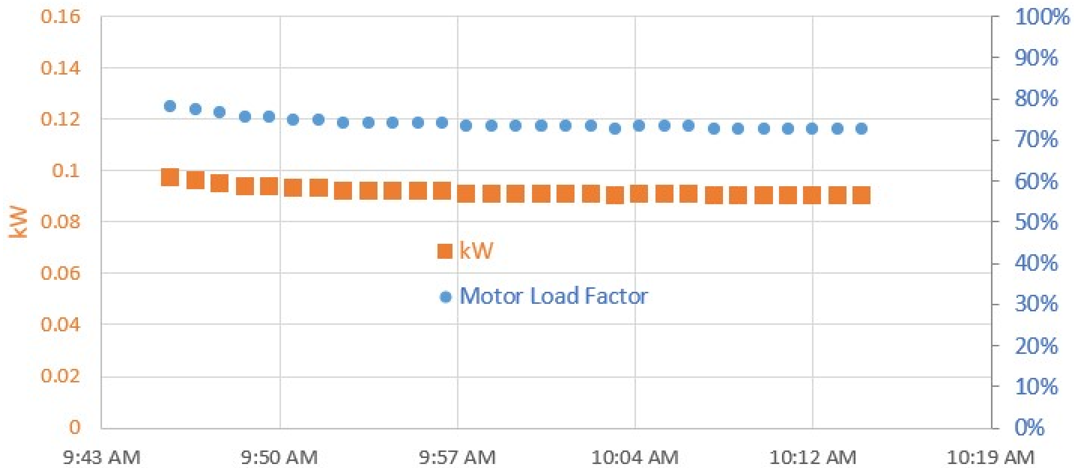


Figure 5-74 shows the baseline and post runtime data for FCU207, which was pulled from the BAS trend data prior to the COVID pandemic. This FCU had baseline and post case operating hours that were most similar to the overall average of the 40 FCUs for which baseline and post trend data were available. A document in the tracking folder indicates that this measure is to “reprogram the fans to cycle off when satisfied”. This appears to have happened based on reviewing the data shown in Figure 5-74. Data from this FCU (which was found to be most similar to the overall average of the 40 FCUs) was used to estimate the peak kW savings impact from the measure overall, after making an adjustment so that the savings using this profile would match the overall project savings.

Figure 5-74 FCU 207 Baseline and Post Runtime Data by Day of Week and Hour of Day

		Baseline Fan Status							Post Fan Status						
		Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat
Hour	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	7	0.72	0.72	0.72	0.72	0.71	0.72	0.72	0.54	0.49	0.57	0.55	0.51	0.52	0.53
	8	0.95	0.95	0.95	0.95	0.94	0.95	0.95	0.60	0.56	0.67	0.58	0.60	0.60	0.62
	9	0.94	0.95	0.94	0.95	0.94	0.95	0.95	0.61	0.58	0.59	0.57	0.59	0.59	0.52
	10	0.95	0.95	0.94	0.95	0.95	0.94	0.94	0.59	0.53	0.54	0.56	0.52	0.55	0.44
	11	0.95	0.95	0.94	0.95	0.95	0.95	0.95	0.53	0.57	0.66	0.55	0.55	0.61	0.57
	12	0.95	0.95	0.94	0.95	0.95	0.95	0.95	0.49	0.56	0.61	0.61	0.50	0.60	0.56
	13	0.95	0.95	0.95	0.96	0.95	0.95	0.95	0.51	0.51	0.44	0.49	0.48	0.52	0.44
	14	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.55	0.53	0.54	0.48	0.51	0.48	0.48
	15	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.53	0.56	0.57	0.54	0.58	0.50	0.50
	16	0.95	0.95	0.95	0.96	0.95	0.95	0.95	0.45	0.50	0.48	0.39	0.46	0.49	0.45
	17	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.46	0.54	0.49	0.49	0.43	0.49	0.44
	18	0.95	0.95	0.95	0.96	0.95	0.95	0.95	0.51	0.49	0.46	0.51	0.52	0.45	0.45
	19	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.41	0.44	0.47	0.37	0.51	0.46	0.49
	20	0.95	0.95	0.95	0.96	0.95	0.95	0.95	0.42	0.42	0.46	0.41	0.41	0.45	0.44
	21	0.95	0.95	0.95	0.96	0.95	0.95	0.95	0.43	0.45	0.49	0.45	0.50	0.43	0.41
	22	0.94	0.94	0.95	0.95	0.94	0.94	0.94	0.48	0.42	0.52	0.46	0.46	0.40	0.46
	23	0.47	0.47	0.47	0.48	0.47	0.47	0.47	0.19	0.16	0.22	0.20	0.20	0.19	0.21

9. **Building 4, Administrative/Office - Add Scheduling Controls to AHU-1, AHU-2, AHU-3**

Figure 5-75 shows the spot kW measurement taken on the 0.75 HP supply fan motor associated with AHU-1. The spot measured kW was 0.567 kW. This corresponds to a 0.76 HP input HP, which is equivalent to an 81%% motor load factor assuming an 80% motor efficiency. This 0.567 kW was used for AHU-2 and AHU-3 also.

Figure 5-75 Spot kW Measurement of AHU-1

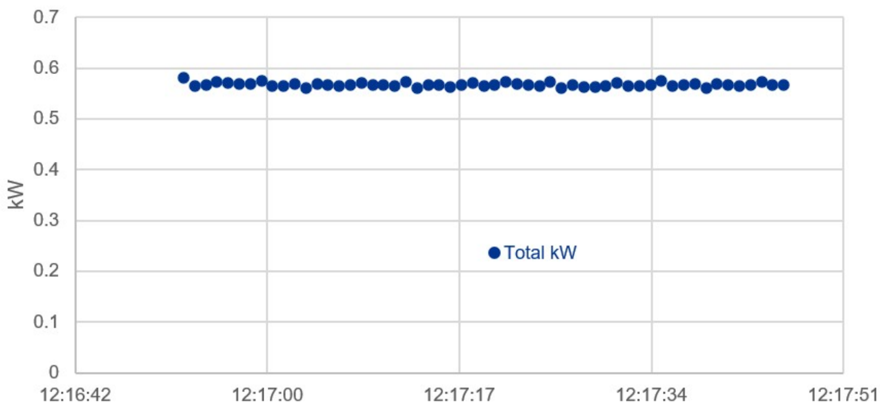


Figure 5-76 shows post runtime profiles of AHU-1, AHU-2, and AHU-3. Baseline data is not available from the BAS. The tracking documentation indicated that the supply fans ran 8,760 hours per year in the baseline period.

Figure 5-76 Post Runtime Data by Day of Week and Hour of Day for AHU-1, AHU-2, and AHU-3

	AHU-1 Post Fan Status						
Hour	Sun	Mon	Tue	Wed	Thu	Fri	Sat
0	0.00	0.01	0.00	0.00	0.06	0.03	0.00
1	0.00	0.04	0.00	0.00	0.00	0.03	0.00
2	0.00	0.03	0.00	0.00	0.11	0.06	0.00
3	0.00	0.03	0.00	0.00	0.10	0.10	0.00
4	0.00	0.11	0.00	0.00	0.09	0.07	0.06
5	0.23	0.25	0.30	0.25	0.32	0.21	0.17
6	0.49	0.55	0.53	0.43	0.62	0.49	0.36
7	0.51	0.63	0.40	0.41	0.63	0.56	0.45
8	0.56	0.59	0.53	0.53	0.60	0.56	0.45
9	0.62	0.54	0.59	0.55	0.61	0.58	0.47
10	0.62	0.53	0.55	0.58	0.70	0.57	0.49
11	0.61	0.60	0.51	0.59	0.70	0.58	0.59
12	0.61	0.60	0.51	0.68	0.77	0.56	0.62
13	0.60	0.59	0.51	0.66	0.87	0.54	0.63
14	0.59	0.61	0.48	0.68	0.92	0.48	0.62
15	0.59	0.61	0.45	0.65	0.92	0.61	0.63
16	0.58	0.59	0.45	0.67	0.92	0.67	0.61
17	0.58	0.58	0.47	0.66	0.92	0.64	0.62
18	0.59	0.51	0.45	0.72	0.91	0.59	0.61
19	0.59	0.51	0.45	0.74	0.91	0.58	0.60
20	0.16	0.13	0.12	0.19	0.24	0.13	0.15
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.06	0.00	0.00

	AHU-2 Post Fan Status						
Hour	Sun	Mon	Tue	Wed	Thu	Fri	Sat
0	0.00	0.20	0.14	0.08	0.00	0.00	0.00
1	0.00	0.22	0.14	0.08	0.00	0.00	0.00
2	0.00	0.20	0.14	0.07	0.00	0.00	0.00
3	0.00	0.20	0.14	0.08	0.00	0.00	0.00
4	0.00	0.21	0.14	0.08	0.00	0.00	0.00
5	0.70	0.74	0.70	0.15	0.57	0.57	0.58
6	0.57	0.68	0.84	0.71	0.84	0.69	0.45
7	0.83	0.84	0.90	0.77	0.60	0.76	0.66
8	0.81	0.90	0.91	0.62	0.61	0.85	0.88
9	0.85	0.80	0.94	0.55	0.69	0.84	0.79
10	0.90	0.91	0.62	0.32	0.49	0.73	0.89
11	0.67	0.65	0.57	0.55	0.86	0.82	0.54
12	0.69	0.30	0.75	0.33	0.83	0.53	0.51
13	0.70	0.80	0.76	0.68	0.71	0.22	0.48
14	0.69	0.84	0.74	0.84	0.77	0.50	0.60
15	0.55	0.94	0.69	0.78	0.81	0.56	0.49
16	0.61	0.89	0.78	0.80	0.79	0.67	0.47
17	0.62	0.81	0.82	0.67	0.83	0.53	0.47
18	0.48	0.73	0.90	0.83	0.85	0.46	0.46
19	0.57	0.86	0.92	0.93	0.79	0.49	0.47
20	0.22	0.25	0.21	0.21	0.18	0.06	0.11
21	0.14	0.16	0.08	0.12	0.00	0.00	0.00
22	0.16	0.18	0.08	0.00	0.00	0.00	0.00
23	0.14	0.18	0.07	0.00	0.00	0.00	0.00

	AHU-3 Post Fan Status						
Hour	Sun	Mon	Tue	Wed	Thu	Fri	Sat
0	0.67	0.60	0.59	0.64	0.65	0.57	0.46
1	0.63	0.59	0.59	0.64	0.66	0.56	0.47
2	0.67	0.59	0.59	0.65	0.65	0.57	0.47
3	0.59	0.60	0.59	0.65	0.65	0.55	0.48
4	0.59	0.60	0.60	0.66	0.66	0.57	0.53
5	0.78	0.71	0.70	0.71	0.80	0.70	0.60
6	0.84	0.75	0.73	0.74	0.81	0.74	0.68
7	0.84	0.76	0.76	0.74	0.81	0.68	0.67
8	0.84	0.76	0.76	0.74	0.82	0.68	0.68
9	0.80	0.77	0.84	0.74	0.89	0.66	0.66
10	0.86	0.76	0.84	0.74	0.86	0.64	0.67
11	0.90	0.76	0.77	0.75	0.81	0.64	0.73
12	0.92	0.76	0.76	0.74	0.81	0.72	0.76
13	0.86	0.81	0.75	0.74	0.82	0.73	0.77
14	0.81	0.76	0.74	0.73	0.82	0.75	0.84
15	0.83	0.76	0.73	0.74	0.74	0.68	0.84
16	0.75	0.75	0.74	0.73	0.73	0.64	0.84
17	0.76	0.76	0.73	0.74	0.73	0.64	0.84
18	0.76	0.76	0.73	0.73	0.70	0.65	0.84
19	0.76	0.76	0.73	0.73	0.65	0.66	0.84
20	0.66	0.59	0.64	0.66	0.57	0.53	0.68
21	0.64	0.59	0.65	0.64	0.56	0.51	0.68
22	0.59	0.58	0.64	0.64	0.55	0.48	0.67
23	0.59	0.59	0.65	0.64	0.57	0.49	0.68

10. **Building 5, Administrative/Office - Add Scheduling Controls to 1 HP FCU**

Figure 5-77 shows post runtime profiles of the 1 HP FCU affected by this measure. Baseline data is not available. The tracking documentation indicated that the supply fans ran 8,760 hours per year in the baseline period. Spot measurements of the kW were not collected for this measure to update the 100% motor load factor used in the tracking calculations. A motor load factor of 79% was used (in reference to the motor load factor measured for AC-3 from measure 4 of this report).

Figure 5-77 Post Runtime Data by Day of Week and Hour of Day for FCU Affected by Measure

Hour	Post Fan Status						
	Sun	Mon	Tue	Wed	Thu	Fri	Sat
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.78	0.84	0.84	0.77	0.71	0.78	0.69
7	0.77	0.74	0.76	0.67	0.71	0.75	0.64
8	0.65	0.69	0.59	0.58	0.65	0.68	0.58
9	0.68	0.67	0.56	0.53	0.58	0.64	0.58
10	0.66	0.70	0.42	0.55	0.59	0.67	0.58
11	0.62	0.64	0.31	0.53	0.49	0.44	0.57
12	0.70	0.57	0.33	0.54	0.52	0.42	0.55
13	0.63	0.43	0.28	0.46	0.43	0.49	0.53
14	0.63	0.40	0.19	0.51	0.44	0.48	0.49
15	0.56	0.46	0.26	0.38	0.49	0.50	0.55
16	0.58	0.56	0.22	0.39	0.51	0.53	0.49
17	0.55	0.46	0.37	0.42	0.51	0.43	0.49
18	0.60	0.38	0.38	0.43	0.46	0.42	0.46
19	0.58	0.57	0.40	0.43	0.53	0.41	0.50
20	0.57	0.53	0.51	0.42	0.58	0.44	0.49
21	0.57	0.51	0.47	0.46	0.59	0.53	0.54
22	0.20	0.11	0.19	0.13	0.17	0.13	0.19
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Evaluation Methods and Findings

Evaluation Description of Baseline

The evaluator reviewed the project files and interviewed the site contact to gather information on the baseline. DNV determined the all the measures are retrofit and using existing conditions as the baseline is appropriate.

Evaluation Calculation Method

This section describes the calculation methods used by the evaluators.

1 Building 1, Recreational Building - Add Scheduling Controls to HV-1

$$Total\ Savings = Baseline\ Energy - Post\ Energy$$

$$Baseline\ Energy = \ MotorkW \times Baseline\ Annual\ Operating\ Hours$$

$$Post\ Energy = \ MotorkW \times Post\ Annual\ Operating\ Hours$$

The motor HP was verified during the site visit. The motor power was measured during the site visit. Only two legs of the motor were operating when the measurement was taken. However, if all three legs of the motor been functional, the same total kW likely would have been drawn, since the air horsepower load (pressure x airflow) is a function of the fan curve, and the system curve. The air horsepower would be the same whether a fan was driven by a 3 HP motor, or oversized, and driven by a 10 HP motor. For this reason, we believe the power would have been the same (or very similar) had all three phases of the motor been functional.

The baseline and post-case annual operating hours were estimated from the trend data including in the tracking documentation from the BAS, from before the COVID pandemic. No cooling savings were claimed by the evaluator, even though cooling savings were claimed for this measure by the applicant, because the applicant indicated that this unit provides heating only, no cooling. Additionally, post case data showed that during the unoccupied hours that the fan was running, the outside air damper was 100% closed, whereas it was open during occupied hours when the fan was on. For this reason, during unoccupied hours, it is reasonable to assume that in the baseline, the unit was not bringing in any outdoor air that needed to be cooled, it was just recirculating air, and providing heat if necessary. Therefore the evaluator is not ascribing any cooling savings for this measure.

2 Building 1, Recreational Building - Add Scheduling Controls to HV-4

The same calculation methodology that was used for measure 1 was used for this measure also.

However, a motor load factor of 71% (assuming 89.5% motor efficiency) was used, based on data collected on AC-3 (measure 4). The applicant calculations assumed a 100% motor load factor. No cooling savings were claimed for this measure, for the same reason as described for measure 1, above.

3 Building 1, Recreational Building - Add Scheduling Controls to HV-2

The same calculation methodology that was used for measure 1 was used for this measure also.

However, a motor load factor of 71% was used (assuming 89.5% motor efficiency), based on data collected on AC-3 (measure 4). The applicant calculations assumed a 100% motor load factor. No cooling savings were claimed for this measure, for the same reason as described for measure 1, above.

4 Building 1, Recreational Building - Add Scheduling Controls to AC-3

The same calculation methodology that was used for measure 1 was used to calculate the fan savings portion of this measure. In addition to the fan savings, this measure also resulted in cooling savings.

$$Total\ Savings = Fan\ Savings + Cooling\ Savings$$

$$Fan\ Savings = Baseline\ Fan\ Energy - Post\ Fan\ Energy$$

$$Baseline\ Fan\ Energy = MotorkW \times Baseline\ Annual\ Operating\ Hours$$

$$Post\ Fan\ Energy = MotorkW \times Post\ Annual\ Operating\ Hours$$

The evaluators used a motor load factor of 79%, based on measurements of AC-3, rather than an assumed motor load factor of 100%, that were used in the applicant calculations.

$$Cooling\ Savings = Baseline\ Cooling\ Energy - Post\ Cooling\ Energy$$

$$Baseline\ Cooling\ Energy = \frac{Total\ CFM \times 0.075\frac{lb}{ft^3} \times 60\frac{min}{hr} \times 1.2\frac{kW}{ton}}{12{,}000\frac{Btu}{ton \cdot hr}} \times \sum_{hour=1}^{8{,}760} Outdoor\ Air\ \% \times (Outdoor\ Air\ Enthalpy - Supply\ Air\ Enthalpy)\ Btu/lb$$

$$Post\ Cooling\ Energy = \frac{Total\ CFM \times 0.075\frac{lb}{ft^3} \times 60\frac{min}{hr} \times 1.2\frac{kW}{ton}}{12{,}000\frac{Btu}{ton \cdot hr}} \times \sum_{hour=1}^{8{,}760} Outdoor\ Air\ \% \times (Outdoor\ Air\ Enthalpy - Supply\ Air\ Enthalpy)\ Btu/lb$$

The outdoor air percent was estimated using trend data from the BAS from data from February to December of 2017, using the following formula:

$$OA\% = Max\left[Min\left[\left(1 - \frac{Mixed\ Air\ Temp - Outdoor\ Air\ Temp}{Return\ Air\ Temp - Outdoor\ Air\ Temp}\right), 1\right], 0\right]$$

A regression relating OA% to outdoor air temperature was then developed, and that estimate for outdoor air percent was used in the equations shown above for baseline and post-case cooling energy.

The supply air enthalpy was assumed to be 22.87 Btu/lb, corresponding with 55° F, and 97% RH, corresponding to saturated air leaving the cooling coil. Cooling was assumed to occur for any temperature above 55°.

5 Building 2, Laboratory - Lab Ventilation Reduction

The same calculation that was used in the tracking documentation was used in the evaluator calculation. The only difference is that rather than assume fan power decreases linearly with decreasing CFM usage, the evaluators assumed that the fan power decreases in accordance with the fan affinity laws, using an affinity exponent of 2.7.

6 Building 2, Laboratory - Modifications to MRI Chilled Water Supply

The evaluator savings follow the algorithms shown below. The MRI is a process load, so there is no dependence on outdoor air temperature. The process load runs 8,760 hours/year, according to the BAS trend data on flow and ΔT. The site contact stated that the post-case chilled water plant efficiency was 0.80 kW/ton. The baseline chilled water plant efficiency was determined to be 1.29 kW/ton, based on reviewing the specification sheets for the old 10-ton air-cooled chiller, and corresponding with the manufacturer of that chiller.

$$Total\ Savings = Baseline\ Energy - Post\ Energy$$

$$Baseline\ Energy = \frac{Baseline\ Chiller\ Plant\ Efficiency\ \left(\frac{kW}{ton}\right) \times 0.13 \frac{ft^3}{gallon} \times 62.4 \frac{lb}{ft^3} \times 60 \frac{min}{hr}}{12{,}000 \frac{Btu}{ton \cdot hr}}\ x\ 1 \frac{Btu}{lbF}$$
$$\times \sum_{hour=1}^{8{,}760} Flow\ Rate\ \times (Chilled\ Water\ Return\ Temperature - Chilled\ Water\ Supply\ Temperature)$$

$$Post\ Energy = \frac{Post\ Chiller\ Plant\ Efficiency\ \left(\frac{kW}{ton}\right) \times 0.13 \frac{ft^3}{gallon} \times 62.4 \frac{lb}{ft^3} \times 60 \frac{min}{hr}}{12{,}000 \frac{Btu}{ton \cdot hr}}\ x\ 1 \frac{Btu}{lbF}$$
$$\times \sum_{hour=1}^{8{,}760} Flow\ Rate\ \times (Chilled\ Water\ Return\ Temperature - Chilled\ Water\ Supply\ Temperature)$$

Actual equation used is kW = sum(tons) * kW/ton where tons is from a data map of load data provided by the BAS based on time of day and day of week.

7 Building 2, Laboratory - Thermostat Cover

The evaluators used the same methodology that were used in the applicant calculations. The only differences are that the evaluators lowered the OAT at which heating would be activated from 85 to 70, and incorporated a motor load factor of 74%, whereas the tracking calculations assumed a motor load factor of 100%. The 74% motor load factor comes from the measured motor load factor for a similar, fractional HP FCU, that was evaluated (measure 8).

The equations used in the tracking calculations for estimating the operating hours are:

Pre hours = (5 hr/day * 365 d/yr) – (42 hr/yr when OAT >70F during those specific hours)

Post hours = (5 hr/day * 229 d/yr) – (62 hr/yr when OAT > 65F during those specific hours)

8 Building 3, Research Office Building - Add Scheduling Controls to FCUs

The evaluators used the same methodology that were used in the applicant calculations (see algorithms for measure 1 above). The only difference is that the evaluators incorporated a motor load factor of 74%, whereas the tracking calculations assumed a motor load factor of 100%. The 74% motor load factor comes from the measured motor load factor for one of the FCUs affected by this measure.

9 Building 4, Administrative/Office - Add Scheduling Controls to AHU-1, AHU-2, AHU-3

The evaluators used the same methodology that were used in the applicant calculations (see algorithms for measure 1 above). The only difference is that the evaluators incorporated a motor load factor of 101%, whereas the tracking calculations assumed a motor load factor of 100%. The 101% motor load factor comes from the measured motor load factor for the supply fan on AHU-1.

10 Building 5, Administrative/Office - Add Scheduling Controls to 1 HP FCU

The evaluators used the same methodology that were used in the applicant calculations (see algorithms for measure 1 above). The only difference is that the evaluators incorporated a motor load factor of 71%, whereas the tracking calculations assumed a motor load factor of 100%. The 71% motor load factor comes from the measured motor load factor for the supply fan on AC-3 from measure 4 above.

Final Results

Explanation of Differences

This section describes the differences in the key variables between the tracking and evaluator savings values.

Table 5-213 shows the values of the baseline and post key parameters used in the tracking and evaluator calculations.

Table 5-213. Summary of Tracking and Evaluator Baseline and Post Key Parameters

		Tracking		Evaluator	
Measure #	Measure Name	Baseline Key Parameters	Post Key Parameters	Baseline Key Parameters	Post Key Parameters
1	Building 1, Recreational Building - Add Scheduling Controls to HV-1	15 HP 8,760 hrs/yr 100% Motor Load Factor	15 HP 6,396 hrs/yr 2,364 hrs reduced 100% Motor Load Factor Cooling Savings = 29% of Fan Savings	15 HP 8,751 hrs/yr 39% Motor Load Factor	15 HP 6,187 hrs/yr 2,564 hrs reduced 39% Motor Load Factor Cooling Savings = 0% of Fan Savings (this unit has no cooling)
2	Building 1, Recreational Building - Add Scheduling Controls to HV-4	10 HP 8,536 hrs/yr 100% Motor Load Factor	10 HP 3,916 hrs/yr 4,620 hrs reduced 100% Motor Load Factor Cooling Savings = 0% of Fan Savings	10 HP 8,536 hrs/yr 79% Motor Load Factor	10 HP 3,919 hrs/yr 4,617 hrs reduced 79% Motor Load Factor Cooling Savings = 0% of Fan Savings
3	Building 1, Recreational Building - Add Scheduling Controls to HV-2	8 HP 8,760 hrs/yr 100% Motor Load Factor	8 HP 5,787 hrs/yr 2,973 hrs reduced 100% Motor Load Factor Cooling Savings = 0% of Fan Savings	8 HP 8,754 hrs/yr 79% Motor Load Factor	8 HP 6,508 hrs/yr 2,246 hrs reduced 79% Motor Load Factor Cooling Savings = 0% of Fan Savings

		Tracking		Evaluator	
Measure #	Measure Name	Baseline Key Parameters	Post Key Parameters	Baseline Key Parameters	Post Key Parameters
4	Building 1, Recreational Building - Add Scheduling Controls to AC-3	5 HP 8,760 hrs/yr 100% Motor Load Factor	5 HP 3,744 hrs/yr 5,016 hrs reduced 100% Motor Load Factor Cooling Savings = 6% of Fan Savings	3 HP 4,621 hrs/yr 79% Motor Load Factor	3 HP 3,201 hrs/yr 1,420 hrs reduced 79% Motor Load Factor Cooling Savings = 67% of Fan Savings
5	Building 2, Laboratory - Lab Ventilation Reduction	23,391 Supply Fan Occupied CFM 28,499 Exhaust Fan Occupied CFM 8,760 Occupied Hrs/Yr 0 Unoccupied Hrs/Yr 0.00120 Occupied Supply Fan kW/Supply Fan CFM 0.00090 Occupied Exhaust Fan kW/Exhaust Fan CFM 0.00120 Unoccupied Supply Fan kW/Supply Fan CFM 0.00090 Unoccupied Exhaust Fan kW/Exhaust Fan CFM 0.00061 Cooling kW/Supply Fan CFM	23,391 Supply Fan Occupied CFM 17,174 Supply Fan Unoccupied CFM 28,499 Exhaust Fan Occupied CFM 25,196 Exhaust Fan Unoccupied CFM 4,112 Occupied Hrs/Yr 4,648 Unoccupied Hrs/Yr 0.00120 Occupied Supply Fan kW/Supply Fan CFM 0.00090 Occupied Exhaust Fan kW/Exhaust Fan CFM 0.00120 Unoccupied Supply Fan kW/Supply Fan CFM 0.00090 Unoccupied Exhaust Fan kW/Exhaust Fan CFM 0.00061 Cooling kW/Supply Fan CFM	23,391 Supply Fan Occupied CFM 28,499 Exhaust Fan Occupied CFM 8,760 Occupied Hrs/Yr 0 Unoccupied Hrs/Yr 0.00120 Occupied Supply Fan kW/Supply Fan CFM 0.00090 Occupied Exhaust Fan kW/Exhaust Fan CFM 0.00120 Unoccupied Supply Fan kW/Supply Fan CFM 0.00090 Unoccupied Exhaust Fan kW/Exhaust Fan CFM 0.00061 Cooling kW/Supply Fan CFM	23,391 Supply Fan Occupied CFM 17,174 Supply Fan Unoccupied CFM 28,499 Exhaust Fan Occupied CFM 25,196 Exhaust Fan Unoccupied CFM 4,112 Occupied Hrs/Yr 4,648 Unoccupied Hrs/Yr 0.00120 Occupied Supply Fan kW/Supply Fan CFM 0.00090 Occupied Exhaust Fan kW/Exhaust Fan CFM 0.00071 Unoccupied Supply Fan kW/Supply Fan CFM 0.00073 Unoccupied Exhaust Fan kW/Exhaust Fan CFM 0.00061 Cooling kW/Supply Fan CFM

		Tracking		Evaluator	
Measure #	**Measure Name**	**Baseline Key Parameters**	**Post Key Parameters**	**Baseline Key Parameters**	**Post Key Parameters**
6	Building 2, Laboratory - Modifications to MRI Chilled Water Supply	688 MMBtu Chiller Load	383 MMBtu Chiller Load	392 MMBtu Annual Chiller Load 1.29 kW/ton chiller plant efficiency	392 MMBtu Annual Chiller Load 0.80 kW/ton post chiller plant efficiency
7	Building 2, Laboratory - Thermostat Cover	3 Fan Coil Units 0.25 HP per Fan Coil 100% Motor Load Factor 1,783 Hrs/Yr	3 Fan Coil Units 0.25 HP per Fan Coil 100% Motor Load Factor 1,084 Hrs/Yr	3 Fan Coil Units 0.25 HP per Fan Coil 74% Motor Load Factor 1,783 Hrs/Yr	3 Fan Coil Units 0.25 HP per Fan Coil 74% Motor Load Factor 1,084 Hrs/Yr
8	Building 3, Research Office Building - Add Scheduling Controls to FCUs	131 Fan Coil Units 12.796 HP Total 100% Load Factor 6,023 Hrs/Yr	131 Fan Coil Units 12.796 HP Total 100% Load Factor 4,552 Hrs/Yr 2,599 Hrs Saved	131 Fan Coil Units 12.796 HP Total 74% Load Factor 5,623 Hrs/Yr	131 Fan Coil Units 12.796 HP Total 74% Load Factor 3,038 Hrs/Yr 2,590 Hrs Saved
9	Building 4, Administrative/Office - Add Scheduling Controls to AHU-1, AHU-2, AHU-3	3 indoor units of split system AHUs 0.75 HP per AHU 100% Motor Load Factor 8,760 Hrs/Yr	3 indoor units of split system AHUs 0.75 HP per AHU 100% Motor Load Factor 6,161 Hrs/Yr 2,599 Hrs Saved	3 indoor units of split system AHUs 0.75 HP per AHU 101% Motor Load Factor 8,760 Hrs/Yr	3 indoor units of split system AHUs 0.75 HP per AHU 101% Motor Load Factor AHU-1: 3,245 Hrs/Yr AHU-2: 4,008 Hrs/Yr AHU-3: 6,101 Hrs/Yr 4,309 Hrs Saved

		Tracking		Evaluator	
Measure #	Measure Name	Baseline Key Parameters	Post Key Parameters	Baseline Key Parameters	Post Key Parameters
10	Building 5, Administrative/Office - Add Scheduling Controls to 1 HP FCU	1 Fan Coil Unit 1 HP 100% Motor Load Factor 8,760 Hrs/Yr	1 Fan Coil Unit 1 HP 100% Motor Load Factor 5,840 Hrs/Yr 2,920 Hrs Saved	1 Fan Coil Unit 1 HP 79% Motor Load Factor 8,760 Hrs/Yr	1 Fan Coil Unit 1 HP 79% Motor Load Factor 3,204 Hrs/Yr 5,556 Hrs Saved

Table 5-41 summarizes the adjustments that were made to the savings estimates for each measure, broken down by administrative adjustments (differences between tracking database values, and tracking calculator values), methodology differences, and operational differences. Operational differences are defined as differences driven by changes to variables within algorithms, based on observed data, whereas methodology adjustments are defined as differences driven by changes to the underlying algorithms themselves. There were no baseline adjustments, but an example of that would be changing from an in-situ baseline to a market, industry standard practice (ISP), or code baseline.

Table 5-214. Summary of Adjustment Factors by Measure

Measure #	Tracking Savings	Adjustment Factor				Evaluated Savings	Realization Rate	Comments
		Admin/ Tracking	Baseline	Methodology	Operational			
1	51,222	-23.1%			-67.4%	12,834	25.1%	Motor load factor, hour reduction changed
2	10,069	242.2%			-20.8%	27,298	271.1%	Motor load factor, hour reduction changed
3	17,823				-40.4%	10,622	59.6%	Motor load factor, hour reduction changed
4	23,224	-23.1%			-50.1%	8,912	38.4%	Motor load factor, hour reduction changed
5	77,377	1.3%		59.7%		125,113	161.7%	Used affinity factor of 2.7 rather than assume fan power reduces linearly with CFM reduction
6	30,397	78.3%		-65.2%		18,845	62.0%	Calculate reduction in chiller efficiency, not reduction in chiller load.
7	391				-76.5%	92	23.5%	Motor load factor changed
8	26,011	3.8%			-32.6%	18,195	69.9%	Motor load factor, hour reduction changed
9	8,231				-11.0%	7,328	89.0%	Motor load factor, hour reduction changed
10	3,251	-33.3%			51.5%	3,286	101.1%	Motor load factor, hour reduction changed
Total	**247,996**	**12.9%**	**0.0%**	**4.1%**	**-20.2%**	**232,524**	**93.8%**	

Ancillary impacts

No ancillary impacts were calculated for the projects analysed in this report.

RICE19C072

Report Date: April 13. 2021

Program Administrator	National Grid	
Application ID(s)	9764300, 10308605, 10309202, 8887850, 9897496, and 10343787	
Project Type	Retrofit	
Program Year	2019	
Evaluation Firm	DNV	
Evaluation Approach	Non-Ops only	
Evaluation Engineer	Laeng Khoun, Shaobo Feng	
Senior Engineer	Stephen Carlson, Srikar Kaligotla, Chad Telarico	

1.5 Evaluated Site Summary and Results

The evaluated project was implemented at a college campus in Providence, RI, and consists of ten different measures in six buildings within one application.

Due to the impacts of the COVID-19 pandemic, the campus is still in a considerably low occupancy and operation level. The evaluators could not apply operation adjustment to the energy saving analysis. However, the evaluators did conduct two site visits to verify both lighting and non-lighting measures were installed and operational. In addition, the evaluators requested BAS trend data on most of the non-lighting measures from site contact to verify the control strategy was in line with what was proposed.

Non-Lighting Part in Table 0-1:

Table 5-215. ECM Summary for Non-Lighting Measures

ECM Number	Application ID	Building (Type)	Measure Description	Tracking Savings kWh
1	9764300	Chiller Plant	New Premium Efficiency Magnetic Bearing Chiller with VFD	392,088
2	9764300	Chiller Plant	Condenser Water Temperature Set Point Programming	94,482
3	10308605	Lab + Classroom	Install New Lab Exhaust system with Variable Volume	192,703
4	10308605	Lab + Classroom	Make Up Air Units 1 &2 Discharge Air Temperature Set Point Programming	664
5	10308605	Lab + Classroom	Install New Lab Fume Hoods as Low Flow Models	181,149
6	10309202	Development Center	AHUs 3&4 Occupancy Control Programming	5,310
7	10309202	Development Center	AHUs 3&4 Demand Control Ventilation Programming	427
Total				866,823

A more detailed description of each measure is provided below.

- 9764300 – Chiller Plant

The existing chiller plant is supplying chilled water to satisfy the cooling demand for the whole campus.

1. New Premium Efficiency Magnetic Bearing Chiller with VFD

This measure included the installation a new 1,000-ton centrifugal chiller which would be used as the lead for the campus central chilled water loop and removed a pre-existing 350-ton chiller which was used for an ice storage system but had been de-activated and was to be removed. The proposed case was one high efficiency, magnetic bearing, water cooled centrifugal chiller with VFD controls which exceeded RI Energy Code efficiency standard(s). The design also included adding a new primary chilled water pump and a condenser water pump as well as two new two-cell cooling towers. Savings are derived from the higher efficiency from the proposed chiller. The total claimed savings for this measure are 392,088 kWh annually.

2. Condenser Water Temperature Set Point Programming

This measure provided programming which reset the new and existing chiller's condenser water supply temperature set point based on outdoor air wet bulb temperature. Electric savings result when proposed condenser water temperature is less than the baseline. The total claimed savings for this measure are 94,482 kWh annually.

The tracking program classification of both measures were New & Replacement Equipment with single baseline. The evaluators agreed that both measures were New & Replacement Equipment with single baseline.

- 10308605 – Lab + Classroom

This is an approximately 80,00 square feet building mainly used for classroom, office and laboratory. There was a phased in approach, construction of 35,000 square feet additional space and renovation of the existing 80,000 square feet work is still ongoing. The measures included in this evaluation plan are for the 45,000 square feet part of the work which have already been completed.

3. Install New Lab Exhaust system with Variable Volume

This measure proposed to install the new exhaust system to serve the new addition and some existing lab spaces. Note this building is separated into two parts (laboratory and vivarium) and each part is supplied by an individual exhaust system. This measure is for the exhaust system serving the laboratory space(s) only and sized to meet future planned expansion/addition. The proposed and installed case is for three 60-HP exhaust fans using variable speed drive control to modulate fan speed to maintain static pressure set point. The total claimed savings for this measure are 192,703 kWh annually.

4. Make Up Air Units (MAUs) 1 & 2 Discharge Air Temperature Set Point Programming

Provided programming which reset the new MAUs 1&2 discharge air supply temperature set point based on outdoor temperature. Electric savings result when proposed discharge air temperature set point is higher than baseline set point. The total claimed savings for this measure are 664 kWh annually.

5. Install New Lab Fume Hoods as Low Flow Models

This measure was to install low flow fume hoods in the third floor chemistry classroom area. It included the installation of 21 constant volume dynamic barrier (combination sash) low flow hoods designed at a lower constant exhaust volume with varying face velocity as a function of sash position. The combination sash would allow switching the position both horizontally and vertically to reduce the maximum face velocity thereby reducing the required fume hood airflow. Electric fan and cooling and hot water (Natural gas) heating savings result from less conditioned air (from MAUs 1&2) due to lower constant exhaust air flow from proposed hoods. The total claimed electric savings for this measure are 181,149 kWh annually.

The tracking program classification of all three measures was New Buildings & Major Renovation with single baseline and the evaluator agreed on that.

- 10309202 – Development Center

This is a multi-purpose building with 56,000 square feet, including a 15,481 square foot, two-court practice facility for men's basketball. It also features improvements for other student-athletes, including an Innovation Lab, an expanded Sports Medicine Center and a student-athlete fueling station.

6. AHUs 3&4 Occupancy Control Programming

Provided controlling for AHUs - 3&4 occupied/unoccupied mode using local automatic occupancy sensors (on spaces). Electric fan and cooling savings result from placing AHUs 3&4 in unoccupied mode when local sensors determine no one is in the space. The total claimed savings for this measure are 5,310 kWh annually.

7. AHUs 3&4 Demand Control Ventilation Programming

Provided controlling AHU- 3&4 minimum outdoor air flow using return air and local CO_2 sensors (on spaces). Electric fan and cooling savings result from reducing minimum air to AHUs 3&4 when CO_2 sensors determine spaces below CO_2 PPM set point. The total claimed savings for this measure are 427 kWh annually.

The tracking program classification of both measures as New Buildings & Major Renovation with single baseline and evaluator agreed on that.

Lighting Part in Table 5-216:

Table 5-216. ECM Summary for Lighting Measures

ECM Number	Application ID	Building (Type)	Measure Description	Tracking Savings kWh
1	8887850, 9897496	Recreation Center	Lighting Retrofit	525,414
2	10343787	Arena	Lighting Retrofit	13,995
Total				**539,401**

A more detailed description of each measure is provided below.

- 8887850, 9897496 – Recreation Center

This is a recreation center which includes gyms, classrooms, offices, dining halls, and pool areas. 1,067 lighting fixtures were proposed to be retrofitted with 997 LED lighting fixtures. Savings from occupancy sensors were claimed for some spaces. The total claimed savings from the project are 525,414 kWh per year.

- 10343787 – Arena

78 fixtures were proposed to be replaced with LEDs in the sports arena which includes locker rooms and hallways. Savings from occupancy controls were claimed for the hallway spaces. The total claimed savings from the project are 13,995 kWh per year. The lighting at this location was retrofitted to LEDs.

Based on a desk review and facility walk-through, the evaluated savings are more than the tracking reported savings due to HVAC interactivity in lighting measures, and tracking and administration errors. The primary source of discrepancies in non-lighting is attributed to an admin error. The primary source of discrepancies in lighting is attributed to additional savings from HVAC interactivity. Though the evaluation could did not further adjust for operational discrepancies due to the impact of the COVID-19 pandemic, this report will document the findings and evaluation efforts. Additionally, Table 5-217 below lists the results summarized by lighting and non-lighting measures.

Table 5-217. Evaluation Results Summary – Lighting and Non-lighting

PA Application ID	Measure Name		Annual Electric Energy (kWh)	% of Energy Savings On-Peak	Summer On-Peak Demand (kW)	Winter On-Peak Demand (kW)
Subtotal Lighting measures		Tracked	539,409	65%	82.5	83.6
		Evaluated	546,764	38%	88.0	82.4
		Realization Rate	107%	60%	107%	99%
Subtotal Non-lighting measures		Tracked	866,823	57%	89.0	10.02
		Evaluated	866,823	57%	68.9	30.1
		Realization Rate	100%	100%	77%	300%

1.5.1 Explanation of Deviations from Tracking

The reason causing the discrepancy in non-lighting measures is Excel equation error on ECM 4 and 5. The evaluator performed a desk review to review application documents and analysis and did not find other discrepancies in regard to baseline, or methodology. The primary reason causing discrepancy in lighting is attributed to HVAC interactivity and a minor documentation error. Further details regarding the project are presented in the following Sections.

1.5.2 Recommendations for Program Designers & Implementers

The evaluator recommends the implementers to update the energy saving calculation spreadsheet especially input parameters based on the post-install control setpoints. This is because the evaluators found discrepancy on duct static pressure setpoint between applicant saving and on-site findings.

1.5.3 Customer Alert

The customer requested to redact site-sensitive information in the site report.

1.6 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 measures below:

Chiller Plant

1. New Premium Efficiency Magnetic Bearing Chiller with VFD
2. Condenser Water Temperature Set Point Programming

Lab + Classroom

3. Install New Lab Exhaust system with Variable Volume
4. Make Up Air Units 1 &2 Discharge Air Temperature Set Point Programming
5. Install New Lab Fume Hoods as Low Flow Models

Development Center

6. AHUs 3&4 Occupancy Control
7. AHUs 3&4 Demand Control Ventilation

Recreation Center

8. Lighting

Arena

9. Lighting

1.6.1 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.

1.6.2 Applicant Description of Baseline

Chiller Plant

The applicant classified both measures in 9764300 – Chiller Plant as New & Replacement Equipment with single baseline, and all the measures in 10308605 – Lab + Classroom and 10309202 – Development Center as New Buildings & Major Renovation with single baseline.

The pre-existing chiller plant consisted of two (2) 1000- ton, water cooled centrifugal chillers with VSD and one 350-ton ice-making water cooled chiller which had been abandoned in place. All three chillers were served by two (2), open evaporative cooling towers (CT-5 and CT-6). Chilled water was distributed by three (3) primary chilled water pumps – two were lead (CHWP 5 & 6, one per chiller) with VFDs controlled to maintain a differential pressure set point, the third was back up only (CHWP-7). The pre-exiting condenser water was distributed by two (2) condenser water pumps – both were equipped with VFDs used to balance flow to chiller design requirement and were rotated based on time of use.

New Premium Efficiency Magnetic Bearing Chiller with VFD

The baseline would be one 1,000 ton water cooled centrifugal chiller without VFD which meets RI (IEEC 2012) Energy Code efficiency standard. The full and part load performance data for the chiller is as follows:

Full load = 0.6084 kW/ton

NPLV = 0.5118 kW/ton

The new chiller would be sequenced to meet the system load as the lead chiller, the two existing Daikin 1,000 ton chillers sequenced individually as lag chillers.

The new chiller would be connected to the chilled water system including new primary chilled water and condenser water pumps and cooling towers. All the new chilled water pump, condenser water pumps and cooling towers sizes and efficiency are same as existing pumps and cooling towers.

The central chilled water system is operating 24 hours per day, 7 days per week, year round to provide for space cooling loads and process loads which include various building labs, tele data and relatively small server rooms.

Condenser Water Temperature Set Point Programming

Baseline is programming cooling towers to provide a constant chiller condenser water entering temperature (70° F).

Lab + Classroom

Install New Lab Exhaust system with Variable Volume

The base case proposed project is three (3) new 60 HP strobic exhaust constant speed fans installed in parallel and used to exhaust lab areas. They are operating 24 hours per day, seven days per week, year round using inlet bypass valves on the exhaust fans to maintain an inlet plenum static pressure set point (2.5"wc ADJ). The bypass will allow exhaust air flow to modulate by maintaining flow through space and maintain required flow through the strobic fans to maintain required plume height while operating the fans at constant speed (60 Hz = 100% full design speed).

Make Up Air Units 1 &2 Discharge Air Temperature Set Point Programming

Baseline is programming MAU 1&2 energy recovery and cooling and heating coils to provide a constant discharge air temperature set point according to the outdoor air temperature in Table 5-218:

Table 5-218 MAU 1&2 Discharge Air Temperature Setpoint – Baseline

OAT	DAT Setpoint
>50°F	55°F
<50°F	62°F

Install New Lab Fume Hoods as Low Flow Models

The base case is installing 21 standard flow hoods designed at a constant exhaust volume with the face velocity rated at 100 FPM. All hoods operate 24 hours per day, seven days per week, year round.

Development Center

AHU-3 is serving new basketball courts and associated support areas; AHU-4 is serving new weight room.

AHUs 3&4 Occupancy Control

Time of Use scheduling programming to schedule occupied and unoccupied modes. Both AHUs occupied scheduled 5 am to 11 pm seven days per week, year round.

Occupied:

- When space thermostat in cooling mode (space temperature exceeds cooling set point of 74°F), the discharge air temperature (DAT) set point is 55°F (constant), except if space humidity (space humidistat) exceeds 58% RH, then DAT set point is 52°F.

- When space temperature thermostat in heating (space thermostat less than heating set point of 70°F), the discharge air temperature set point varies from 55°F to max of 100°F to maintain space temperature set point. Duct mounted hot water coils have their own T Stat. Hot water control valve modulated to maintain space temperature set point (70°F).

Unoccupied:

- Unit will turn on to maintain night set back set points (80°F cool, 55°F heat).

AHUs 3&4 Demand Control Ventilation

The baseline situation is based on the implementation of previous ECM above and set the minimum outdoor air flow is 1,000 cfm for AHU-3 and 400 cfm for AHU-4. Mixed air dampers modulate to provide minimum outdoor air whenever unit is NOT in economizer mode. The minimum cfm is calculated based on IECC 2021 table 403.3 as:

AHU-3: 0.3 cfm/ft^2 x 3,600 ft^2 = 1,080 cfm

AHU-4: 0.06 cfm/ft^2 x 1,520 ft^2 + 10 people/1,000ft^2 x 1,520 ft^2 x 20 CFM/person= 395 cfm

Recreation Center

The applicant classified the measure as a retrofit with the baseline as the existing condition. The baseline condition for the 1,067 fixtures was a mix of compact fluorescent, halogen, T5, and T8 fixtures. Annual operating hours were split into usage groups of 3285, 4381, 5997, 6362, and 8761 hours. The applicant documentation does not state what controls were present as a baseline condition.

Arena

The applicant classified the measure as a retrofit with the baseline as the existing condition. The baseline condition for the 78 fixtures was a mix of halogen, T5, and T8 fixtures. Annual operating hours were split into usage groups of 4171 and 6205 hours. The applicant documentation does not state what controls were present as a baseline condition.

Applicant Description of Installed Equipment and Operation

Chiller Plant

New Premium Efficiency Magnetic Bearing Chiller with VFD

Proposed installed chiller is one 1,000-ton, premium efficient, magnetic bearing chiller with VSD controls. The proposed chiller performance data is:

Full load = 0.6084 kW/ton

NPLV = 0.3366 kW/ton

The proposed case assumes the chiller plant is controlled and operated on the same operating schedule and set points as described in the baseline.

Condenser Water Temperature Set Point Programming

Proposed design would reset the condenser water temperature between 45°F and 85°F according to: ECWT set point = (OAT wb) + 5°F.

Lab + Classroom

Install New Lab Exhaust system with Variable Volume

The proposed case is three (3) new 60 HP strobic exhaust fans with VFD installed in parallel and used to exhaust lab areas. They are operating 24 hours per day, seven days per week, year round.

Program the VFDs to modulate the exhaust fan speed to maintain the inlet plenum static pressure (2.5" wc). And each individual fan VFD would modulate fan speed between minimum (32 Hz) and maximum (52 Hz). If below 32 Hz then program will shut off the fan with the most run hours. If above 52 Hz then program will enable (start) next fan with lowest run hours.

Make Up Air Units 1 &2 Discharge Air Temperature Set Point Programming

The proposed design would set the MAUs 1 and 2 discharge air temperature setpoint reset according to outdoor air temperature in Table 5-219 below:

Table 5-219. MAU 1&2 Discharge Air Temperature Setpoint – Proposed

OAT	DAT Setpoint
>65°F	55°F
<25°F	62°F

Install New Lab Fume Hoods as Low Flow Models

The proposed design includes installing low flow hoods. These hoods have both vertical and horizontal sashes to provide for safe operation at varying face velocities at specified vertical and horizontal sash height(s) and width(s).

Development Center

AHUs 3&4 Occupancy Control

Install two occupancy sensors, one in practice court area and one in weight room and connect them to BAS.

During the occupied hours, program new occupancy sensors to control its dedicated AHU (AHU-3 or 4) occupancy mode based on monitored space occupancy. If occupied, AHU is placed in occupied mode. If no occupancy sensed AHU is placed in unoccupied mode.

During the unoccupied hours, if occupancy is sensed, AHU is placed in occupied mode with a time limit of 1 hour (ADJ). If no occupancy sensed leave AHU in unoccupied mode.

AHUs 3&4 Demand Control Ventilation

Install one CO_2 sensor in each of these spaces: practice court area, weight room area, AHU-3 return air duct and AHU-4 return air duct.

Program AHU-3: Use area CO_2 sensor and return air sensor. If both sensors monitor CO_2 level < 800 PPM (ADJ), then modulate mixed air dampers for minimum outdoor air flow of 750 cfm. If either of CO_2 sensors are > 800 PPM move minimum outdoor air to 1,000 cfm, if either still > 800 PPM modulate mixed air damper up to 100% open (limit mixed air damper operation to ensure mixed air temperature > 45°F).

Program AHU-4: Use area CO_2 sensor and return air sensor. If both sensors monitor CO_2 level < 800 PPM (ADJ), then modulate mixed air dampers for minimum outdoor air flow of 300 cfm. If either of CO_2 sensors are > 800 PPM move minimum outdoor air to 400 cfm, if either still > 800 PPM modulate mixed air damper up to 100% open (limit mixed air damper operation to ensure mixed air temperature > 45°F).

Recreation Center

The applicant proposed installing 997 LED lighting fixtures to replace the existing fixtures. Annual operating hours were consistent with the baseline assumed hours for fixture usage groups. Occupancy controls were claimed for some spaces.

Arena

The applicant proposed installing 78 LED lighting fixtures to replace the existing fixtures. Annual operating hours were consistent with the baseline assumed hours for fixture usage groups. Occupancy controls were claimed for hallway spaces.

Applicant Energy Savings Algorithm

For all the measures below, the applicant calculated the savings using custom EXCEL spreadsheets bin hour analysis with NOAA hourly weather data from 2011 (TF Green Airport) (Providence, RI) in combination with trend data and screenshot of BAS control strategy. For each building, applicant considered the previous ECM proposed situation as the next ECM baseline situation and used individual tabs to calculate the energy consumption in different situations (baseline, ECM1 proposed, ECM2 proposed and so on)

Chiller Plant

New Premium Efficiency Magnetic Bearing Chiller with VFD

Condenser Water Temperature Set Point Programming

$$Chiller\ Plant\ Consumption = Occupied\ kWh + Unoccupied\ kWh$$

$$Occupied/Unoccupied\ kWh = \sum_{All\ bin\ hour} Hours \times Total\ kW$$

$$Total\ kW = Chiller\ kW + Cooling\ Tower\ Fan\ kW$$

Where,

- Chiller plant is running 24 hours per day, 7 days per week, year round. Occupied hours are 10 am to 6pm Mon – Sun, and unoccupied hours are 6pm – 10 am Mon – Sun.
- Chiller kW is based on the building load from trending data, which is a quadratic relation with outdoor air temperature when OAT is above 45°F db, and fixed 69.5 tons when OAT is below 45°F db.
- When OAT is less than 85°F, only single chiller is in operation (new chiller); when OAT is above 85°F, two 1,000 ton chillers (new one plus an old one) will share the load equally.
- Cooling tower fan kW is based on the equipment spec sheet applying with affinity law. The fan speed is decided by a regression result between outdoor air wet-blub temperature and fan speed.

Table 5-220 presents the input differences between baseline and proposed bin calculation:

Table 5-220.Applicant Baseline Summary – Chiller Plant

				Baseline	ECM-1	ECM-2	
OAT db	**Tons**	**% Full Load**	**ECWT**	**kW/ton**	**kW/ton**	**ECWT**	**kW/ton**
95.0	826.19	83% (two chillers)	81	0.554	0.489	81	0.489
90.0	692.04	69% (two chillers)	80	0.558	0.469	80	0.469
85.0	570.50	57% (two chillers)	76	0.532	0.403	76	0.403
80.0	923.18	92%	75	0.520	0.464	75	0.464
75.0	730.60	73%	73	0.524	0.415	73	0.388
70.0	563.27	56%	70	0.500	0.350	70	0.350
65.0	421.18	42%	70	0.548	0.340	64	0.285
60.0	304.34	30%	70	0.597	0.354	59	0.234
55.0	212.74	21%	70	0.683	0.396	55	0.191
50.0	146.39	15%	70	0.683	0.396	50	0.177
45.0	69.50	7%	70	0.760	0.650	46	0.190
<= 40	69.50	7%	70	0.760	0.650	45	0.190

Lab + Classroom

$$Total\ Consumption = Fan\ kWh + Cooling\ kWh$$

Heating consumption is not in consideration for this evaluation effort since this facility is heated by natural gas.

$$Fan/Cooling\ kWh = \sum_{All\ bin\ hours} Occupied\ Hours \times Total\ Occupied\ kW + \sum_{All\ bin\ hours} Unoccupied\ Hours \times Total\ Unoccupied\ kW$$

$$Total\ fan\ kW = Supply\ Fan\ kW + Exhaust\ Fan\ kW$$

$$Total\ cooling\ kW = \big((4.5 \times cfm\ \times (\ OA\ Btu/lb\ -\ DA\ Btu/lb)\ /\ 12{,}000\ Btu/ton \cdot hr) - Heat\ Recovery\ Ton\big) \times Chilled\ Plat\ Efficiency\ kW/ton$$

Where,

- Occupied hours are 6 am to 10pm Mon – Fri, 10am to 6pm Sat – Sun and unoccupied hours are rest of the time.
- The baseline Lab Exhaust (LEF 1-3) airflow (cfm) is based on regression curve from BAS trend data. The baseline make-up air flow was calculated by adjusting exhaust air flow by design offset (-0.1 cfm per square foot). BAS trend data for the make-up air fans was used to verify feasibility of supply air flow calculations.
- The central chilled water plant efficiency (kW/ton) from the previous central chilled water TA report (April 2019) was used in cooling calculations. (This resulted in erroneous double counting some savings because the efficiency of the chiller plant for both baseline and proposed should be the new plant efficiency. This is because the saving due to efficiency upgrade of the plant is already included in the chiller plant measure.)
- Equipment assumptions used in analysis were based on base/pre-retrofit case and proposed case exhaust fan, fume hood and make up air specifications and submittals provided by the operating personnel and manufacture representative.

Install New Lab Exhaust system with Variable Volume

$$Fan\ kW = Fan\ BHP \times 0.746 \div Motor\ Efficiency$$

The full load (100% speed) exhaust fan air flow reduction is based on the baseline and proposed equipment specification sheet:

$$Full\ Load\ Airflow\ Reduction = 17{,}256 - 8{,}073 = 9{,}183\ cfm$$

The applicant used BAS trend data for all three exhaust fans in 2019 to get a regression relationship between fan speed% and outside air temperature, then applied the coefficients to the OAT bin data to get the fan speed%. The bin static pressure is:

$$TSP = TSP_{Full\ Speed} \times \sqrt{Fan\ Speed\%}$$

Fan efficiency is based on the specification sheet attached to the spreadsheet and agrees with the applicant assumption.

$$BHP\ Fan = cfm\ per\ fan \times TSP \div (6{,}356 \times Fan\ Efficiency)$$

Table 5-221 presents the input differences between baseline and proposed bin calculation:

Table 5-221. Key Input Comparison – Exhaust Fans

	Baseline Exhaust Fans					Proposed Exhaust Fans				
OAT db	**% Speed**	**TSP**	**Efficiency**	**BHP/fan**	**BHP total**	**% Speed**	**TSP**	**Efficiency**	**BHP/fan**	**BHP total**
92.5	100%	8	0.65	32.7	98.2	58%	4.70	0.55	22.7	68.2
87.5	100%	8	0.65	32.7	98.2	60%	4.75	0.55	23.0	68.9
82.5	100%	8	0.65	32.7	98.2	61%	4.80	0.55	23.2	69.6
77.5	100%	8	0.65	32.7	98.2	62%	4.83	0.55	23.4	70.1
72.5	100%	8	0.65	32.7	98.1	62%	4.86	0.55	23.5	70.5
67.5	100%	8	0.65	32.7	98.1	63%	4.88	0.55	23.6	70.8
62.5	100%	8	0.65	32.7	98.1	63%	4.90	0.55	23.7	71.0
57.5	100%	8	0.65	32.7	98.1	64%	4.90	0.55	23.7	71.1
52.5	100%	8	0.65	32.7	98.2	64%	4.90	0.55	23.7	71.1
47.5	100%	8	0.65	32.7	98.2	63%	4.90	0.55	23.7	71.0
42.5	100%	8	0.65	32.7	98.2	63%	4.88	0.55	23.6	70.9
37.5	100%	8	0.65	32.8	98.3	63%	4.86	0.55	23.5	70.6
32.5	100%	8	0.65	32.8	98.3	62%	4.84	0.55	23.4	70.2
27.5	100%	8	0.65	32.8	98.4	61%	4.80	0.55	23.3	69.8
22.5	100%	8	0.65	32.8	98.4	60%	4.76	0.55	23.1	69.2
17.5	100%	8	0.65	32.8	98.5	59%	4.71	0.55	22.8	68.5
12.5	100%	8	0.65	32.9	98.6	57%	4.65	0.55	22.6	67.7

Make Up Air Units 1 &2 Discharge Air Temperature Set Point Programming

Electric consumption savings are from the cooling saving:

$$Occupied/Unoccupied\ kWh = \sum_{All\ bin\ hours} Hours \times Total\ Cooling\ kW$$

$$Cooling\ kW = (Coil\ Tons - HRU\ Recovered\ Tons) \times Plant\ kW/ton$$

$$Coil\ Tons = \left(Mixed\ Air\frac{Btu}{lb} - Discharge\ Air\frac{Btu}{lb}\right) \times 4.5 \times cfm \div 12000\ Btu/ton{\cdot}hr$$

Where,

- Mixed air enthalpy equal to the outdoor air enthalpy since it is 100% outside air.
- Maximum and minimum enthalpy is based on the psychrometric chart and others are assumed as linear relation between max and min.
- When OAT is above 70°F, heat recovery unit recovered 5 tons to the coil.
- Plant efficiency has considered the two ECMs implemented in the chiller plant.

Table 5-222 presents the input differences between baseline and proposed bin calculation:

Table 5-222. Key Input Comparison – MAU DAT Reset

	Baseline				Proposed			
OAT db	**Discharge Air Btu/lb**	**Coil Tons**	**HRU Recovered Tons**	**Net Tons**	**Discharge Air Btu/lb**	**Coil Tons**	**HRU Recovered Tons**	**Net Tons**
92.5	22.6	208.5	5.0	203.4	22.6	208.5	5.0	203.4
87.5	22.6	163.3	5.0	158.3	22.6	163.3	5.0	158.3
82.5	22.6	168.9	5.0	163.9	22.6	168.9	5.0	163.9
77.5	22.6	142.6	5.0	137.6	22.6	142.6	5.0	137.6
72.5	22.6	127.6	5.0	122.5	22.6	127.6	5.0	122.5
67.5	22.7	82.0	-	82.0	22.6	84.4	-	84.4
62.5	22.6	45.0	-	45.0	22.6	45.0	-	45.0
57.5	22.7	11.3	-	11.3	22.7	11.3	-	11.3
52.5	22.9	-		-	22.9	-		-
47.5	23.0				23.0			
42.5	23.1				23.2			
37.5	23.3				23.3			
32.5	23.4				23.5			
27.5	23.5				23.6			
22.5	23.9				23.9			

Install New Lab Fume Hoods as Low Flow Models

The supply fan airflow reduction is:

$$Supply\ Airflow\ Reduction = Exhaust\ Airflow\ Reduction - lab\ area \times 0.1\ cfm/SF\ supply\ air\ offset\ (to\ keep\ labs\ negative)$$

Where,

- Exhaust airflow reduction is 9,183 cfm from the measure above
- Lab area is 3,296 ft^2

Table 5-223 presents the input differences between baseline and proposed bin calculation:

Table 5-223.Key Input Comparison – Low Flow Fume Hoods

OAT db	cfm	Baseline Supply Air TSP	Efficiency	BHP	cfm	Proposed Supply Air TSP	Eff'y	BHP
92.5	50,078	7.7	71.0%	85.0	41,225	6.9	71.0%	63.5
87.5	50,059	7.7	71.0%	84.9	41,206	6.9	71.0%	63.4
82.5	50,044	7.7	71.0%	84.9	41,191	6.9	71.0%	63.4
77.5	50,033	7.7	71.0%	84.8	41,180	6.9	71.0%	63.4
72.5	50,026	7.7	71.0%	84.8	41,172	6.9	71.0%	63.3
67.5	50,022	7.7	71.0%	84.8	41,169	6.9	71.0%	63.3
62.5	50,022	7.7	71.0%	84.8	41,169	6.9	71.0%	63.3
57.5	50,026	7.7	71.0%	84.8	41,173	6.9	71.0%	63.3
52.5	50,034	7.7	71.0%	84.8	41,181	6.9	71.0%	63.4
47.5	50,046	7.7	71.0%	84.9	41,193	6.9	71.0%	63.4
42.5	50,062	7.7	71.0%	84.9	41,208	6.9	71.0%	63.4
37.5	50,081	7.7	71.0%	85.0	41,228	6.9	71.0%	63.5
32.5	50,105	7.7	71.0%	85.0	41,251	6.9	71.0%	63.5
27.5	50,132	7.7	71.0%	85.1	41,278	7.0	71.0%	63.6
22.5	50,163	7.7	71.0%	85.2	41,309	7.0	71.0%	63.7
17.5	50,198	7.7	71.0%	85.3	41,344	7.0	71.0%	63.7
12.5	50,236	7.7	71.0%	85.4	41,383	7.0	71.0%	63.8

Development Center

$$Total\ Consumption = Fan\ kWh + Cooling\ kWh$$

$$Fan/Cooling\ kWh = \sum_{All\ bin\ hours} Occupied\ Hours \times Total\ Occupied\ kW + \sum_{All\ bin\ hou} Unoccupied\ Hours \times Total\ Unoccupied\ kW$$

$$Total\ fan\ kW = Supply\ Fan\ kW$$

$$Total\ cooling\ kW = \left((4.5 \times cfm\ \times (\ OA\ Btu/lb\ -\ DA\ Btu/lb)\ /\ 12{,}000\ Btu/ton{\cdot}hr) - Heat\ Recovery\ Ton\right) \times Chilled\ Plat\ Efficacy\ (\frac{kW}{ton})$$

Where,

- Occupied hours are 5 am to 11 pm Mon – Sun. And unoccupied hours are rest of the time.
- The baseline AHU 3 & 4 airflow (cfm) is based on BAS trend data. The baseline AHU ventilation is based on constant minimum outdoor air per code whenever economizer is disabled.
- Plant efficiency has considered the two ECMs implemented in the chilled plant.

AHUs 3&4 Occupancy Control

Applicant assumed 25% estimated occupied time would be considered as the reduction to unoccupied hours by occupancy control.

AHUs 3&4 Demand Control Ventilation

The min OA is reduced from 1000 cfm to 750 cfm for AHU 3 and reduced from 400 cfm to 300 cfm for AHU 4.

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

Lighting Retrofit

The applicant used the National Grid Lighting tool to estimate the tracking savings. No savings from HVAC interactivity were claimed as part of this application. The savings are calculated using the formulas shown below:

$$Baseline\ Fixture\ kWh = \frac{Quantity_B * Wattage_{\boldsymbol{B}}}{1000} * Existing\ Operating\ Hours$$

$$Proposed\ Fixture\ kWh = \frac{Quantity_P * Wattage_{\boldsymbol{P}}}{1000} * Proposed\ Operating\ Hours$$

$$Control\ kWh\ Savings = Proposed\ Fixture\ kW\ * (Evaluated\ Operating\ Hours\ without\ controls - Evaluated\ EFL\ Operating\ Hours\ with\ controls)$$

$$Fixture\ kWh\ Savings = Baseline\ Fixture\ kWh - Proposed\ Fixture\ kWh$$

$$Total\ kWh\ Savings = Fixture\ kWh\ Savings + Control\ kWh\ Savings$$

Table 5-224 and Table 5-225 show the tracking system fixture inputs and savings calculations for the recreation center and arena, respectively.

Table 5-224. Tracking System Fixture Inputs and kWh Savings – Recreation Center

	A	B	C	D	E	F=A*B*E /1000	G=C*D*E/1000	H	I=F-G	J=H+I
Space Type	**Baseline Quantity**	**Baseline Watts per Fixture**	**Installed Quantity**	**Installed Watts per Fixture**	**Annual Hours**	**Baseline kWh**	**Installed kWh**	**Control kWh Savings**	**kWh Fixture Savings**	**Total kWh Fixture and Control Savings**
Usage Group D	14	100	14	9	4,381	6,133	552	0	5,581	5,581
Usage Group D	6	48	6	8	4,381	1,262	210	0	1,051	1,051
Usage Group A	3	112	3	52	8,761	2,944	1,367	0	1,577	1,577
Usage Group A	5	60	5	26	8,761	2,628	1,139	109	1,489	1,599
Usage Group A	24	28	24	13	8,761	5,888	2,733	656	3,154	3,810
Usage Group A	57	30	57	13	8,761	14,982	6,492	0	8,490	8,490
Usage Group A	0	65	0	8	8,761	0	0	0	0	0
Usage Group A	1	17	1	11	8,761	149	96	0	53	53
Usage Group A	52	59	52	26	8,761	26,879	11,845	2,843	15,034	17,877
Usage Group A	1	40	1	8	8,761	350	70	0	280	280
Usage Group A	19	40	19	13	8,761	6,659	2,164	0	4,494	4,494
Usage Group A	1	32	1	11	8,761	280	96	0	184	184
Usage Group A	13	24	13	13	8,761	2,733	1,481	0	1,253	1,253
Usage Group A	8	38	8	13	8,761	2,663	911	0	1,752	1,752
Usage Group B	5	112	5	52	6,362	3,563	1,654	0	1,909	1,909
Usage Group B	4	60	4	16	6,362	1,527	407	0	1,120	1,120
Usage Group B	185	60	185	26	6,362	70,622	30,603	40	40,019	40,059
Usage Group B	10	63	10	30	6,362	4,008	1,909	0	2,100	2,100
Usage Group B	6	53	6	33	6,362	2,023	1,260	0	763	763
Usage Group B	81	88	81	39	6,362	45,350	20,099	0	25,252	25,252
Usage Group B	35	224	35	52	6,362	49,880	11,579	2,779	38,301	41,080
Usage Group B	10	28	10	9	6,362	1,781	573	0	1,209	1,209
Usage Group B	26	28	26	13	6,362	4,632	2,150	516	2,481	2,997
Usage Group B	25	30	25	13	6,362	4,772	2,068	0	2,704	2,704
Usage Group B	0	123	0	55	6,362	0	0	0	0	0
Usage Group B	12	455	12	17	6,362	34,738	1,298	311	33,440	33,752
Usage Group B	15	455	15	100	6,362	43,423	9,543	0	33,879	33,879
Usage Group B	1	70	1	16	6,362	445	102	0	344	344
Usage Group B	10	70	10	26	6,362	4,454	1,654	0	2,799	2,799
Usage Group B	3	17	3	11	6,362	324	210	0	115	115
Usage Group B	0	52	0	24	6,362	0	0	0	0	0
Usage Group B	0	29	0	12	6,362	0	0	0	0	0
Usage Group B	8	59	8	15	6,362	3,003	763	0	2,240	2,240
Usage Group B	15	59	15	26	6,362	5,631	2,481	556	3,149	3,705

Usage Group B	37	40	37	13	6,362	9,416	3,060	0	6,356	6,356
Usage Group B	1	32	1	11	6,362	204	70	0	134	134
Usage Group B	52	32	52	15	6,362	10,587	4,963	1,191	5,624	6,815
Usage Group B	14	24	14	13	6,362	2,138	1,158	0	980	980
Usage Group B	5	38	5	13	6,362	1,209	414	0	795	795
Usage Group B	12	47	12	25	6,362	3,588	1,909	0	1,680	1,680
Usage Group B	4	20	4	6	6,362	509	153	0	356	356
Usage Group B	3	67	3	6	6,362	1,279	115	0	1,164	1,164
Usage Group B	30	177	30	78	6,362	33,784	14,888	0	18,896	18,896
Usage Group B	140	351	70	217	6,362	312,643	96,643	0	216,000	216,000
Usage Group B	36	68	36	8	6,362	15,575	1,832	0	13,743	13,743
Usage Group B	19	34	19	8	6,362	4,110	967	0	3,143	3,143
Usage Group B	4	140	4	52	6,362	3,563	1,323	0	2,240	2,240
Usage Group B	1	15	1	6	6,362	95	38	0	57	57
Usage Group B	1	54	1	6	6,362	344	38	0	305	305
Usage Group C	4	60	4	26	3,285	789	342	0	447	447
Usage Group C	6	88	6	39	3,285	1,735	769	0	966	966
Usage Group E	2	112	2	52	5,997	1,343	624	0	720	720
Usage Group E	17	63	17	30	5,997	6,423	3,059	0	3,364	3,364
Usage Group E	22	53	22	33	5,997	6,993	4,354	0	2,639	2,639
Usage Group E	2	88	2	39	5,997	1,056	468	0	588	588
Usage Group E	0	52	0	24	5,997	0	0	0	0	0
Usage Group E	0	29	0	12	5,997	0	0	0	0	0
Total	**1067**		**997**			**771,108**	**254,696**	**9,001**	**516,413**	**525,414**

Table 5-225. Tracking System Fixture Inputs and kWh Savings – Arena

	A	B	C	D	E	F=A*B*E /1000	G=C*D*E/1000	H	I=F-G	J=H+I
Space Type	**Baseline Quantity**	**Baseline Watts per Fixture**	**Installed Quantity**	**Installed Watts per Fixture**	**Annual Hours**	**Baseline kWh**	**Installed kWh**	**Control kWh Savings**	**kWh Fixture Savings**	**Total kWh Fixture Savings**
lockerrms	0	60	0	0	4,171	0	0	0	0	0
lockerrms	16	60	16	24.2	4,171	4,004	1,615	0	2,389	2,389
lockerrms	24	59	24	20.1	4,171	5,906	2,012	0	3,894	3,894
common	1	60	1	32.9	6,205	372	204	60	168	229
common	37	59	37	32.9	6,205	13,546	7,553	2,236	5,992	8,228
Total	**78**		**78**			**23,828**	**11,385**			**14,740***

*The evaluator also identified a documentation error resulting in a difference of 745 kWh.

Evaluation Assessment of Applicant Methodology

The applicant's overall method for calculating the savings is appropriate and of sufficient rigor for both measures. The evaluator reviewed the application files with respect to baseline, methodology, trend and administrative errors.

The main concern with the application is for the MAU discharge air temperature measure in the lab + classroom facility, there is an Excel equation error in the applicant calculation spreadsheet, which made the discharge air enthalpy not follow the proper linear relationship when OAT is below 65°F. Evaluator fixed this error and got the evaluated discharge air enthalpy as shown Table 5-226. The saving difference will be discussed and presented in the next section.

Table 5-226. Discharge Air Enthalpy Corrected

	Tracking				Evaluated			
OAT db	**Discharge Air Btu/lb – Tracking**	**Coil Tons**	**HRU Recovered Tons**	**Net Tons**	**Discharge Air Btu/lb – Evaluated**	**Coil Tons**	**HRU Recovered Tons**	**Net Tons**
92.5	22.6	208.5	5.0	203.4	22.6	208.5	5.0	203.4
87.5	22.6	163.3	5.0	158.3	22.6	163.3	5.0	158.3
82.5	22.6	168.9	5.0	163.9	22.6	168.9	5.0	163.9
77.5	22.6	142.6	5.0	137.6	22.6	142.6	5.0	137.6
72.5	22.6	127.6	5.0	122.5	22.6	127.6	5.0	122.5
67.5	22.7	82.0	-	82.0	22.6	84.4	-	84.4
62.5	22.6	45.0	-	45.0	22.7	42.3	-	42.3
57.5	22.7	11.3	-	11.3	22.9	11.3	-	11.3
52.5	22.9	-		-	23.0	-		-
47.5	23.0				23.2			
42.5	23.1				23.3			
37.5	23.3				23.5			
32.5	23.4				23.6			
27.5	23.5				23.8			
22.5	23.9				23.9			

1.6.3 On-Site Inspection and Metering

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

Summary of On-site Findings

The evaluator conducted a site visit on May 13, 2021 verifying the installation and operation of the lighting measures, and another visit on May 18, 2021 verifying all non-lighting measures. During the site visit, the evaluator interviewed the physical plant engineers and verified all ECMs were installed and operating as proposed. The evaluator took a walk through on all buildings and plant with the site contact to understand the lighting with controls, central plant sequence of operations and building level HVAC controls.

During the site audit, the evaluator was able to collect the information below:

Chiller Plant

- Evaluator observed a new York YMC2 1,000 ton chiller operating and checked the condenser water setpoint is from 45°F to 85°F.

- The new chiller (Chiller 7) is operating as the lead chiller, the two other pre-existing 1,000 ton chillers sequenced individually as lag chiller (Chiller 5 and 6).
- The new chiller is connected to the chilled water system including new primary chilled water (CHWP-8) and condenser water pumps (CWP-7) and cooling towers (CT-7 and CT-8). All the new chilled water pump, condenser water pumps and cooling towers sizes and efficiency are identical as the existing system(s).
- The central chilled water system is operating 24 hours per day, 7 days per week, year round to provide for space cooling loads which include various building tele data and relatively small server rooms.
- During the site visit, BAS showed the instantaneous outdoor air web blub temperature was 58.6°F, and effective setpoint for condenser water temperature was 66.5°F.

Lab + Classroom

- Evaluator observed the three new installed 60 Hp exhaust fans as LEF1, 2, and 3, each exhaust fan was equipped with a VFD.
- With assistance from the site contact, evaluator was able to check the BAS control and found the duct static pressure setpoint and the instantaneous readings were both 2.25 in wg (tracking was 2.5 in wg). Since no operation adjustment will be applied to this site due to the COVID impact and the evaluation methodology is consistent with the application method, evaluator does not apply this discrepancy to the saving analysis. However, the evaluators recommend that the project implementor update the saving analysis inputs based on the post-inspection findings.
- During the site visit, BAS showed the instantaneous fan speed for LEF 1, 2 and 3 were all at 62% speed.
- Regarding to MAU-1 and 2, the BAS showed discharge air temperature high and low limit were set to 65°F (while tracking was 62°F) and 55°F. Since no operation adjustment will be applied to this site due to the COVID impact and evaluation methodology is consistent with the application method, evaluator will not apply this discrepancy to the saving analysis.
- Evaluator observed there were 21 fume hoods in the third floor chemistry classroom/lab area, which matched what applicant proposed.

Development Center

- Evaluators were able to locate the CO_2 sensor (box) installed in the AHU-3 and AHU-4 return duct, and the occupancy sensor in the basketball court and weight room.
- During the site visit, BAS showed the instantaneous return CO_2 was 373 ppm for AHU-3, and 464 ppm for AHU-4. Both areas were in the occupied mode.

Recreation Center

- Evaluators were able to inspect lighting for each location type and operating hour group. The evaluator confirmed 20% of the lights claimed in the application.
- Evaluators confirmed occupancy sensors to be present in the relevant areas claimed in the application. The site contact reported lesser foot traffic and occupancy in the facility. However, since this evaluation would not apply operational differences due to the Covid pandemic, the evaluation did not include on-site EM&V metering, and usage was not verified as it would not be included as an evaluated discrepancy.

Arena

- Evaluators were able to inspect lighting for all fixture locations, operating hour groups, and confirmed the fixtures to match the proposed fixture description shown in the documentation. The evaluator confirmed 70% of the lights claimed in the application.
- Evaluators confirmed occupancy sensors to be present in the relevant areas claimed in the application. The site contact reported lesser foot traffic and occupancy in the facility. However, since this evaluation would not include operational differences due to the Covid pandemic, there was no on-site EM&V metering, usage was not verified, these claims were not verified and therefore could not be included as an evaluated discrepancy.

Measured and Logged Data

Instead of conducting metering for the operation adjustment, the following reasons caused the evaluator to do a non-operation adjustment for this site:

- The campus was affected by COVID and it is not in the 100% occupancy situation.
- Full cooling season is not complete.
- It is difficult to distinguish individual energy savings by installing kW logger since there are multiple measures implemented on the se equipment.

Therefore, the evaluator will focus on verifying the equipment installation and their control strategy by requesting some trend data and screenshots from BAS through the site contact.

Before the site visit, the evaluator requested related trend data across different chiller plant, lab building, and the development center and site contact had sent some of them. During the site visit, the evaluator worked with the site contact to extract some additional screenshots and trend data from BAS to verify all non-lighting ECMs. The evaluator conducted a walkthrough of the facilities and inspected lights to confirm control types, fixture types, and fixture counts. This will be discussed in the next section.

1.6.4 Evaluation Methods and Findings

This section describes the evaluator methods and findings.

Evaluation Description of Baseline

The evaluator reviewed the project files and interviewed the site contact to gather information on the baseline. The evaluator classified both measures in 9764300 – Chiller Plant as New & Replacement Equipment with single baseline, all three measures in 10308605 – Lab + Classroom as New Buildings & Major Renovation with single baseline and both measures in 10308605 – Lab + Classroom and 10309202 – Development Center as New Buildings & Major Renovation with single baseline, which are identical as tracking.

The evaluator determined the lighting measure is a retrofit with a dual baseline measure, where the baseline would be the pre-existing fixtures identified in the lighting audit. The dual baseline for the analysis of lifetime savings follows the model where 1/3 lifetime is attributed to a baseline of the existing fixtures, and 2/3 will be assumed using a 60% of the baseline fixture wattage for that remaining period regardless of existing fixture age or reported condition.

Evaluation Calculation Method

Since the spreadsheet-based calculator for all ECMs have reasonable methodologies and inputs, the evaluator will use a similar approach as the applicant but will address the input differences (non-operational only) between baseline and proposed situation for each measure. In addition, the evaluator did go through the collected trend data and compare with the applicant proposed operation and tracking trends if they were collected before.

Chiller Plant

Evaluator collected chiller 7 (new chiller) VSD input power data from January 2020 to May 2021 as seen in Figure 2-1. As it shows, the proposed chiller was operating almost across the whole trending period except for some time in

January and February 2021. Surprisingly, the chart shows higher operation profile in the summer than in the winter. Based on this chart the evaluators concluded that the proposed chiller was installed and operating properly but the evaluators can not verify that the installed chiller is operating as the lead chiller as intended.

Figure 5-78. Proposed Chiller kW Input Power

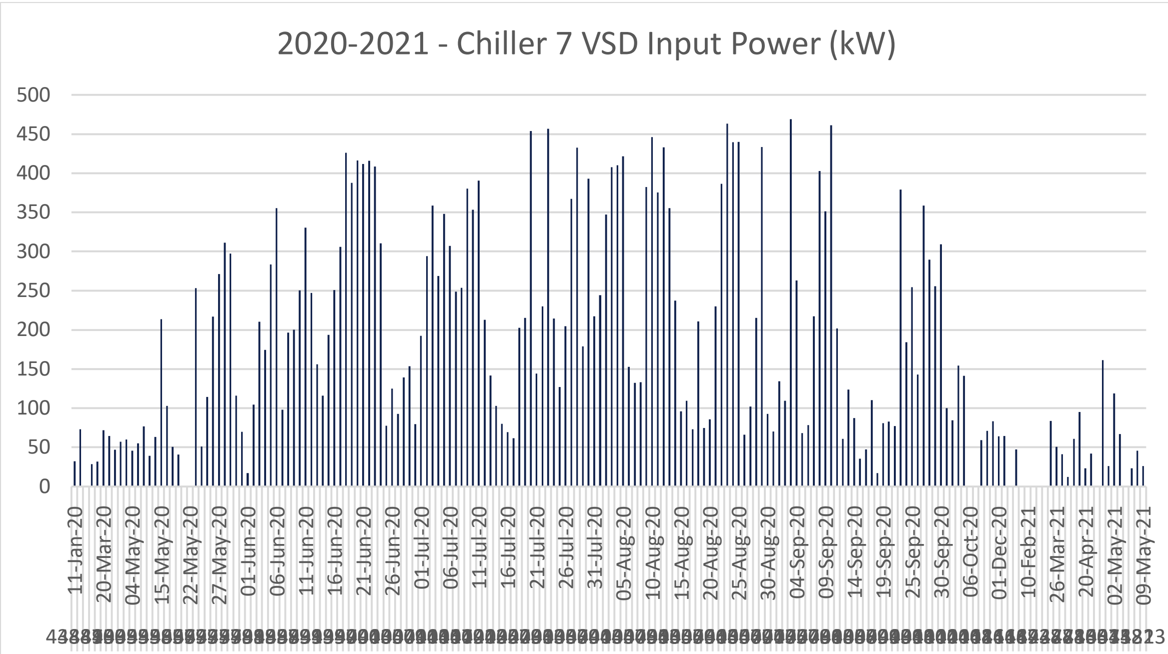
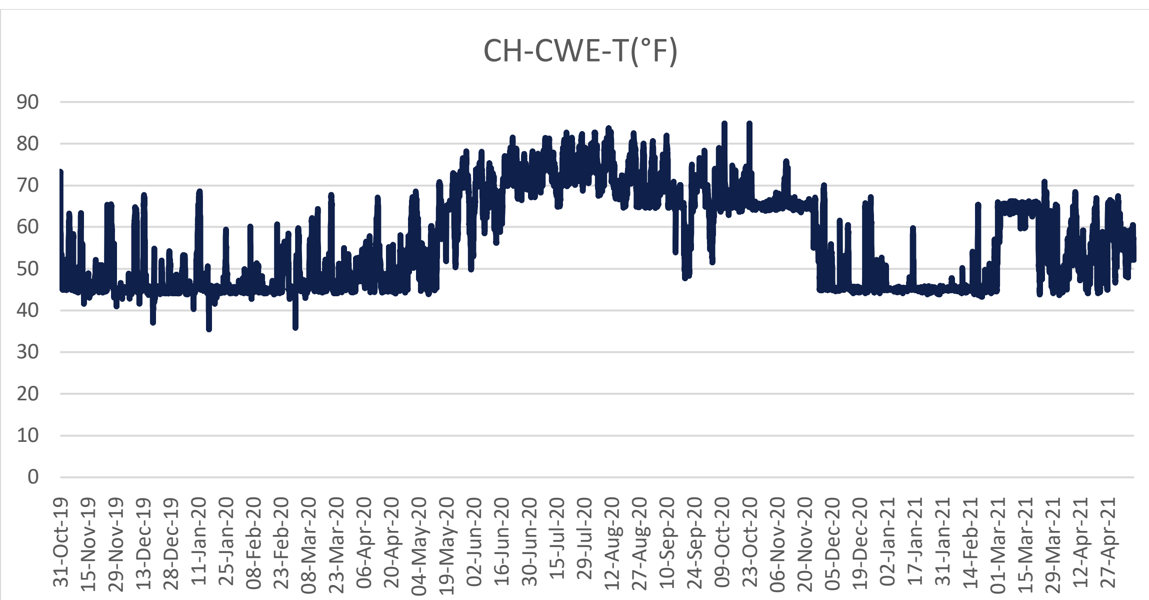


Figure 2-2 shows the condensing water temperature from November 2019 to April 2021. The temperature fluctuated from 45°F to 85°F for most of the time, especially in a lower level during the winter season and higher level during the summer season.

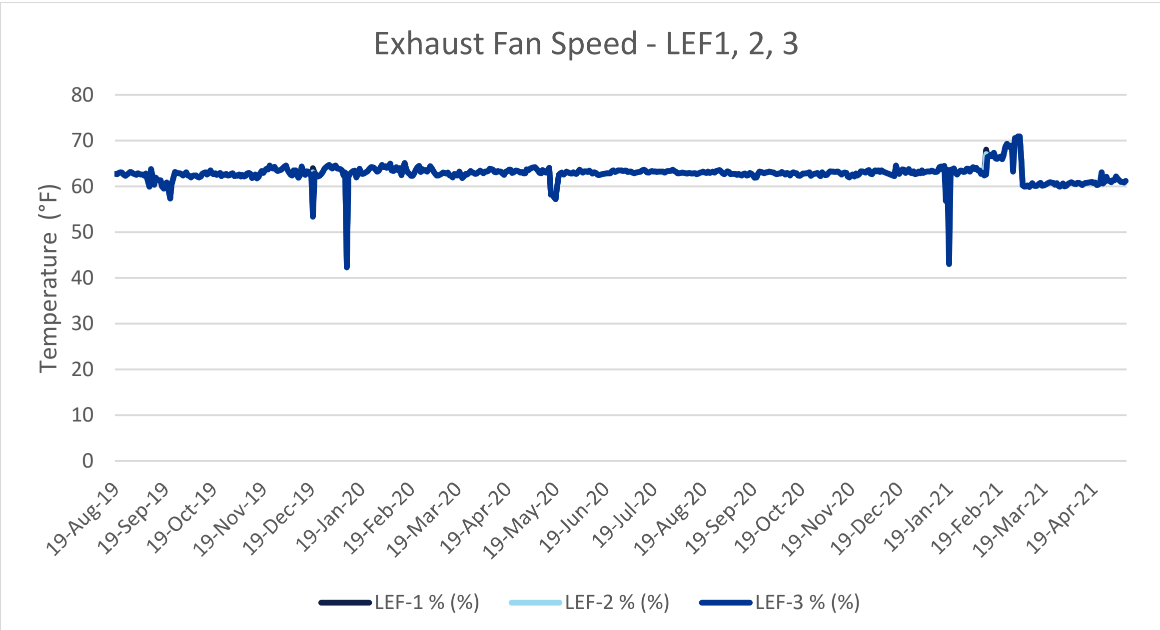
Figure 5-79. Proposed Condensing Water Temperature



Lab + Classroom

The Evaluator collected the exhaust fans (LEF1, 2, and 3) percent speed in one-day intervals from October 2019 to May 2021 (Figure 2-3). During most of the trending period the fans were operating at 60~65% speed as applicant proposed. Since all three fan speeds were almost at the same level, the trend lines are covering one another.

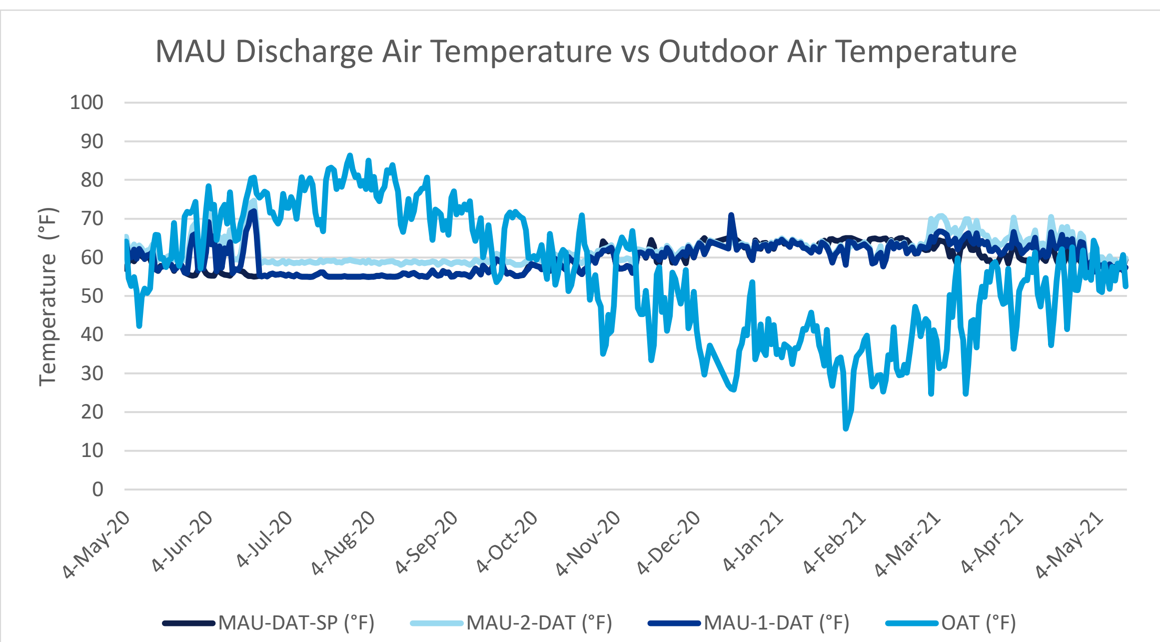
Figure 5-80. Proposed Exhaust Fan Speed%



Install New Lab Exhaust system with Variable Volume

Evaluator collected the MAU-1 and MAU-2 discharge air temperature and the setpoint along with outdoor air temperature from May 2020 to May 2021 and plotted the chart in Figure 2-4. The discharge air temperature setpoint, in blue line, is showing the setpoint is from 55°F to 65°F and varies based on the outside air temperature.

Figure 5-81. Proposed MAU DAT vs OAT

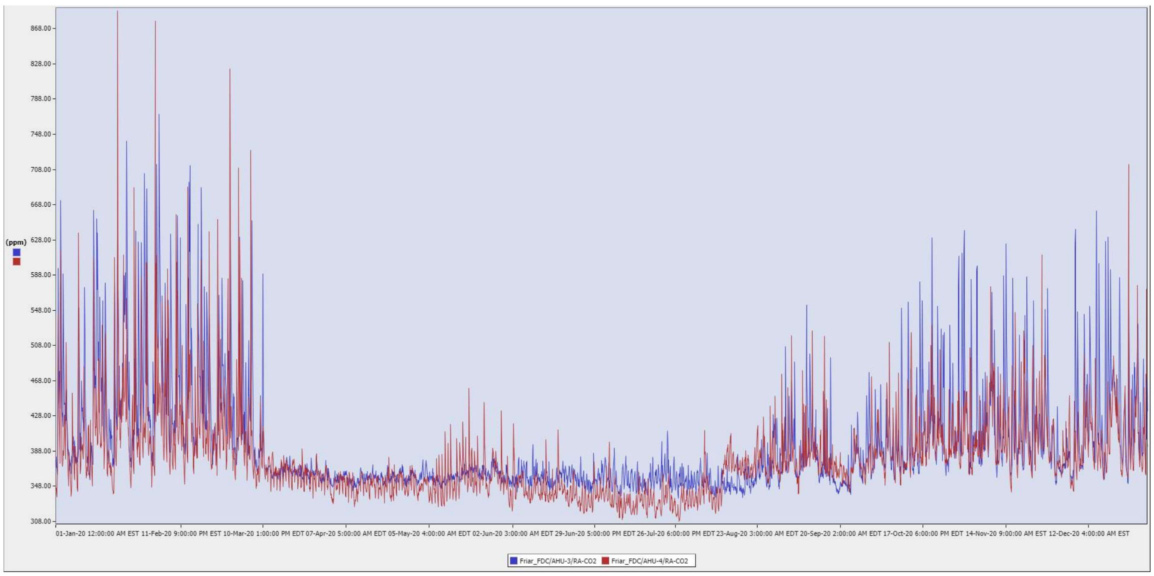


During the site visit, the evaluator also collected the airflow trend screenshot on the fume hood. This has been documented in the evaluated folder as reference.

Development Center

Figure 2-5 below is the CO_2 level trend on AHU-3 and AHU-4 return duct from January 2020 to December 2020, which was collected during the second site visit. In Figure 2-5 the blue line indicates AHU-3 serving the basketball court had a minimum CO_2 around 350 ppm and red line indicates AHU-4 serving the weight room had a minimum CO_2 around 300 ppm, while both had a highest CO_2 reading of no more than 900 ppm. This shows the demand control ventilation works and both AHUs' operation was adjusted properly in this building.

Figure 5-82. Proposed Return Air CO_2 Level – AHU-3 and AHU-4



Lighting

The evaluator calculated the savings using a similar approach to the applicant. The evaluator used the Custom Lighting tool to determine the evaluated savings. The savings algorithms used in the tool are as follows:

$$\text{Baseline Fixture kWh} = \frac{Quantity_B * Wattage_B}{1000} * Evaluated\ Operating\ Hours$$

$$\text{Proposed Fixture kWh} = \frac{Quantity_P * Wattage_P}{1000} * Evaluated\ Operating\ Hours$$

$$\text{Fixture kWh Savings} = Baseline\ Fixture\ kWh\ - Proposed\ Fixture\ kWh$$

$$\text{HVAC Interactive Fixture Savings} = (pre\ connected\ kW - post\ connected\ kW) * Coincident\ Occupied\ Cooling\ Hours * \frac{0.8}{Cooling\ COP}$$

$$\text{Control kWh Savings} = Proposed\ Fixture\ kW\ * (Evaluated\ Operating\ Hours\ without\ controls - Evaluated\ EFL\ Operating\ Hours\ with\ controls)$$

$$\text{Total kWh Savings} = Fixture\ kWh\ Savings + HVAC\ Interactive\ Fixture\ Savings + Control\ kWh\ Savings$$

All spreadsheets used to estimate evaluation savings will be made available to the PAs for review at their request. For site cooling hours, the evaluator assumed cooling would only occur between May and October. For each hourly interval within that range of months in the 8760 model, if dry bulb temperature taken from local TMY3 data was greater than or equal to the setpoint of 55°F, then that hour was determined to be a cooling hour. Cooling hours that coincided with the lighting hours were used to determine total annual cooling savings. The cooling COP is assumed to be 5.5 for the chillers that serve the recreation center and arena. Table 2-10 and Table 2-11 show the evaluation inputs and savings calculations for the fixtures and controls in the recreation center. Table 5-227 and Table 5-228 show the evaluation inputs and savings calculations for the fixtures and controls in the arena.

Table 5-227. Evaluation Fixture Inputs and kWh Savings – Recreation Center

	A	B	C	D	E	F	G=A*B*E/1000	H=C*D*E/1000	I=G-H	J	K	L	M=F*J*K*0.8/L	N=I+M
Space Type	Baseline Quantity	Baseline Watts per Fixture	Installed Quantity	Installed Watts per Fixture	Annual Pre Hours	Connected kW Savings	Baseline kWh	Installed kWh	kWh Fixture Savings	% of Space Cooled	Annual Cooling Hours	Cooling COP	Interactive Cooling Savings	Total kWh Fixture Savings
Usage Group D	14	100	14	9	4,381	1.274	6,133	552	5,581	100%	438	5.5	81	5,662
Usage Group D	6	48	6	8	4,381	0.240	1,262	210	1,051	100%	438	5.5	15	1,067
Usage Group A	3	112	3	52	8,761	0.180	2,944	1,367	1,577	100%	670	5.5	17	1,594
Usage Group A	5	60	5	26	8,761	0.170	2,628	1,139	1,489	100%	670	5.5	16	1,506
Usage Group A	24	28	24	13	8,761	0.360	5,888	2,733	3,154	100%	670	5.5	35	3,189
Usage Group A	57	30	57	13	8,761	0.969	14,982	6,492	8,490	100%	670	5.5	94	8,584
Usage Group A	0	65	0	8	8,761	0.000	0	0	0	100%	670	5.5	0	0
Usage Group A	1	17	1	11	8,761	0.006	149	96	53	100%	670	5.5	1	53
Usage Group A	52	59	52	26	8,761	1.716	26,879	11,845	15,034	100%	670	5.5	166	15,201
Usage Group A	1	40	1	8	8,761	0.032	350	70	280	100%	670	5.5	3	283
Usage Group A	19	40	19	13	8,761	0.513	6,659	2,164	4,494	100%	670	5.5	50	4,544
Usage Group A	1	32	1	11	8,761	0.021	280	96	184	100%	670	5.5	2	186
Usage Group A	13	24	13	13	8,761	0.143	2,733	1,481	1,253	100%	670	5.5	14	1,267
Usage Group A	8	38	8	13	8,761	0.200	2,663	911	1,752	100%	670	5.5	19	1,772
Usage Group B	5	112	5	52	6,362	0.300	3,563	1,654	1,909	100%	543	5.5	24	1,932
Usage Group B	4	60	4	16	6,362	0.176	1,527	407	1,120	100%	543	5.5	14	1,134
Usage Group B	185	60	185	26	6,362	6.290	70,622	30,603	40,019	100%	543	5.5	494	40,513
Usage Group B	10	63	10	30	6,362	0.330	4,008	1,909	2,100	100%	543	5.5	26	2,125
Usage Group B	6	53	6	33	6,362	0.120	2,023	1,260	763	100%	543	5.5	9	773
Usage Group B	81	88	81	39	6,362	3.969	45,350	20,099	25,252	100%	543	5.5	312	25,564

Usage Group B	35	224	35	52	6,362	6.020	49,880	11,579	38,301	100%	543	5.5	473	38,774
Usage Group B	10	28	10	9	6,362	0.190	1,781	573	1,209	100%	543	5.5	15	1,224
Usage Group B	26	28	26	13	6,362	0.390	4,632	2,150	2,481	100%	543	5.5	31	2,512
Usage Group B	25	30	25	13	6,362	0.425	4,772	2,068	2,704	100%	543	5.5	33	2,737
Usage Group B	0	123	0	55	6,362	0.000	0	0	0	100%	543	5.5	0	0
Usage Group B	12	455	12	17	6,362	5.256	34,738	1,298	33,440	100%	543	5.5	413	33,853
Usage Group B	15	455	15	100	6,362	5.325	43,423	9,543	33,879	100%	543	5.5	418	34,298
Usage Group B	1	70	1	16	6,362	0.054	445	102	344	100%	543	5.5	4	348
Usage Group B	10	70	10	26	6,362	0.440	4,454	1,654	2,799	100%	543	5.5	35	2,834
Usage Group B	3	17	3	11	6,362	0.018	324	210	115	100%	543	5.5	1	116
Usage Group B	0	52	0	24	6,362	0.000	0	0	0	100%	543	5.5	0	0
Usage Group B	0	29	0	12	6,362	0.000	0	0	0	100%	543	5.5	0	0
Usage Group B	8	59	8	15	6,362	0.352	3,003	763	2,240	100%	543	5.5	28	2,267
Usage Group B	15	59	15	26	6,362	0.495	5,631	2,481	3,149	100%	543	5.5	39	3,188
Usage Group B	37	40	37	13	6,362	0.999	9,416	3,060	6,356	100%	543	5.5	78	6,434
Usage Group B	1	32	1	11	6,362	0.021	204	70	134	100%	543	5.5	2	135
Usage Group B	52	32	52	15	6,362	0.884	10,587	4,963	5,624	100%	543	5.5	69	5,694
Usage Group B	14	24	14	13	6,362	0.154	2,138	1,158	980	100%	543	5.5	12	992
Usage Group B	5	38	5	13	6,362	0.125	1,209	414	795	100%	543	5.5	10	805
Usage Group B	12	47	12	25	6,362	0.264	3,588	1,909	1,680	100%	543	5.5	21	1,700
Usage Group B	4	20	4	6	6,362	0.056	509	153	356	100%	543	5.5	4	361
Usage Group B	3	67	3	6	6,362	0.183	1,279	115	1,164	100%	543	5.5	14	1,179
Usage Group B	30	177	30	78	6,362	2.970	33,784	14,888	18,896	100%	543	5.5	233	19,129
Usage Group B	140	351	70	217	6,362	33.950	312,643	96,643	216,000	100%	543	5.5	2,668	218,668
Usage Group B	36	68	36	8	6,362	2.160	15,575	1,832	13,743	100%	543	5.5	170	13,912
Usage Group B	19	34	19	8	6,362	0.494	4,110	967	3,143	100%	543	5.5	39	3,182

Usage Group B	4	140	4	52	6,362	0.352	3,563	1,323	2,240	100%	543	5.5	28	2,267
Usage Group B	1	15	1	6	6,362	0.009	95	38	57	100%	543	5.5	1	58
Usage Group B	1	54	1	6	6,362	0.048	344	38	305	100%	543	5.5	4	309
Usage Group C	4	60	4	26	3,285	0.136	789	342	447	100%	380	5.5	7	454
Usage Group C	6	88	6	39	3,285	0.294	1,735	769	966	100%	380	5.5	16	982
Usage Group E	2	112	2	52	5,997	0.120	1,343	624	720	100%	524	5.5	9	729
Usage Group E	17	63	17	30	5,997	0.561	6,423	3,059	3,364	100%	524	5.5	43	3,407
Usage Group E	22	53	22	33	5,997	0.440	6,993	4,354	2,639	100%	524	5.5	33	2,672
Usage Group E	2	88	2	39	5,997	0.098	1,056	468	588	100%	524	5.5	7	595
Usage Group E	0	52	0	24	5,997	0.000	0	0	0	100%	524	5.5	0	0
Usage Group E	0	29	0	12	5,997	0.000	0	0	0	100%	524	5.5	0	0
Total	**1067**		**997**			**80.29**	**771,108**	**254,696**	**516,413**				**6,352**	**522,764**

Table 5-228. Evaluation Controls Inputs and kWh Savings – Recreation Center

	A	B	C	D=A*B/1000	E=C*D	F	G	H	I=D*F*G*0.8/H	J=E+X
Space Type	Installed Quantity	Installed Watts per Fixture	Annual Hours Reduction	Connected kW	kWh Controls Savings	Percent of Space Cooled	Annual Cooling Hours Reduction	Cooling COP	Interactive Cooling Savings	Total kWh Controls Savings
Usage Group A	2	26	2,102.69	0.05	109	100%	111	5.5	1	110
Usage Group A	52	26	2,102.69	1.35	2,843	100%	111	5.5	22	2,865
Usage Group A	24	13	2,102.69	0.31	656	100%	111	5.5	5	661
Usage Group B	1	26	1,526.95	0.03	40	100%	81	5.5	0	40
Usage Group B	14	26	1,526.95	0.36	556	100%	81	5.5	4	560
Usage Group B	52	15	1,526.95	0.78	1,191	100%	81	5.5	9	1,200
Usage Group B	12	17	1,526.95	0.20	311	100%	81	5.5	2	314
Usage Group B	35	52	1,526.95	1.82	2,779	100%	81	5.5	21	2,800
Usage Group B	26	13	1,526.95	0.34	516	100%	81	5.5	4	520
Total	**218**			**5.25**	**9,001**				**69**	**9,070**

Table 5-229. Evaluation Fixture Inputs and kWh Savings – Arena

	A	B	C	D	E	F	G=A*B*E/1000	H=C*D*E/1000	I=G-H	J	K	L	M=F*J*K*0.8/L	N=I+M
Space Type	Baseline Quantity	Baseline Watts per Fixture	Installed Quantity	Installed Watts per Fixture	Annual Pre Hours	Connected kW Savings	Baseline kWh	Installed kWh	kWh Fixture Savings	% of Space Cooled	Annual Cooling Hours	Cooling COP	Interactive Cooling Savings	Total kWh Fixture Savings
lockerrms	0	60	0	0	4,171	0.000	0	0	0	100%	431	5.5	0	0
lockerrms	16	60	16	24.2	4,171	0.573	4,004	1,615	2,389	100%	431	5.5	36	2,425
lockerrms	24	59	24	20.1	4,171	0.934	5,906	2,012	3,894	100%	431	5.5	58	3,952
common	1	60	1	32.9	6,205	0.027	372	204	168	100%	538	5.5	2	170
common	37	59	37	32.9	6,205	0.966	13,546	7,553	5,992	100%	538	5.5	75	6,067
Total	**78**		**78**			**2.50**	**23,828**	**11,385**	**12,444**				**171**	**12,615**

Table 5-230. Evaluation Controls Inputs and kWh Savings – Arena

	A	B	C	D=A*B/1000	E=C*D	F	G	H	I=D*F*G*0.8/H	J=E+X
Space Type	Installed Quantity	Installed Watts per Fixture	Annual Hours Reduction	Connected kW	kWh Controls Savings	Percent of Space Cooled	Annual Cooling Hours Reduction	Cooling COP	Interactive Cooling Savings	Total kWh Controls Savings
common	1	32.9	1,836.68	0.03	60	100%	97	5.5	0	61
common	37	32.9	1,836.68	1.22	2,236	100%	97	5.5	17	2,253
Total	**38**			**1.25**	**2,296**				**18**	**2,314**

1.7 Final Results

The summary of the measures the project consists of and the resulting evaluated savings are shown below.

Table 5-231: Final results

Building	Measure Name	Annual Electric Energy (kWh)
Chiller Plant	New Premium Efficiency Magnetic Bearing Chiller with VFD	392,088
Chiller Plant	Condenser Water Temperature Reset	94,482
Lab + Classroom	Install New Lab Exhaust system with Variable Volume	192,703
Lab + Classroom	Make Up Air Units 1 &2 Discharge Air Temperature Reset	1,243
Lab + Classroom	New Lab Fume Hoods as Low Flow Models	180,570
Development Center	AHUs 3&4 Occupancy Control	5,310
Development Center	AHUs 3&4 Demand Control Ventilation	427
Recreation Center	Lighting Retrofit	531,835
Arena	Lighting Retrofit	14,929

The evaluated kWh savings for MAU DAT reset are 87.2% higher and the evaluated savings for low flow fume hood are 3% less than tracking due to an administrative error. However, these two discrepancies offset one another on the overall non-lighting savings. The parameters impacting the analysis are summarized in The evaluated savings for the lighting project were slightly greater than the applicant-reported savings primarily due to a discrepancy stemming from heating and cooling interaction. Detailed values are shown in Table 5-196. Summary of Key Parameters, comparing changes in the baseline and proposed conditions for both the application and evaluation hours of use for each area.

Table 5-85 above.

The evaluated kWh savings for the recreation center lighting retrofit are 1.22 % higher due to the inclusion of HVAC interactivity. The evaluated kWh savings for the arena lighting retrofit is 6.67% higher due the inclusion of HVAC interactivity and a documentation error. The tracking savings reported a savings of 13,995 kWh whereas the applicant calculator reports a savings of 14,740 kWh. The evaluated kWh savings for the lighting retrofit are higher due to the inclusion of HVAC interactivity. A summary of the key parameters in the non-lighting and lighting analysis are shown in The evaluated savings for the lighting project were slightly greater than the applicant-reported savings primarily due to a discrepancy stemming from heating and cooling interaction. Detailed values are shown in Table 5-196. Summary of Key Parameters, comparing changes in the baseline and proposed conditions for both the application and evaluation hours of use for each area.

Table 5-85below.

Table 5-232. Summary of Changes to Key Parameters

Parameter	Applicant	Evaluator
Recreation Center - Baseline Fixture Quantity	1067	997
Recreation Center - Installed Fixture Quantity	1067	997
Recreation Center - HVAC	Not Included	Heating: Steam Boiler Cooling: Chiller (COP 5.5)
Arena - Baseline Fixture Quantity	78	78
Arena - Installed Fixture Quantity	78	78
Arena -HVAC	Not Included	Heating: Steam Boiler Cooling: Chiller (COP 5.5)

1.7.1 Explanation of Differences

The evaluation results for non-lighting equal the tracking reported savings. Although the evaluator did not make operational adjustments in consideration of COVID-19 impacts, there were evaluation corrections which offset each other. As for lighting, the evaluation results are slightly greater due to inclusion of HVAC interaction. Table 5-205. Summary of DeviationsTable 5-233 provides a summary of the primary differences between tracking and evaluated values for lighting and non-lighting portions of the savings in total.

Table 5-233. Summary of Deviations

End-use	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
10308605 – MAU DAT Reset	Tracking & Admin	Discharge Air Enthalpy	+0.07%	**Positive** – due to the equation input error on discharge air enthalpy bin data
10308605 – Low Flow Fume Hoods	Tracking & Admin	Discharge Air Enthalpy	-0.07%	**Negative** – due to the equation input error on discharge air enthalpy bin data
Lighting	Interactive	HVAC Interactivity	+1.23%	**Positive –** a difference of 6,609 kWh was determined by the inclusion of HVAC interactivity in the evaluator's savings algorithms.
Lighting	Tracking & Admin	kWh Savings	+0.14%	**Positive** – a difference of 745 kWh was identified between the tracking savings reported and the applicant analysis

Application ID(s)	10587516, 9153589, 87166710	
Project Type	C&I Initial Purchase & End of Useful Life	
Program Year	2019	
Evaluation Firm	DNV	DNV
Evaluation Approach	Non-Lighting: M&V and Ops Lighting: non-ops only	
Evaluation Engineer	Shravan Iyer	
Senior Engineer	Olav Hegland	

Evaluated Site Summary and Results

The site is a 200,000 ft^2 industrial facility that uses injection molding machines (IMM) of various sizes and types (hydraulic and all-electric) to manufacture plastic dispensers and containers 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. to 6:45 a.m. The plant operates 24 hours per day, 5 days per week (Monday through Friday) and operates during some weekends depending on production requirements. The plant is typically shut down for two days per year for preventive maintenance. The site installed both lighting and non-lighting measures. This site was categorized as an essential service and was therefore allowed to operate as usual during the COVID 19 pandemic in 2020. The production staff worked onsite but the corporate, administrative, and other support staff had transitioned to work from home. Since some of the lighting retrofit took place in the office areas, the lighting measure was evaluated as non-ops only. The measures installed at the site can broadly be classified as Non-lighting and lighting measures which are described below:

The Non-lighting measures installed at the site include:

a) **New molds for the all-electric injection molding machine (IMM)-** The measure involves replacing the (2) existing 24 and 32 cavity molds that were run on the (2) all-hydraulic presses with (1) new 48 cavity mold which is sized such that it is compatible and can be run with on an existing all-electric injection molding machines. The all-electric press has a lower rated kW draw and is more efficient than the hydraulic press in terms of production capability. Additionally, the cycle time on the all-electric press is lower compared to the hydraulic press. The measure was categorized as a new-construction measure.

b) **Replaced the air-cooled molds with water cooled molds-**The site replaced the compressed air cooling on “spout 20A” mold and “24 CR 321” mold with a chilled-water cooling system. The molds will have the same run hours regardless of the type of cooling system used which are 1,950 hours and 420 hours respectively. The measure was categorized as a new-construction measure.

The lighting measures installed at the site include:

a) **LED Lighting and Controls-** The site replaced their existing F32T8 linear fluorescent fixtures with LEDs and installed occupancy sensors on existing LEDs in different spaces within the facility. The measure was categorized as a retrofit project.

A brief note on how each non-lighting measure saves energy is described below:

a) **New molds for the all-electric injection molding machine (IMM)-** The energy savings for this measure is due to the reduction in both demand (kW consumption) and operating hours of all-electric press.

b) **Replaced the air-cooled molds with water cooled molds-** The energy savings for this measure comes from the change in the cooling system from compressed air to chilled water because water is a better conductor of heat than air and chilled water systems are more efficient than compressed air systems.

A brief note on how the lighting measure saves energy is described below:

a) **LED Lighting and Controls-** The energy savings for this measure comes from the reduced wattages of LEDs and from the reduced hours of use of the fixtures due to the use of occupancy sensors.

The evaluation found the total lighting and non-lighting measure savings to be 232,983 kWh annually, which is higher than the tracking savings listed in the applicant documentation. The evaluation results are presented in Table 1-1.

Table 5-234. 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)
8716670/ 9153539	New Molds for eIMM and New Water-Cooled Molds	Tracked	115,641	67%	19.70	19.70
		Evaluated - ops	142,634	23%	17.95	16.51
		Realization Rate	123%	34%	91%	84%
10587516	Lighting Retrofit with Controls	Tracked	105,949	62%	2.81	0.87
		Evaluated - ops	86,434	53%	3.08	0.37
		Realization Rate	82%	62%	109%	43%
Totals		**Tracked**	**221,590**	**65%**	**22.5**	**20.6**
		Evaluated - ops	**229,068**	**34%**	**21.0**	**16.9**
		Realization Rate	**103%**	**53%**	**93%**	**82%**

Explanation of deviations from tracking

The evaluated savings for the non-lighting measures are higher than the applicant reported savings primarily due to the lower kW draw of the efficient all-electric press and the increased efficiency of the chilled-water cooling system. The lighting is non-ops only and HVAC interactive effects, not accounted for in the tracking estimate, were accounted for in the evaluation savings methodology. It appears that there is an administrative/documentation error in the tracking summer and winter kW savings for this site because there is a discrepancy between the demand savings listed in the applicant documentation and the demand savings listed in the tracking system. Further details regarding deviations from the tracked savings are presented in Section 3-4.

Recommendations for program designers & implementers

It is recommended that the energy savings, summer, and winter demand savings are documented accurately so that it mirrors what is claimed in the applicant documentation.

Customer Alert

There were no customer alerts.

Evaluated Measures

The measures installed at this site include:

a) **New molds for the all-electric injection molding machine (IMM)-** The site replaced the (2) existing 24 and 32 cavity molds (#321 and #241) that were run on the (2) all-hydraulic presses (rated at 39.2 kW and 32.8 kW respectively) with (1) new 48 cavity mold (#481) which is sized such that it can be run with all currently existing and any future all-electric injection molding machines. The all-electric press is estimated to be rated at 20.8 kW and is more efficient than the hydraulic press in terms of production capability. Additionally, the cycle time on the all-electric press is lower compared to the hydraulic press.

b) **Replaced the air-cooled molds with water cooled molds-**The site replaced the compressed air cooling on “spout 20A” mold and “24 CR 321” mold with a chilled-water cooling system. The molds will have the same run hours regardless of the type of cooling system used which are 1,950 hours and 420 hours respectively.

c) **LED Lighting and Controls-** The site replaced their existing F32T8 linear fluorescent fixtures with LEDs and installed occupancy sensors on existing LEDs in different spaces within the facility.

Application Information and Applicant Savings Methodology

a) **New molds for the all-electric injection molding machine (IMM)-** The facility installed a new mold that is compatible with the all-electric press instead of refurbishing old molds that were at the end of their useful life. The electric presses are more efficient compared to the hydraulic presses and running the molds on the electric press would use less energy. The applicant savings calculation was based on metered data obtained by installing data loggers on the hydraulic presses to estimate kW draw during a given production run. The savings calculation compares the machines while running the same parts on both the hydraulic and electric presses.

b) **Replaced the air-cooled molds with water cooled molds-** The facility replaced the cooling system on two molds that earlier used compressed air cooling with chilled water cooling. The applicant documentation states that the cfm was measured using a spot reading taken during the operation of the press running the mold (30 cfm) and was the same method used during the installation of similar projects earlier at the site. The cooling requirement for the molds using the chillers was estimated based on a previous project (15,000 Btu/hour). The mold for that project was double the size of the molds and 50% of the cooling value was used.

c) **LED Lighting and Controls-** The facility replaced some existing F32T8s with the new LEDs and installed occupancy sensors in certain spaces. The applicant estimated savings using a custom lighting spreadsheet-based calculator that estimates savings based on user-provided inputs such as fixture type, model, rated wattage, control strategies and hours of operation.

The following section provides additional description of the affected systems, i.e. the injection molders and the cooling systems:

Description of Affected Systems

Non-Lighting Measures- Injection Molding System:

The site had (2) existing 24 and 32 cavity molds (#321 and #241) that were installed on two all-hydraulic presses. Mold #321 ran in Press #8 which is rated at 39.8 kW and mold #241 ran in Press #11 which is rated at 32.8 kW. The (2) molds were worn out and were at the end of their service life and had to be refurbished for their continued use. Additionally, the molds could only be used on the all-hydraulic presses and not on the all-electric presses. The electric presses are more efficient and have lower cycle times, therefore the facility procured a new 48 cavity mold that can be run with the all-electric presses with inserts to produce parts of different sizes depending on the product being run at any given time. The two product types that were being run were the PS-211 and PS-211L. The facility also used compressed air to cool certain air-cooled molds on certain presses such as “Spout 20A” mold and “24 CR 321” mold. Each mold requires about 30 cfm of compressed air (while operating at 90 psi) to cool them while in production. The facility planned to transition from compressed air cooling to chilled water cooling on the molds by replacing the air-cooled molds with water cooled molds and by making use of the facility’s central chiller system.

Lighting System:

The facility’s lighting system consists of (566) fixtures installed in multiple spaces across the building ranging from private offices, walkways, production areas etc. The pre-case fixtures generally consisted of F32T8 linear fluorescent fixtures and LED fixtures of varying fixture wattages depending on the spaces that they were installed. The project documentation does not describe the pre-case fixtures having any control strategies such as occupancy sensors or dimming controls. The retrofitted linear fluorescent lamps were all replaced one-for one with LEDs. In some spaces where LEDs existed previously, the fixtures were installed with either occupancy sensors or dimming controls. In all, a total of (49) pre-existing F32T8s were replaced with LEDs and the remaining lights (which were LEDs) were either left as is or were installed with controls such as occupancy sensors and high-end trim controls (high-end trim to 90% max output). A brief list of the new light fixtures that were installed as part of the project is shown below:

Table-2-1-1- Post Case LED lights installed by the facility[65]

Mfg	Model	Quantity	Wattage
Lithonia	BLWP4 20L ADP GZ10 LP840	2	15.69
RAB	EZPAN2X2-17N/D10	5	19.8
RAB	EZPZN2X4-30N/D10	6	32.4
ILP	FX4-24W-U-40-VC	1	24.63
ILP	FX8-48W-U-50-VC	23	49.46
Lithonia	IBE L48 18000LM ATC MD MVOLT GZ10 40K 80CRI	5	128.16
RemPhos	RPT-P-LEDBARKITJ-20W-4FT-2L-840	2	19.21
RemPhos	RPT-P-LIVC-G2-4FT-20L-840-FWFC-R-S1-OCC	4	39.81
TechBrite	V474SS1B40BS000	1	37.43

The evaluators found the applicant savings calculations to be reasonable after reviewing the applicant documentation and the savings calculation methodologies used to estimate the tracking savings.

Applicant Description of Baseline

a) **New molds for the all-electric injection molding machine (IMM)-** In the pre-case, the project documentation states that the applicant could have refurbished the (2) 24 and 32 cavity molds (#321 and #241) which were in poor shape and were at the end of their service life and could have continued to run them in the all-hydraulic presses. The mold run hours were estimated using total production per year (from the individual press) and the cycle time. The measure was categorized as a new-construction measure.

b) **Replaced the air-cooled molds with water cooled molds-** In the pre-case, the facility used compressed air to cool air-cooled molds “spout 20A” and “24 CR 231”. The facility replaced the air cooled molds with water cooled molds and transitioned from compressed air to chilled water cooling, which resulted in energy savings. The measure should have been categorized as a retrofit measure.

c) **LED Lighting and Controls-** In the pre-case, the facility’s lighting inventory consisted of F32 T8 linear fluorescent and LED fixtures with no control strategies. The linear fluorescents were replaced with LEDs and some of the new lights were installed with controls and some controls were added to existing lights. The measure can be categorized as a retrofit project.

The following table (Table 2-1) lists the key baseline parameters used to estimate the baseline consumption by the applicant:

Table 5-235. Applicant baseline key parameters

			BASELINE	
Measure	**Parameter**	**Value(s)**	**Source of Parameter Value**	**Note**
Molds for the all-electric injection molding machine (IMM)	Production Volume for PS-211	5,145,814 units	Project Documentation	Adjusted based on site findings
Molds for the all-electric injection molding machine (IMM)	Production Volume for PS-211L	9,932,301 units	Project Documentation	Adjusted based on site findings
Molds for the all-electric injection molding machine (IMM)	Average IMM kW draw (Running 28 cavity mold)	39.8 kW	Project Documentation	From applicant metered data
Molds for the all-electric injection	Average IMM kW draw (Running 32 cavity mold)	32.8 kW	Project Documentation	From applicant metered data

[65] Provided in project documentation

molding machine (IMM)				
Molds for the all-electric injection molding machine (IMM)	Actual Cycle Time (seconds) for 24 cavity mold	30.2 seconds	Project Documentation	
Molds for the all-electric injection molding machine (IMM)	Actual Cycle Time (seconds) for 32 cavity mold	26.9 seconds	Project Documentation	
Molds for the all-electric injection molding machine (IMM)	Mold Cavitation (24 cavity mold)	24	Project Documentation	
Molds for the all-electric injection molding machine (IMM)	Mold Cavitation (32 cavity mold)	32	Project Documentation	
Replaced the air-cooled molds with water cooled molds	Cooling cfm (Using Compressed air)	30 cfm	Project Documentation	From similar project installed earlier at the site
Replaced the air-cooled molds with water cooled molds	Mold Run hours	1950 hours and 420 Hours	Project Documentation	
LED Lighting and Controls	Pre-Retrofit Fixture count that were LEDs	517	Project Documentation	
LED Lighting and Controls	Pre-Retrofit Fixture count that were F32T8 linear fluorescent	49	Project Documentation	

Applicant Description of Installed Equipment and Operation

The post-case/installed case equipment for each of the measures is described below:

a) **New molds for the all-electric injection molding machine (IMM)-** In the post-case, the new 48 cavity mold was installed on the all-electric press which is more efficient than the hydraulic press. The reduced cycle time from 30.2 seconds and 26.9 seconds (on molds #241 and #321 running on hydraulic presses) respectively to 26.5 seconds on the all-electric press resulted in reduced run hours and therefore led to energy savings.

b) **Replaced the air-cooled molds with water cooled molds-** In the post-case, the facility replaced two air-cooled molds with water cooled molds and transitioned from compressed air to chilled water cooling, which resulted in energy savings.

c) **LED Lighting and Controls-** The post-case included retrofitting F32T8 fixtures with LEDs and installing occupancy sensors and high-end trimming in some spaces. The fixture replacement was one-for-one. The hours of operation ranged between 1,040, 7,000 and 8,760 hours depending on the space type. The LEDs have a lower wattage and when combined with the occupancy sensors result in significant energy savings.

The following table (Table 2-2) lists the key post-case parameters used to estimate the post-case consumption by the applicant:

Table 5-236: Application proposed key parameters

Measure	Parameter	Value(s)	PROPOSED Source of Parameter Value	Note
New molds for the all-electric injection molding machine (IMM)	Production Volume for PS-211	5,145,814 units	Project Documentation	Updated based on site findings
New molds for the all-electric injection molding machine (IMM)	Production Volume for PS-211L	9,932,301 units	Project Documentation	Updated based on site findings
New molds for the all-electric injection molding machine (IMM)	Average IMM kW draw (Running 48 cavity mold)	20.85 kW	Project Documentation	From applicant metered data
New molds for the all-electric injection molding machine (IMM)	Actual Cycle Time (seconds) for 48 cavity mold	26.5 seconds	Project Documentation	
New molds for the all-electric injection molding machine (IMM)	Mold Cavitation- 48 cavity mold	48	Project Documentation	
Replaced the air-cooled molds with water cooled molds	Cooling Btu/hr (Using Chilled water)	15,000 Btu/hr	Project Documentation	From similar project installed earlier at the site
Replaced the air-cooled molds with water cooled molds	Mold Run hours	1950 hours and 420 Hours	Project Documentation	
Replaced the air-cooled molds with water cooled molds	Chiller Efficiency	1 kW/Ton	Project Documentation	
LED Lighting and Controls	Fixtures with controls installed		Project Documentation	
LED Lighting and Controls	Post-Retrofit Fixture count (New LED lights installed)	49	Project Documentation	

Applicant Energy Savings Algorithm

Some general facility related information along with the energy savings calculation methodology found in the applicant document for each measure is described below:

Weekly Hours= 120 Hours (24 hours/day x 5 days/week)
Annual Production weeks= 49 weeks (This does not align with the two week shutdown noted in the tracking analysis.)
Annual Production hours= 5,880 hours

New molds for the all-electric injection molding machine (IMM)- The savings for this measure were estimated by comparing the production runs of the same parts on both the hydraulic and the electric injection molders by using production data and metered data. The tracking analysis used metered data to estimate the kW-draw of the two hydraulic presses that used the two old molds (#321 and #241) using a Dent kW logger[66]. Customer provided values were used for annual production output and the cycle times for the two machines to estimate annual run hours. The mold cavitation value was used as opposed to the actual cavitation of the molds because the applicant documentation stated that the molds were in poor shape and were at the end of their useful life so not all cavities were active and would have been inaccurate to use the actual cavitation at the time. For the proposed case, the kW draw of the all-electric press was estimated using spot measurements. The same methodology described above was used to determine annual

[66] Based on metered data provided in the project documentation

run hours on the electric press. A brief description of the savings methodology and the associated calculation is described below:

Table-2.2.2-1- Base Case- Molds Running in All-Hydraulic Injection Molding Machine:

A	B	C	D	E	F	G=F/C	H=G x E /(60 x 60)	I	J= H x I
Product #	Mold #	Mold Cavitation	Actual Cavitation	Cycle Time (s)	2016 Volume	Cycles	Run Hours	Avg kW	kWh
PS-211	241	24	12.85	30.2	5,145,814	214,408.9	1,798.7	32.8	59,013
PS-211L	321	32	28.5	26.9	9,932,301	310,384.4	2,319.3	39.8	92,414

Total Base Case kWh Consumption= J= 151,428 kWh

Table-2.2.2-2- Post Case- Molds Running in All-Electric Injection Molding Machine:

A	B	C	D	E	F	G=F/C	H=G x E / (60 x 60)	I	J= H x I
Product #	Mold #	Mold Cavitation	Actual Cavitation	Cycle Time (s)	2016 Volume	Cycles	Run Hours	Avg kW	kWh
PS-211	481	48	48	26.5	5,145,814	107,204.5	789	20.85	16,451
PS-211L	481	48	48	26.5	9,932,301	206,922.9	1,523	20.85	31,755

Total Post Case kWh Consumption= 48,205.2 kWh

Replaced the air-cooled molds with water cooled molds- The savings for this measure was estimated by comparing the energy use of a compressed air system on the (2) older air cooled molds with the energy use of the chilled water system on the (2) new water cooled molds. It should be noted that both the molds and the cooling system were changed as part of this project[67]. The hours of operation for the new molds remain the same based on customer estimates i.e. 1,950 and 420 hours respectively. The cooling cfm required for the air-cooled molds was estimated using a spot measurement of flow, which is similar to the way the site estimated cooling cfm requirements on previous mold replacement projects[68]. The cooling cfm in this case was estimated to be 30 cfm in the base case. The site also used an average kW/cfm value of 0.216 to estimate base case demand and energy use. For the post case chilled water cooling system, the assumption made is that the chiller efficiency is 1 kW/Ton and the cooling requirement of 15,000 Btu/hr. for the water cooled molds is based on 50% of the cooling requirement that was required for a mold double the size of the mold installed in this case[69]. The savings calculation methodology is described briefly below:

Table-2.2.2-3- Base Case- Compressed Air-Cooled Molds

A	B	C	D	E= C X D	F= E x B
Mold #	Run Hours	Cooling Requirement (CFM)/Mold	Average kW/CFM	Demand/Mold (kW/Mold)	kWh Consumption/Mold
Spout Mold 20A	1950	30	0.216	6.5	12,655
24 CR 321 Mold	420	30	0.216	6.5	2,726

Total Base Case kWh Consumption= 15,381 kWh

Table-2.2.2-3- Post Case- Chilled Water-Cooled Molds

[67] Molds used in injection molding can be either air cooled, or water cooled.
[68] As stated in the project documentation.
[69] In reference to a similar project installed previously at the site.

A	B	C	D=C/12,000 Btu/hr.	E (Estimated Chiller kW/Ton)	F= D x E	G= B x F
Mold #	**Run Hours**	**Estimated Cooling Requirement (Btu/Hr)/Mold**	**Cooling Requirement Ton/Mold**[70]	**Estimated kW/Ton**	**Demand/Mold (kW/Mold)**	**kWh Consumption/Mold**
Spout Mold 20A	1950	15,000	1.3	1	1.3	2,438
24 CR 321 Mold	420	15,000	1.3	1	1.3	525

Total Post Case kWh Consumption= 2,963 kWh

Total Energy Savings for EEM-1 and EEM-2[71]
Total Base Case Energy Consumption for EEM-1= 151,428 kWh
Total Base Case Energy Consumption for EEM-2= 15,381 kWh

kW Averaged over Plant Hours[72]= (151,428 kWh + 15,381 kWh)/5,880 Hours
kW Averaged over Plant Hours= 28.4 kW

Total Post Case Energy Consumption for EEM-1= 48,205 kWh
Total Post Case Energy Consumption for EEM-2= 2,963 kWh

kW Averaged over Plant Hours= (48,205 kWh + 2,963 kWh)/5,880 Hours
kW Averaged over Plant Hours= 8.7 kW

Total Demand Savings= 28.4 kW- 8.7 kW
Total Demand Savings= 19.7 kW

Total Energy Savings= Base Case kWh- Post Case kWh
Total Energy Savings= (151,428 kWh + 15,381 kWh) – (48,205 kWh + 2,963 kWh)
Total Energy Savings= 115,641 kWh

LED Lighting and Controls- The savings for this measure was estimated using a custom spreadsheet-based savings calculator tool. The savings calculator considered: fixture savings, control savings, summer, and winter kW reduction. The tracking savings did not account for HVAC interactive effects. The control savings included savings from both occupancy sensors and high-end trimming. The applicant savings spreadsheet used a 24% savings factor for fixtures with occupancy sensors only and uses a 32% savings factor for fixtures with both occupancy sensors and high-end trim controls. Both savings factor values were obtained from the applicant spreadsheet savings calculator and correspond for values in the RI TRM. The general savings algorithm used by the applicant savings calculator tool can be described as shown below:

Baseline Fixture kWh = $\frac{Quantity_B * Wattage_B}{1000} * Applicant\ Operating\ Hours$

Proposed Fixture kWh = $\frac{Quantity_P * Wattage_P}{1000} * Applicant\ Operating\ Hours$

Fixture kWh Savings = $Baseline\ Fixture\ kWh\ - Proposed\ Fixture\ kWh$

[70] Verified similar cooling requirements based on standard industry practice: https://coolingbestpractices.com/industries/plastics-and-rubber/5-sizing-steps-chillers-plastic-process-cooling
[71] The tracking system lists the total savings for EEMs 1 & 2 and does not show a break-down of the savings.
[72] According to the project documentation, the savings was averaged over plant operating hours because the molds do not consistently run at the same time every day, the kW savings was averaged over the entire plant operating hours (7,200 hrs.).

Control kWh Savings = $Proposed\ Fixture\ kW - (\frac{Quantity_P * Wattage_P}{1000} * Applicant\ Operating\ Hours * \%Control\ reduction)$

Total kWh Savings = $Fixture\ kWh\ Savings + Control\ kWh\ Saving$

The applicant savings calculation and the inputs used to estimate the savings is described below in Table 2.2.2-4:

Table 2.2.2-4 Tracking Lighting Savings Calculation

	A	B	C	D	E	F	G=A*B*E/1000	H=C*D*E/1000	I=H*F	J=(G-H)
Space Type	Baseline Quantity	Baseline Watts per Fixture	Installed Quantity	Installed Watts per Fixture	Annual Hours	Controls % Reduction	Baseline kWh	Installed kWh	Control kWh Savings	kWh Fixture Savings
Loading Dock 4&5	3	88	3	49.5	7,000	0%	1,848	1,040	0.00	809
Assembly Area Mezzanine	60	64	60	64	7,000	0%	26,880	26,880	0.00	0
Assembly Stairs	2	60	2	39.8	8,760	0%	1,051	697	0.00	354
Mezzanine Walkway	8	64	8	64	7,000	0%	3,584	3,584	0.00	0
Mezzanine Walkway	2	112	2	49.5	7,000	0%	1,568	693	0.00	875
Mezzanine Walkway Roller Area	6	64	6	64	7,000	0%	2,688	2,688	0.00	0
Tool Room Cut Through	5	64	5	64	7,000	0%	2,240	2,240	0.00	0
Chiller Room #1	4	88	4	49.5	7,000	0%	2,464	1,386	0.00	1,078
Ultrasonic Room #1	4	88	4	49.5	7,000	0%	2,464	1,386	0.00	1,078
Maintenance Department	5	88	5	49.5	7,000	0%	3,080	1,733	0.00	1,348
Maintenance Department	1	60	1	37.4	1,040	0%	62	39	0.00	24
Electric Parts Storage	1	112	1	49.5	2,600	0%	291	129	0.00	163
Electric Parts Storage	1	60	1	24.6	2,600	0%	156	64	0.00	92
Maintenance Storage	4	112	4	49.5	2,600	0%	1,165	515	0.00	650
Cafeteria Back Stairs	2	60	2	39.8	8,760	0%	1,051	697	0.00	354
n/a	0		0	128.2	2,080	0%	-	-	0.00	0
Facilities Department	6	64	6	64	7,000	0%	2,688	2,688	0.00	0
Oil Storage Room	2	64	2	64	7,000	0%	896	896	0.00	0
2nd Floor Office Hall	1	60	1	15.7	3,120	0%	187	49	0.00	138
Mail/Storage/Printer Rooms	2	60	2	19.2	2,080	0%	250	80	0.00	170
IT Room	1	60	1	15.7	2,080	0%	125	33	0.00	92
IT Room 2	3	60	3	19.8	2,080	0%	374	124	0.00	251
Men's/Ladies Rooms	2	88	2	19.8	2,080	0%	366	82	0.00	284
SalesPrivate Offices	6	88	6	32.4	2,600	24%	1,373	505	121.31	867
PAPS Loading Dock Area/Elec Room	5	300	5	128.2	2,080	32%	3,120	1,333	426.65	1,787
PC 1 and High Bays	40	300	40	300	7,000	32%	84,000	84,000	26,880.00	0
Assembly Area Controls	64	33	64	33	7,000	24%	14,784	14,784	3,548.16	0
Assembly Area Mezzanine	60	64	60	64	7,000	24%	26,880	26,880	6,451.20	0
Mezzanine Walkway	8	64	8	64	7,000	24%	3,584	3,584	860.16	0

Mezzanine Walkway Roller Area	6	64	6	64	7,000	24%	2,688	2,688	645.12	0
Supervisor's Office Sindle Mulb Cover	4	30	4	30	2,600	24%	312	312	74.88	0
Supervisor 2 office	2	30	2	30	2,600	24%	156	156	37.44	0
Tool Room Cut through	5	64	5	64	7,000	24%	2,240	2,240	537.60	0
Tool Room Cut through	16	300	16	300	7,000	32%	33,600	33,600	10,752.00	0
Tool Room Office	2	30	2	30	2,600	24%	156	156	37.44	0
Maintenance Room	8	300	8	300	7,000	32%	16,800	16,800	5,376.00	0
Employee Cafeteria	12	30	12	30	7,000	24%	2,520	2,520	604.80	0
High Bay PAPS Area	54	300	54	300	7,000	32%	113,400	113,400	36,288.00	0
Facilities Department	6	64	6	64	7,000	24%	2,688	2,688	645.12	0
Oil Storage Room	2	64	2	64	7,000	24%	896	896	215.04	0
Engineering Private Offices	22	30	22	30	3,120	24%	2,059	2,059	494.21	0
Engineering Open Area	21	30	21	30	3,120	24%	1,966	1,966	471.74	0
Front Private Offices	12	30	12	30	2,600	24%	936	936	224.64	0
Front Conference Room	4	30	4	30	3,120	24%	374	374	89.86	0
Accounting Private Offices	24	30	24	30	3,120	24%	2,246	2,246	539.14	0
Accounting Open Area	13	30	13	30	3,120	24%	1,217	1,217	292.03	0
Sales Office Hall	9	30	9	30	3,120	24%	842	842	202.18	0
Sales Private Office	12	30	12	30	2,600	24%	936	936	224.64	0
Sales Open Area	14	30	14	30	2,600	24%	1,092	1,092	262.08	0
Training Room 1 Areas	10	30	10	30	3,120	24%	936	936	224.64	0
Total	**565**		**565**				**377,270**	**366,859**	**95,537**	**10,412**

The measure resulted in a total energy savings of 105,949 kWh.

The total energy savings for the project as listed in the tracking system was 221,590 kWh and the summer and winter peak demand savings were 3.443 kW and 0.546 kW respectively.

Evaluation Assessment of Applicant Methodology

New molds for the all-electric injection molding machine (IMM)- The evaluators agree with the applicant savings methodology for this measure. The evaluators agree with the applicant methodology of using data loggers to meter the both the hydraulic and electric presses to determine kW draw and operating hours and using inputs such as mold cavitation, cycle time etc. to determine the kWh consumption for the pre and post case.

Replaced the air-cooled molds with water cooled molds- The evaluators agree with the applicant methodology, which was based on production data, data used for similar projects that were installed earlier at the site and reasonable assumptions made in the analysis. The evaluators however found an error in the applicant calculation in the use of the kW/cfm value to estimate baseline energy consumption for the air-cooled molds. This is further discussed in section 2.4 of this report.

LED Lighting and Controls- The evaluators agree with the applicant savings calculation methodology and find it reasonable.

Site Inspection

A site visit was performed on 2/23/2021 to verify the new 48 cavity mold, the chilled water cooling system and the LED lights and controls that were installed as part of the project and to install ElitePRO power loggers to capture trend data (voltage, amperage, and power factor) on the presses in the facility. The evaluators had initial discussions with the Process Engineer (who was the site contact) and learned that the hydraulic presses which ran the old 24 and 32 cavity molds (#321 and #241) that were at the end of their useful lives were on presses #10 and #11 which are both 50HP, 350 Ton hydraulic presses. The new 48 cavity mold was found to be running on Press #23 which is a 330 Ton electric press. The site contact informed the evaluators that the hydraulic presses were running completely different part families at the time of the site visit as opposed to product lines PS 211 and PS 211L that were being run on the presses at the time of the installation of the project. This would mean that the presses have completely different operating profiles, kW draw cycle time and throughput. This would imply that that the comparisons made between the applicant and evaluator baselines would be inconsistent. The evaluators learned that Press #23 (the electric press) was running parts that are very similar to the ones that were running during the project installation and that the production parameters would be consistent with what was claimed in the applicant documentation. Therefore, the evaluators installed an ElitePRO kW logger (XC1808046) on the electric press to monitor its operating profile and kW draw. Additionally, the evaluators also collected annual production and cycle time data onsite.

The evaluators then verified the presses that ran the molds which had their cooling systems replaced from compressed air to chilled water cooling. The evaluators verified that there were no air-cooled molds onsite at the time of the site visit. The evaluators also verified the existence and operation of the molds (“Spout 20A”and “24 CR 321”) which still exist but are now running chilled water for their cooling using the central process chiller for the plant. At the time of the site visit, the molds were being run on Press #41 which is a 110 Ton electric press and Press #11 a 50 HP hydraulic press. The evaluators installed one ElitePRO kW logger (XC1308069) on Press #41 which ran the “Spout 20A” mold and one ElitePRO kW logger (XC1803067) on Press #11 which ran the “24 CR 321” mold. The meters were installed on these presses to gain insight into the operating profile of the presses and to determine run hours. The evaluators then inspected the facility’s chilled water system which consists of two process chillers. Chiller #2 serves most of the presses in the plant and Chiller #1 serves the remainder. The evaluators verified that all presses involved in this project are served by Chiller #2. The operating parameters of the chiller were verified, and it was found that the chiller had an EWT of 60^{o}F, LWT of 64.9^{o}F and CWT of 52.3^{o}F.

The evaluators verified the facility's lighting system. The lighting measure was determined to be non-ops only because the facility's administrative and nonproduction staff had transitioned to work from home due the COVID-19 pandemic. The fixture quantities, space types and control types were verified and confirmed to be the same as what was claimed in the applicant documentation. The evaluators also found that the facility used RTUs (electric air-to-air heat pumps) for both heating and cooling. The facility had no gas fired boilers or RTUs.

The meters were installed at the site for around four weeks. The following section summarizes the principal findings made by the evaluators onsite:

Summary of Site Findings

The evaluators made the following observations on site:

- Based on conversations with the Process Engineer, the evaluators learned onsite that the presses that ran the 24 and 32 cavity molds are now running completely different part families and therefore it would not be an even comparison to compare the pre and post case operations of the presses.
- The facility operating hours were verified to be 24 hours, 7 days per week 52-weeks per year with a two-day shutdown for preventive maintenance during the July 4th weekend.
- The evaluators obtained annual production data, mold inventory, press inventory, cycle time data and associated spec-sheets.
- No air-cooled molds existed in the facility at the time of the site visit. The site contact verified air-cooled molds had previously been used.

The following table lists the parameters verified by the evaluators during the site visit:

Table 5-237. Measure Verification

Measure Name	Verification Method	Verification Result
New molds for the all-electric injection molding machine (IMM)	Verify the existence of the new 48 cavity mold on the all-electric press via physical inspection	The 48-cavity was found to be running on the all-electric press
New molds for the all-electric injection molding machine (IMM)	Verify Cycle times on the all-electric press	Obtained from Period Overall Equipment Effectiveness Report
New molds for the all-electric injection molding machine (IMM)	Collect production data onsite	Collected onsite from Period Overall Equipment Effectiveness Report
Replaced the air-cooled molds with water cooled molds	Verify the existence of air cooled molds onsite via physical inspection	No air cooled molds exist onsite
Replaced the air-cooled molds with water cooled molds	Verify the chiller used for chilled water cooling via physical inspection	Verified. Collected chiller operating parameters

LED Lighting and Controls	Verify the fixture counts claimed in the project files by physical inspection	Verified fixture counts in all spaces
LED Lighting and Controls	Verify the control types claimed in the project files by physical inspection	Verified control types in all spaces

Evaluation Methods and Findings

This section describes the evaluator methods and findings.

Evaluation Description of Baseline

The evaluator reviewed the project files and interviewed the site contact to gather information on the baseline and installed case for the each of the measures installed at the facility that were claimed in the applicant documentation. The evaluators essentially agree with the applicant baseline but found an error in the applicant calculation methodology in one of the measures which is discussed in detail in section 2.4.2 below. The evaluators physically verified the installation of the projects at the site and determined that the measures were categorized appropriately.

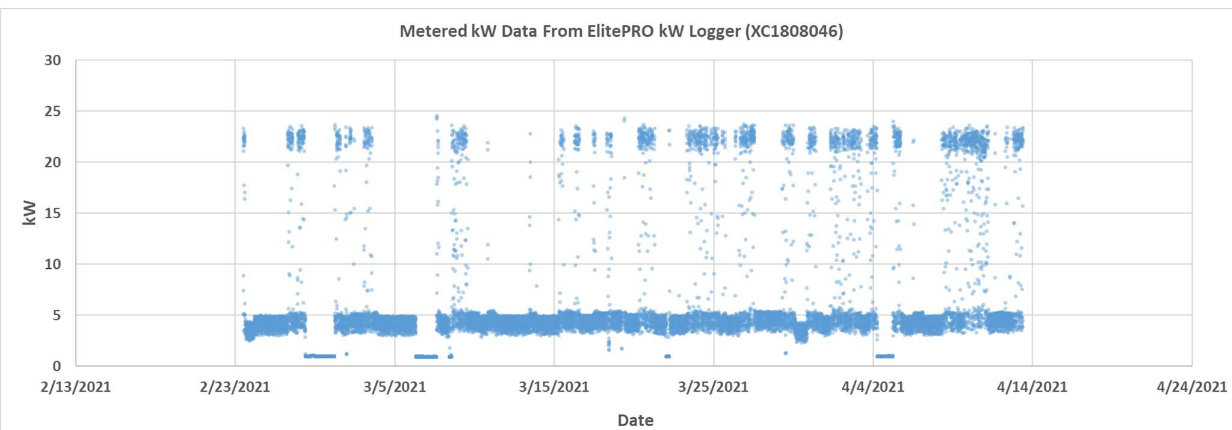
Evaluation Calculation Method

The evaluator savings calculation methodologies for each of the measures is described in detail below:

New molds for the all-electric injection molding machine (IMM)

The evaluators used metered data obtained from the all-electric press which ran the new 48 cavity mold. The logger was installed between February 23rd and April 14th for four weeks. During this period the operating profile of the press from the metered data was observed to be as shown below:

Fig.1- Raw kW Data for All-Electric Press Running the 48-Cavity Mold



From the above figure, we can observe that the electric press runs mostly at a constant load during the metering period with some fluctuation in the kW draw. The metered data was then aggregated into hourly data for each hour of the day and each day of the week to model a typical operating profile over a 24 hour and 7-day timeframe during the metering period. The following heatmap shows the typical operating kW profile of the electric press:

Fig.2- Average Hourly kW draw of the electric press running the 48 Cavity Mold

Operating Profile of Press #23 Running The 48 Cavity Mold							
Hour/Day	Sun	Mon	Tue	Wed	Thu	Fri	Sat
0:00	8.36	3.36	10.20	7.11	6.23	5.74	10.94
1:00	6.06	3.16	5.78	8.44	4.47	4.29	9.79
2:00	5.62	2.89	6.32	6.24	6.57	6.80	9.66
3:00	9.22	2.90	7.87	10.14	4.90	8.64	9.31
4:00	5.51	2.90	6.70	8.38	6.29	5.67	9.51
5:00	6.96	3.40	11.25	5.27	4.40	7.34	5.88
6:00	5.00	6.52	5.45	9.30	5.52	5.65	11.33
7:00	3.42	7.21	8.70	5.75	6.49	6.50	8.16
8:00	2.88	8.10	9.76	7.96	8.60	8.99	11.83
9:00	2.88	8.67	7.94	5.99	5.86	8.25	8.86
10:00	2.87	8.67	7.62	7.59	7.37	6.27	10.26
11:00	2.87	10.85	9.28	7.38	5.79	8.94	8.43
12:00	2.87	5.43	9.25	7.65	8.19	6.26	10.25
13:00	2.89	9.91	9.46	7.61	10.04	6.06	8.72
14:00	2.89	9.52	8.60	6.08	7.11	8.76	6.08
15:00	4.99	8.82	4.15	4.30	6.80	4.60	6.83
16:00	4.12	8.67	4.76	4.75	6.86	10.20	6.85
17:00	4.84	8.31	5.64	4.94	8.27	6.85	6.59
18:00	3.49	7.81	4.13	4.30	6.87	7.94	5.76
19:00	3.40	7.21	4.71	4.25	8.03	9.32	6.08
20:00	3.40	8.63	5.73	4.90	5.89	9.47	8.30
21:00	3.34	7.60	4.96	6.43	6.02	9.70	8.13
22:00	3.35	8.15	6.82	4.40	6.02	7.24	8.30
23:00	3.37	8.86	4.31	4.31	5.00	9.11	8.01

The above heat map shows the operating profile of the electric press. The metered data was then annualized using an 8,760-spreadsheet and the average kW draw of the all-electric press was estimated to be 6.99 kW[73] when in operation. The evaluators found the applicant savings methodology to be reasonable but could not meter the two hydraulic presses that ran the old 24 and 32 cavity molds. Therefore, the evaluators could not use metered data to re-adjust the base case consumption and will not make any adjustment to the base case kW draw of the hydraulic presses. However, the evaluators updated the production data[74] and cycle time that was obtained onsite. The evaluation savings methodology is described below:

Table-2.4.2-1- Base Case- Molds Running in All-Hydraulic Injection Molding Machine:

A	B	C	D	E	F	G=F/C	H=G x E / (60 x 60)	I	J= H x I
Product #	Mold #	Mold Cavitation	Actual Cavitation	Cycle Time (s)	2020 Volume[75]	Cycles	Run Hours	Avg kW[76]	kWh
PS-211	241	24	12.85	30.2	3,013,919	125,579	1,053	32.8	34,554
PS-211L	321	32	28.5	26.9	5,817,379	181,793	1,358	39.8	54,064

Total Base Case kWh consumption= 88,618 kWh

[73] From metered data
[74] Obtained onsite from: *Overall Equipment Effectiveness Report*
[75] Same product ratio as in 2016 relative to total annual production- Per Site contact
[76] No metering was performed because the presses are running completely different part families, so it would not be an even pre-post comparison. Only production data was updated to estimate baseline consumption

Table-2.4.2-2- Post Case- Molds Running in All-Electric Injection Molding Machine:

A	B	C	D	E	F	G=F/C	H=G x E / (60 x 60)	I	J= H x I
Product #	**Mold #**	**Mold Cavitation**	**Actual Cavitation**	**Cycle Time[77] (s)**	**2020 Volume**	**Cycles**	**Run Hours**	**Avg kW[78]**	**kWh**
PS-211	481	48	48	26.9	3,013,919	62,790	469	6.99	3,278
PS-211L	481	48	48	26.9	5,817,379	121,195	905	6.99	6,328

Total Post Case kWh consumption= 9,606 kWh

Demand (kW) Savings:

Base Case kW Savings Averaged over plant hours= 88,618/8,760

Base Case kW Savings Averaged over plant hours= 10.12 kW

Post Case kW Savings Averaged over plant hours= 9,606/8,760

Post Case kW Savings Averaged over plant hours= 1.10 kW

Base Case – Post Case kW= 10.12 kW -1.10 kW

kW Saved= 9.02 kW

Average Summer Peak percent load (From Metered Data) = 1.07

Average Winter Peak percent load (From Metered Data) = 0.972

Total Summer Peak kW= 1.07 x 9.02 kW

Total Summer Peak kW= 9.67 kW

Total Winter Peak kW= 0.972 x 9.02 kW

Total Winter Peak kW= 8.77 kW

Replaced the air-cooled molds with water cooled molds

The evaluators used determined the applicant savings methodology to be reasonable and therefore used the same calculation methods to estimate the evaluation savings. However, during the review of the applicant documentation, the evaluators noticed that the applicant had used a savings factor of 0.216 kW/cfm to estimate the baseline energy consumption of the presses running the compressed air cooled molds. On further investigation, it was found that the applicant had used the 21.6 kW of input power that was saved as a result of a previous compressed air leak project that had been completed earlier at the site, as the savings factor (kW/cfm) per mold that used compressed air cooling[79]. The evaluators observed that this value had been used erroneously and that the 21.6 kW of input power should have been converted to specific power before determining the kW draw per cfm of cooling. Therefore, the evaluators used the compressor CAGI sheet data to model the specific power of the compressor (kW/100acfm) for the given input power of

[77] Verified onsite
[78] From metered data
[79]Refer project RICE18N053. The tracking documentation shows that the compressed air leak audit conducted previously at the site saved 21.6 kW of input power.

21.6 kW using a regression model. The specific power of the compressor at 21.6 kW was found to be at a point on the curve which yields a 18.58 kW/100acfm. Therefore, the kW requirement per cfm would be 0.186 kW/cfm. Here, it should be noted that the applicant documentation states that the methodology used to calculate the savings in this case (as described above) was the same methodology that was used in previously approved mold conversion projects at this facility.

Additionally, the evaluators used metered data to determine the run hours of the two presses which had similar operating profiles. A sample heatmap showing the operating profile of the press running “Spout mold 20A” is shown below:

Fig.3- Operating profile of the press running Spout Mold 20A

Hour/Day	Sun	Mon	Tue	Wed	Thu	Fri	Sat
0:00	0.48	0.48	1.37	1.49	1.28	1.13	1.11
1:00	0.48	0.48	1.49	1.49	1.28	1.07	1.11
2:00	0.49	0.48	1.50	1.49	1.28	1.07	1.05
3:00	0.48	0.48	1.50	1.48	1.28	1.09	1.02
4:00	0.48	0.48	1.49	1.49	1.27	1.28	1.02
5:00	0.48	1.60	1.49	1.48	1.28	1.28	0.96
6:00	0.48	1.11	1.38	1.39	1.20	1.28	0.91
7:00	0.48	1.52	1.29	1.28	1.07	1.25	0.56
8:00	0.48	1.73	1.29	1.28	1.07	1.28	0.65
9:00	0.48	1.54	1.14	1.28	1.07	1.28	0.68
10:00	0.48	1.52	1.09	1.28	1.07	1.34	0.68
11:00	0.48	1.45	1.10	1.28	0.93	1.27	0.68
12:00	0.48	1.51	1.10	1.28	1.08	1.41	0.69
13:00	0.48	1.51	1.25	1.26	1.09	1.50	0.69
14:00	0.48	1.47	1.28	0.93	1.01	1.50	0.69
15:00	0.48	1.29	1.28	0.87	0.86	1.48	0.69
16:00	0.48	1.29	1.28	0.87	0.85	1.27	0.68
17:00	0.47	1.29	1.28	0.86	0.84	1.27	0.68
18:00	0.47	1.29	1.28	0.86	0.84	1.27	0.68
19:00	0.47	1.29	1.28	0.87	0.84	1.27	0.68
20:00	0.48	1.29	1.28	0.86	0.85	1.27	0.68
21:00	0.48	1.29	1.28	0.87	0.87	1.27	0.68
22:00	0.48	1.38	1.36	1.18	0.96	1.26	0.60
23:00	0.48	1.47	1.49	1.28	1.08	1.01	0.48

The evaluators also collected the chiller operational data during the site visit and observed that the chiller had the following operating parameters: the chiller’s entering water temperature was 60°F, Leaving water temperature was 64.9°F, and condenser water temperature was 52.3°F. On looking up the chiller spec-sheet and using the chiller’s operational data described previously, the chiller’s IPLV value was found to be 0.528 kW/Ton[80].

Using the above findings, the evaluators re-adjusted the baseline to determine the pre and post-case kWh consumption as shown below:

Table-2.4.2-3- Base Case- Compressed Air-Cooled Molds

A Mold #	B Run Hours	C Cooling Requirement (CFM)/Mold	D Average kW/CFM	E= C X D Demand/Mold (kW/Mold)	F= E x B kWh Consumption/Mold
Spout Mold 20A	6,426	30	0.186	5.58	35,857
24 CR 321 Mold	6575	30	0.186	5.58	36,689

[80] From Chiller spec sheet.

Total Base Case kWh Consumption= 72,546 kWh

Table-2.4.2-4- Post Case- Chilled Water-Cooled Molds

A	B	C	D=C/12,000 Btu/hr.	E (Estimated Chiller kW/Ton)	F= D x E	G= B x F
Mold #	**Run Hours**	**Estimated Cooling Requirement (Btu/Hr)/Mold**	**Cooling Requirement Ton/Mold**	**Estimated kW/Ton**	**Demand/Mold (kW/Mold)**	**kWh Consumption/Mold**
Spout Mold 20A	6,426	15,000	1.3	0.528	0.69	4,960
24 CR 321 Mold	6575	15,000	1.3	0.528	0.69	4,513

Total Post Case kWh Consumption= 8,924 kWh

Demand (kW) Savings:

Base Case kW Savings Averaged over plant hours= 72,546/8,760

Base Case kW Savings Averaged over plant hours= 8.28 kW

Post Case kW Savings Averaged over plant hours= 8,924/8,760

Post Case kW Savings Averaged over plant hours= 1.02 kW

Base Case – Post Case kW= 8.28 kW -1.02 kW

kW Saved= 7.26 kW

Average Summer Peak percent load (From Metered Data) = 1.06

Average Winter Peak percent load (From Metered Data) = 1.13

Total Summer Peak kW= 1.13 x 7.26 kW

Total Summer Peak kW= 8.28 kW

Total Winter Peak kW= 1.13 x 7.26 kW

Total Winter Peak kW= 8.28 kW

Total Energy Savings for EEM-1 and EEM-2

Total Base Case Energy Consumption for EEM-1 and EEM-2= (72,546 kWh + 88,618 kWh)
Total Base Case Energy Consumption for EEM-1 and EEM-2= 161,114 kWh

Total Post Case Energy Consumption for EEM-1 and EEM-2= (8,924 kWh + 9,606 kWh)
Total Post Case Energy Consumption for EEM-1 and EEM-2= 18,530 kWh

Total Energy Savings= Base Case kWh- Post Case kWh
Total Energy Savings= (161,114 kWh – 18,530 kWh)
Total Energy Savings= 142,634 kWh

The total energy savings for this measure was estimated to be 142,634 kWh

Total Demand Savings:

Summer Peak kW Savings for EEM-1= 9.67 kW

Winter Peak kW Savings for EEM-1= 8.77 kW

Summer Peak kW Savings for EEM-2= 8.28 kW

Winter Peak kW Savings for EEM-2= 7.74 kW

Total Summer Peak kW Savings for EEM-1 and EEM-2= (9.67 kW + 8.28 kW)

Total Summer Peak kW Savings for EEM-1 and EEM-2= 17.95 kW

Total Winter Peak kW Savings= (8.77 kW + 7.74 kW)

Total Winter Peak kW Savings= 16.51 kW

LED Lighting and Controls

The savings for the lighting measure was calculated using a custom lighting spreadsheet calculator. Since this was a non-ops only measure, the evaluators did not install meters during the site visit and hence had no metered operational data. The evaluators included HVAC interactive effects by collecting the heating and cooling system information for each space during the site visit.

The following tables list the evaluated fixture savings and the evaluated control savings. The evaluated interactive heating penalties was found to be 19,515 kWh which is a negative penalty observed due to electric heating during the winter. Therefore, total lighting kWh savings is:

Total Evaluated Lighting kWh savings= Evaluated fixture savings + Evaluated Control Savings

Total Evaluated Lighting kWh savings= 8,656 kWh + 77,778 kWh

Total Evaluated Lighting kWh savings= 86,434 kWh

Table 2.4.2.-5- Evaluated Fixture Savings

	A	B	C	D	E	F	G=A*B*E /1000	H=C*D*E/1000	I=G-H	J	K	L	M=F*J*K*0.8/L	N	O	P	Q=-F*N*0.8*O/P	R=I+M+Q
Space Type	**Baseline Quantity**	**Baseline Watts per Fixture**	**Installed Quantity**	**Installed Watts per Fixture**	**Annual Hours**	**Connected kW Savings**	**Baseline kWh**	**Installed kWh**	**kWh Fixture Savings**	**Percent of Space Cooled**	**Annual Cooling Hours**	**Cooling COP**	**Interactive Cooling Savings**	**Percent of Space Heated**	**Annual Heating Hours**	**Heating COP**	**Interactive Heating Savings**	**Total kWh Fixture Savings**
Loading Dock 4&5	3	88	3	49.5	7,000	0.116	1,848	1,040	808	0%	N/A	N/A	0	100%	2,640	1.5	-163	646
Assembly Stairs	2	60	2	39.8	8,760	0.040	1,051	697	354	0%	N/A	N/A	0	100%	3,308	1.5	-71	283
Mezzanine Walkway	2	112	2	49.5	7,000	0.125	1,568	693	875	0%	N/A	N/A	0	100%	2,640	1.5	-176	699
Chiller Room #1	4	88	4	49.5	7,000	0.154	2,464	1,386	1,078	0%	N/A	N/A	0	100%	2,640	1.5	-217	861
Ultrasonic Room #1	4	88	4	49.5	7,000	0.154	2,464	1,386	1,078	0%	N/A	N/A	0	100%	2,640	1.5	-217	861
Maintenance Department	5	88	5	49.5	7,000	0.193	3,080	1,733	1,348	0%	N/A	N/A	0	100%	2,640	1.5	-271	1,077
Maintenance Department	1	60	1	37.4	1,040	0.023	62	39	24	0%	N/A	N/A	0	100%	368	1.5	-4	19
Electric Parts Storage	1	112	1	49.5	2,600	0.063	291	129	163	0%	N/A	N/A	0	100%	964	1.5	-32	130
Electric Parts Storage	1	60	1	24.6	2,600	0.035	156	64	92	0%	N/A	N/A	0	100%	964	1.5	-18	74
Maintenance Storage	4	112	4	49.5	2,600	0.250	1,165	515	650	0%	N/A	N/A	0	100%	964	1.5	-129	521
Cafeteria Back Stairs	2	60	2	39.8	8,760	0.040	1,051	697	354	0%	N/A	N/A	0	100%	3,308	1.5	-71	283
2nd Floor Office Hall	1	60	1	15.7	3,120	0.044	187	49	138	0%	N/A	N/A	0	100%	1,165	1.5	-28	111
Mail/Storage/Printer Rooms	1	60	1	9.6	2,080	0.050	125	20	105	0%	N/A	N/A	0	100%	764	1.5	-21	84

IT Room	1	60	1	15.7	2,080	0.044	125	33	92	100%	951	3.9	9	0%	N/A	N/A	0	101
IT Room 2	3	60	3	19.8	2,080	0.121	374	124	251	100%	951	3.9	23	0%	N/A	N/A	0	274
Mens/Ladies Rooms	2	88	2	19.8	2,080	0.136	366	82	284	100%	951	3.9	27	100%	764	1.5	-56	255
SalesPrivate Offices	6	88	6	32.4	2,600	0.334	1,373	505	867	100%	1,142	3.9	78	100%	964	1.5	-172	774
PAPS Loading Dock Area/Elec Room	5	300	5	128.2	2,080	0.859	3,120	1,333	1,787	100%	951	3.9	167	100%	764	1.5	-350	1,604
Total	**49**		**49**			**2.78**	**377,156**	**366,809**	**10,347**				**304**				**-1,994**	**8,656**

Table 2.4.2.-6- Evaluated Control Savings

Space Type	Installed Quantity	Installed Watts per Fixture	Annual Hours Reduction	Connected kW	kWh Controls Savings	Percent of Space Cooled	Annual Cooling Hours Reduction	Cooling COP	Interactive Cooling Savings	Percent of Space Heated	Annual Heating Hours Reduction	Heating COP	Interactive Heating Savings	Total kWh Controls Savings
Assembly Area Mezzanine	60	64	1,680	3.84	6,451	0%	N/A	N/A	0	100%	640	1.5	-1,310	5,141
Mezzanine Walkway	8	64	1,680	0.51	860	0%	N/A	N/A	0	100%	640	1.5	-175	685
Mezzanine Walkway Roller Area	6	64	1,680	0.38	645	0%	N/A	N/A	0	100%	640	1.5	-131	514
Facilities Department	6	64	1,680	0.38	645	100%	639	3.9	50	100%	640	1.5	-131	564
Oil Storage Room	2	64	1,680	0.13	215	100%	639	3.9	17	100%	640	1.5	-44	188
SalesPrivate Offices	6	32.4	624	0.19	121	100%	234	3.9	9	100%	239	1.5	-25	106

PAPS Loading Dock Area/Elec Room	5	128.2	666	0.64	427	100%	259	3.9	34	100%	252	1.5	-86	374
PC 1 and High Bays	40	300	2,240	12.00	26,880	0%	N/A	N/A	0	100%	852	1.5	-5,450	21,430
Assembly Area Controls	64	33	1,680	2.11	3,548	0%	N/A	N/A	0	100%	640	1.5	-721	2,827
Supervisor's Office Sindle Mulb Cover	4	30	624	0.12	75	100%	234	3.9	6	100%	239	1.5	-15	65
Supervisor 2 office	2	30	624	0.06	37	100%	234	3.9	3	100%	239	1.5	-8	33
Tool Room Cut through	16	300	2,240	4.80	10,752	0%	N/A	N/A	0	100%	852	1.5	-2,180	8,572
Tool Room Cut through	5	64	1,680	0.32	538	0%	N/A	N/A	0	100%	640	1.5	-109	428
Tool Room Office	2	30	624	0.06	37	100%	234	3.9	3	100%	239	1.5	-8	33
Maintenance Room	8	300	2,240	2.40	5,376	100%	858	3.9	422	100%	852	1.5	-1,090	4,708
Employee Cafeteria	12	30	1,680	0.36	605	100%	639	3.9	47	100%	640	1.5	-123	529
High Bay PAPS Area	54	300	2,240	16.20	36,288	0%	N/A	N/A	0	100%	852	1.5	-7,357	28,931
Engineering Private Offices	22	30	749	0.66	494	100%	289	3.9	39	100%	284	1.5	-100	433
Engineering Open Area	21	30	749	0.63	472	100%	289	3.9	37	100%	284	1.5	-96	414
Front Private Offices	12	30	624	0.36	225	100%	234	3.9	17	100%	239	1.5	-46	196
Front Conference Room	4	30	749	0.12	90	100%	289	3.9	7	100%	284	1.5	-18	79
Accounting Private Offices	24	30	749	0.72	539	100%	289	3.9	43	100%	284	1.5	-109	473
Accounting Open Area	13	30	749	0.39	292	100%	289	3.9	23	100%	284	1.5	-59	256

Sales Office Hall	9	30	749	0.27	202	100%	289	3.9	16	100%	284	1.5	-41	177
Sales Private Office	12	30	624	0.36	225	100%	234	3.9	17	100%	239	1.5	-46	196
Sales Open Area	14	30	624	0.42	262	100%	234	3.9	20	100%	239	1.5	-54	229
Training Room 1 Areas	10	30	749	0.30	225	100%	289	3.9	18	100%	284	1.5	-45	197
Total	**441**			**48.75**	**96,526**				**828**				**-19,515**	**77,778**

HVAC interactive savings were found to be 19,515 kWh. The total energy savings for this measure was found to be 86,434 kWh.

Final Results

The following table summarizes the key parameters that were used in the estimation of savings and compares them with the tracking and post case:

Table 5-238. Summary of Key Parameters

Parameter	BASELINE Tracking Value(s)	BASELINE Evaluation Value(s)	PROPOSED / INSTALLED Tracking Value(s)	PROPOSED / INSTALLED Evaluation Value(s)
Product PS 211 Annual Production	5,145,814	3,013,919	5,145,814	3,013,919
Product PS 211L Annual Production	9,932,301	5,817,379	9,932,301	5,817,379
Spout Mold 20A Run Hours	1,950	7,226	1,950	7,226
24 CR 321 Mold Run Hours	420	6,575	420	6,575
Compressor kW/cfm	0.216	0.186	0.216	0.186
Chiller kW/Ton	1	0.528	1	0.528
Interactive Heating and Cooling (kWh)	0	19,515	0	19,515

Explanation of Differences

This section describes the key drivers behind the difference in the application and evaluation estimates. The major parameters that have caused the differences in the savings are the post case operation of the equipment and the increased efficiency of the cooling system compared to what was considered in the applicant calculation. Additionally, the post case operation resulted in lower kW draw but higher operating hours. For the lighting measure, the HVAC interactive effects were accounted for in the evaluation analysis. It was observed that the reduction in savings was due to heating penalties during the winter due to electric heating which were greater than the additional cooling benefits. Table 3-2 provides a summary of the differences between tracking and evaluated values.

Table 5-239. Summary of Deviations

Measure	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
8716670/ 9153539 Non-lighting	Operation	Post-Case power and Hours	23%	**Increased savings – 26,993 kWh**
10587516 Lighting	Technology	HVAC Interactivity	-18%	**Decreased savings – 19,515 kWh**
		Final Combined RR		**103%**

Ancillary impacts

There are no ancillary impacts.

RICE19L006

Report Date: 05/28/2021

Program	RICE2019	
Application ID(s)	8884147	
Project Type	Existing Building Retrofit	
Program Year	2019	
Evaluation Firm	DNV	DNV
Evaluation Type	Non-Ops only	
Evaluation Engineer	Kristen Schleir	
Senior Engineer	Srikar Kaligotla	

17 Evaluated Site Summary and Results

The application installed internal and external LED lights in a fast food restaurant with no controls. The pre-existing condition consisted of T8 and T12 systems, CFLs, metal halides and a number of LED fixtures. The lighting retrofit generated an annual energy savings of 15,124 kWh, summer peak demand savings of 2.3 kW, and winter peak savings of 1.7 kW. The evaluation results are presented in Table 1-1.

The site was not operating under normal conditions due to the Pandemic. Therefore, this evaluation does not include any metered data or operational data, but it includes verifying measure installed quantities and technologies by an onsite visit.

Table 5-240: Evaluation Results Summary

PA Application ID	Measure Name		Annual Electric Energy (kWh)	Summer On-Peak Demand (kW)	Winter On-Peak Demand (kW)	%On Peak Energy
8884147	Lighting Retrofit	Tracked	15,124	1.9	2.7	54%
		Evaluated	16,421	2.7	1.7	48%
		Realization Rate	109%	142%	63%	89%

17.1 Explanation of Deviations from Tracking

The evaluated savings are 8.9% more than the applicant-reported savings due to the addition of HVAC interactivity which is included in the evaluator's lighting tool but not in the applicant's analysis. Further details regarding deviations from the tracked savings are presented in Section 3-4.

17.2 Recommendations for Program Designers & Implementers

There are no recommendations currently.

17.3 Customer Alert

No alerts.

18 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 internal LED fixtures throughout the applicant's manufacturing floor.

18.1 Application Information and Applicant Savings Methodology

This section describes the applicant's application information, savings methodology, and evaluation assessment of the applicant's savings calculation algorithm. Project savings were generated from a reduction in fixture wattage.

18.2 Applicant Description of Baseline

This project is classified as a lighting retrofit project in the application. The pre-existing condition consisted of T8 and T12 systems, CFL’s, metal halides and a number of LED fixtures. These fixtures ran from 500 to 6,205 annual hours.

Table 5-241: Applicant baseline key parameters

Measure	Parameter	BASELINE Value(s)	Source of Parameter Value	Note
Lighting Retrofit	Fixture Wattage	Varies	Project Files	None
Lighting Retrofit	Fixture Quantity	85	Project Files	None
Lighting Retrofit	Operating Hours	6205 (internal), 4380 (external)	Project Files	None

18.2.1 Applicant Description of Installed Equipment and Operation

The facility upgraded its lighting system by retrofitting older fixtures with LEDs of varying wattages. Operating schedules and fixture counts observed in the baseline description are maintained for the installed fixtures. Project savings were generated from the installation of LED fixtures.

Table 5-2: Application proposed key parameters

Measure	Parameter	PROPOSED Value(s)	Source of Parameter Value	Note
Lighting Retrofit	Fixture Wattage	Varies	Project Files	None
Lighting Retrofit	Fixture Quantity	85	Project Files	None
Lighting Retrofit	Operating Hours	6205 (internal), 4380 (external)	Project Files	None

18.2.2 Applicant Energy Savings Algorithm

Savings were calculated using a custom lighting savings excel workbook using the following equations. The primary driver for this measure's energy savings is a reduction in fixture/lamp wattage. No controls were installed as a part of this project. Energy savings algorithms are as follows:

$$\text{Fixture kWh Savings} = Pre-existing\ Fixture\ kWh - Retrofit\ Fixture\ kWh$$

$$\text{Pre-existing Fixture kWh} = \frac{Quantity_B * Wattage_B}{1000} * Pre-retrofit\ Operating\ Hours$$

$$\text{Retrofit Fixture kWh} = \frac{Quantity_P * Wattage_P}{1000} * Pre-retrofit\ Operating\ Hours$$

Table 5-3: Applicant baseline key parameters

	A	B	C	D	E	F=A*B*E /1000	G=C*D*E/1000	H	H=F-G
Space Type	**Baseline Quantity**	**Baseline Watts per Fixture**	**Installed Quantity**	**Installed Watts per Fixture**	**Annual Hours**	**Baseline kWh**	**Installed kWh**	**Control kWh Savings**	**kWh Fixture Savings**
Dining area	12	9 (LED)	12	8	6,205	670	596	0	74
Dining area	26	60	26	32	6,205	9,679	5,162	0	4,517
Dining area	1	25	1	8	6,205	155	50	0	105
Dining area	4	25	4	6	6,205	620	149	0	472
Above counter	4	88	4	32	6,205	2,184	794	0	1,390
Employee only storage	1	88	1	32	6,205	546	199	0	347
Above lemonade	2	25	2	8	6,205	310	99	0	211
Back kitchen area	17	60	17	32	6,205	6,329	3,375	0	2,953
Back kitchen area	1	88	1	32	6,205	546	199	0	347
Back office	1	60	1	32	6,205	372	199	0	174
Men's room	2	60	2	32	6,205	745	397	0	347
Women's room	2	60	2	32	6,205	745	397	0	347
Entrance/exit lobby	2	60	2	32	6,205	745	397	0	347
Exterior	4	122	4	75	4,380	2,137	1,314	0	823
Exterior	2	80	2	30	4,380	701	263	0	438
Exterior double side pylon	2	135	2	65	4,380	1,183	569	0	613
Exterior	1	340	1	120	4,380	1,489	526	0	964
Exterior flag pole	1	190	1	41	4,380	832	180	0	653
Total	**85**		**85**			**29,988**	**14,863**	**-**	**15,124**

18.2.3 Evaluation Assessment of Applicant Methodology

The evaluator agrees with the analysis approach used by the applicant.

18.3 Onsite Inspection

The evaluator completed an onsite visit on May 6th, 2021 and verified quantities and technology in all spaces listed in Table 5-241 except Employee only Storage and Back Office space.

18.3.1 Summary of Site Visit Findings and Metering

The evaluator did not install any meters as the facility is impacted by the Pandemic. There were were no discrepancies in quantities and technology found onsite. For cooling and heating, the facility uses a Packaged Roof top unit with heating by natural gas.

18.3.2 Measured and Logged Data

No metering or trend data available for this site.

18.4 Evaluation Methods and Findings

This section describes the evaluator methods and findings.

18.4.1 Evaluation Description of Baseline

Baseline condition for this retrofit project consisted of T8 and T12 systems, CFL's, metal halides and a number of LED fixtures. The application includes savings due to HVAC interactive effects. The application documentation does not list pre-existing lighting controls. The evaluator reviewed the project files and interviewed the site contact. A site visit to gather information on the baseline was conducted.

18.4.2 Evaluation Metered Data and Analysis Methodology

The evaluator calculated the savings using a similar approach to the applicant. The evaluator used a similar approach to the applicant and used DNV's custom lighting tool to determine the evaluated savings which includes HVAC interactivity. The savings algorithms used in the tool are as follows:

Baseline Fixture kWh = $\frac{Quantity_B * Wattage_B}{1000} * Evaluated\ Operating\ Hours$

Proposed Fixture kWh = $\frac{Quantity_P * Wattage_P}{1000} * Evaluated\ Operating\ Hours$

Fixture kWh Savings = $Baseline\ Fixture\ kWh - Proposed\ Fixture\ kWh$

HVAC Interactive Fixture Savings =
$(pre\ connected\ kW - post\ connected\ kW) * Coincident\ Occupied\ Cooling\ Hours * \frac{0.8}{Cooling\ COP}$

Total kWh Savings = $Fixture\ kWh\ Savings + HVAC\ Interactive\ Fixture\ Savings + Control\ kWh\ Savings$

All spreadsheets used to estimate evaluation savings will be made available to the PAs for review at their request. For site cooling hours, the evaluator assumed cooling would only occur between May and October. For each hourly interval within that range of months in the 8760 model, if dry bulb temperature taken from local TMY3 data was greater than or equal to the cooling balance point of 65°F, then that hour was determined to be a cooling hour. Cooling hours that coincided with the lighting hours were used to determine total annual cooling savings. The cooling COP is assumed to be 2.93 for the Packaged System that serves the space.

19 Final Results

This section will summarize the evaluation results determined in the analysis above. The evaluator's estimated savings values result from observed changes to the applicant's pre and post-cases. Table 5-242 shows the evaluation inputs and savings calculations for the fixtures in the recreation center and arena, respectively.

Table 5-242. Evaluation Fixture Inputs and kWh Savings

	A	B	C	D	E	F	G=A*B*E /1000	H=C*D*E /1000	I=G-H	J	K	L	M=F*J*K*0.8 /L	N=I+M
Space Type	**Baseline Quantity**	**Baseline Watts per Fixture**	**Installed Quantity**	**Installed Watts per Fixture**	**Annual Hours**	**Connected kW Savings**	**Baseline kWh**	**Installed kWh**	**kWh Fixture Savings**	**Percent of Space Cooled**	**Annual Cooling Hours**	**Cooling COP**	**Interactive Cooling Savings**	**Total kWh Fixture Savings**
Dining area	12	9	12	8	6,205	0.012	670	596	74	100%	2,612	2.93	9	83
Dining area	26	60	26	32	6,205	0.728	9,679	5,162	4,517	100%	2,612	2.93	519	5,036
Dining area	1	25	1	8	6,205	0.017	155	50	105	100%	2,612	2.93	12	118
Dining area	4	25	4	6	6,205	0.076	620	149	472	100%	2,612	2.93	54	526
Above counter	4	88	4	32	6,205	0.224	2,184	794	1,390	100%	2,612	2.93	160	1,550
Employee only storage	1	88	1	32	6,205	0.056	546	199	347	100%	2,612	2.93	40	387
Above lemonade	2	25	2	8	6,205	0.034	310	99	211	100%	2,612	2.93	24	235
Back kitchen area	17	60	17	32	6,205	0.476	6,329	3,375	2,953	100%	2,612	2.93	339	3,293
Back kitchen area	1	88	1	32	6,205	0.056	546	199	347	100%	2,612	2.93	40	387
Back office	1	60	1	32	6,205	0.028	372	199	174	100%	2,612	2.93	20	194
Men's room	2	60	2	32	6,205	0.056	745	397	347	100%	2,612	2.93	40	387
Women's room	2	60	2	32	6,205	0.056	745	397	347	100%	2,612	2.93	40	387
Entrance/exit lobby	2	60	2	32	6,205	0.056	745	397	347	0	0	0	0	347
Exterior	4	122	4	75	4,380	0.188	2,137	1,314	823	0	0	0	0	823
Exterior	2	80	2	30	4,380	0.100	701	263	438	0	0	0	0	438
Exterior double side pylon	2	135	2	65	4,380	0.140	1,183	569	613	0	0	0	0	613
Exterior	1	340	1	120	4,380	0.220	1,489	526	964	0	0	0	0	964
Exterior flagpole	1	190	1	41	4,380	0.149	832	180	653	0	0	0	0	653
Total	**85**		**85**			**2.672**	**29,988**	**14,863**	**15,124**				**1,297**	**16,421**

19.1 Explanation of Differences

The evaluation is 8.9% more than the applicant reported savings. Table 3-3 provides a summary of the primary differences between tracking and evaluated values.

Table 3-3: Summary of Key Differences

End-use	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
Lighting	Interactive	HVAC Interactivity	+8.9%	**Increased Savings**- a difference of 1,297 kWh was determined by the inclusion of HVAC interactivity in the evaluator's savings algorithms.

19.1.1 Ancillary impacts

There are no fuel-based ancillary impacts associated with this project.

RICE19L091

Report Date: May 20, 2021

Program Administrator	National Grid
Application ID(s)	5387391
Project Type	New construction performance lighting
Program Year	2019
Evaluation Firm	DNV
Evaluation Analysis Type	Non-ops only
Evaluation Engineer	Ryan Brown
Senior Engineer	Chad Telarico

Evaluated site summary and results

The evaluated project was installed at a university campus and consisted of installing performance lighting as part of a new construction project. Project savings are based on the comparison between the proposed lighting and building code for the identified space (1.20 W/sf for a university building, IECC 2012). The applicant proposal identifies lighting fixtures but does not mention if controls are included.

Due to the COVID-19 pandemic, University occupancy has been severely cut as they took an online approach for classes so operational hours for the lighting measure would be severely reduced compared to a typical year. Based on this information, the evaluation will only consider non-operational impacts such as quantity and technology changes.

The evaluators modelled energy savings based on the given inputs in the lighting proposal, which were vetted on-site during the in-person audit. The site tracking estimated energy savings of 302,413 kWh, 65.2 on peak summer kW and 33.4 on peak winter kW. The evaluated savings are estimated to be 167,659 kWh due to a change in baseline code LPD. The evaluation results are presented in Table 5-42.

Table 5-243. 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)
5387391	**New construction lighting**	**Tracked**	302,413	66%	53.2	53.2
		Evaluated	167,659	64%	29.5	29.5
		Realization rate	55%	97%	55%	55%

Explanation of deviations from tracking

The evaluated savings are lower than the applicant reported savings, primarily due to the reduction in code LPD which is based on the Rhode Island Commercial and Industrial Impact Evaluation of 2013-2015 Custom CDA Installations[81] findings that standard practice is outpacing code. Further details regarding deviations from the tracked savings are presented in Section 3-1.

Recommendations for program designers and implementers

Rather than applying a general operating schedule to the whole building, it is recommended to apply operating schedules to fixtures that coincide with the area type and control scheme installed. For this site, some areas such as classrooms and office spaces were found to be installed with occupancy control. Although IECC 2012 requires occupancy control to be installed to areas such as these, the annual operating schedule for these areas are expected to be reduced compared to the general schedule applied to the whole building.

Customer alert

There are no customer alerts for this project.

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 information available. The project consisted of performance interior lighting as part of a newly constructed building on a college campus.

Application information and applicant savings methodology

This section describes the application information, savings methodology provided by the applicant, and the evaluation assessment of the savings calculation algorithm used by the applicant. Applicant project savings were primarily based on the reduction in lighting power density (LPD) compared to code for the university building.

---

[81] http://rieermc.ri.gov/wp-content/uploads/2019/05/ri_cda_programreport_final.pdf

Applicant description of baseline

The applicant classified the measure as a new construction lighting measure with a single baseline, which is equivalent to code compliance for the identified building type. The baseline code used was 1.20 W/sf LPD for the university building, based on IECC 2012.

Applicant description of installed equipment and operation

The proposed condition for the lighting measure consisted of installing 1,621 LEDs throughout the building. Fixtures ranged between 2 and 144 W and were proposed to operate for 5,680 annual hours. The proposal calculates to a LPD of 0.61 W/sf. Control measures beyond what is required by code were not mentioned as part of the proposal.

Applicant energy savings algorithm

The applicant calculated savings using a custom analysis spreadsheet, which compares the lighting proposal to code compliancy. The lighting energy savings are calculated using the following formula:

$$Annual\ kWh = \frac{\Delta LPD * Area}{1{,}000} * Hours * Diversity\ Factor$$

$$LPD\ Proposed = \frac{\Sigma(Qty * W)}{Area}$$

Where,

$LPD\ baseline$	= 1.2 W/sqft
$LPD\ proposed$	= 0.61 W/sqft
$Area$	= 94,595 sqft
$Diversity\ Factor$	= 95%
$Hours$	= 5,680

The diversity factor represents the percent of time that the equipment operates at maximum load or demand. The 95% factor used is the assumption that the device operates at maximum load approximately 95% of the time that the lights are turned on. Additional details on the applicant algorithm could be found in the project files.

Evaluation assessment of applicant methodology

The applicant correctly used the custom analysis tool for the lighting measure, and the evaluator determined the application calculation methodology reasonable as the proposed inputs and comparison to code was used correctly in the algorithms presented above. IECC 2012 code compliancy is an appropriate baseline in this case as the project design plans are dated in 2015 when IECC 2012 was still adapted. However, findings from the Rhode Island Commercial and Industrial Impact Evaluation of 2013-2015 Custom CDA Installations study found that the energy code requirements for interior lighting power density is not reflective of current standard practices. The DNV GL team's analysis of interior LPD results, factoring in PA program participation, suggests that standard lighting practices exceed the code requirements, which is mostly due to the increased penetration of LEDs. The findings from this study state that on average, the installed lighting LPDs were 0.78 of the code requirements for buildings permitted under IECC 2009. Though this result is for an older adoption of code, the recommendation to come out of the CDA study was to use this factor until a final LPD factor for IECC 2012 was determined under subsequent studies. Therefore, the evaluator deemed it reasonable to apply the 0.78 factor to the baseline code LPD for the evaluation analysis to adjust for the study findings.

On-site inspection

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

Summary of on-site findings

The evaluators conducted a site visit on May 6, 2021. During the site visit, the evaluators interviewed the Associate Director of Facilities and Operation for the university and verified the installed lighting. A summary of the on-site verification is provided in DNV interviewed the facility staff and verified the equipment installed onsite. DNV completed an initial site visit on 4/8/21 to visually verify and collect data on select measures.

Table 5-34 shows the verification method and result for each of the ten measures evaluated within this report.

Table 5-34.

Table 5-244. Measure verification

Measure Name	Verification Method	Verification Result
New construction lighting	Visual audit	Confirmed the installed lighting measure is according to the proposal and operating. Fixture quantities were verified using the lighting electrical plans for the building.

The site visit was spent interviewing the site contact, gathering building electrical plans, and auditing the installed lighting fixtures. The evaluator used the lighting plans to easily break down the provided lighting proposal and determine a sample of fixtures on-site to visually verify, and to ensure the count on the plans is accurate. For the sample verified, the evaluator found the lighting plans to be precise in terms of quantity and fixture, so after the site visit the plans were used more thoroughly to ensure the rest of the fixtures were installed as specified. While on-site the evaluator found a handful of rooms such as offices and suites that were equipped with occupancy sensors. Though areas such as these are required per IECC 2012 to have occupancy controls, annual operating hours for these areas are expected to be reduced compared to the general schedule the applicant applied to the whole building.

Evaluation methods and findings

This section describes the evaluator methods and findings.

Evaluation description of baseline

The evaluator reviewed the project files and interviewed the site contact to gather information on the baseline. The evaluator determined the measure is a new construction single baseline measure where the baseline is code compliancy for the area type established. In this case, code is 1.2 W/sf LPD for the university building based on IECC 2012. A factor will be applied to baseline LPD based on the findings of the Rhode Island Commercial and Industrial Impact Evaluation of 2013-2015 Custom CDA Installations study which suggest that standard lighting practices exceed code requirements. A 0.78 factor will be applied bringing the baseline LPD to 0.936 W/sf.

Evaluation calculation method

The evaluator calculated the savings using the same approach as the applicant but used verified parameters. Considering metering data could not be collected for this site due to changes in operation from COVID, operational impacts are not considered for this application. The savings equations used are presented below:

$$Annual\ kWh = \frac{\Delta LPD * Area}{1{,}000} * Hours * Diversity\ Factor$$

$$LPD\ Proposed = \frac{\Sigma(Qty * W)}{Area}$$

Where,

$LPD\ baseline$	= 1.2 *0.78 = 0.936 W/sqft
$LPD\ proposed$	= 0.61 W/sqft
$Area$	= 94,595 sqft
$Diversity\ Factor$	= 95%
$Hours$	= 5,680

Final Results

The evaluated savings for the lighting project were less than the applicant reported savings due to a change in baseline LPD. All other parameters used in the evaluation were consistent with the application including operational hours, quantity, and wattage. Main factors impacting savings are shown below.

Table 5-245. Main factors impacting savings

Factor	Applicant	Evaluation
Baseline LPD (W/sf)	1.20	0.936
Proposed LPD (W/sf)	0.607	0.607
Quantity	1,621	1,621
Proposed kW	57.47	57.47
Hours	5,680	5,680
Building area (sf)	94,595	94,595
Savings (kWh)	302,413	167,659

Explanation of differences

The evaluated savings are equivalent with the tracked savings. Table 5-51 provides a summary of the differences between tracking and evaluated values.

Table 5-246. Summary of deviations

End-use	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
Lighting	Baseline	LPD	-45%	Decrease in savings due to the change in baseline LPD. The evaluator applied a .78 factor to code LPD, which is based on the findings from the Rhode Island Commercial and Industrial Impact Evaluation of 2013-2015 Custom CDA Installations report that suggests standard practices outpace code LPD.

Ancillary impacts

There are no ancillary impacts associated with this measure.

RICE19L114

Report Date: 5/12/21

Program Administrator	National Grid	
Application ID(s)	9994194	
Project Type	Retrofit	
Program Year	2019	
Evaluation Firm	DNV	DNV
Analysis Type	NON-OPS (with HVAC interactivity)	
Evaluation Engineer	Laengheng Khoun	
Senior Engineer	Chad Telarico	

Evaluated Site Summary and Results

This lighting retrofit project was completed at a mall and mainly involved the cinema and exterior lighting. 581 lighting fixtures were proposed to be replaced with LEDs. The application claimed the lights were split into usage groups of 3128, 5266, 4380, 1564, and 8760 hours. Savings from occupancy and daylight sensors were claimed on some interior lights. No savings from HVAC interactivity were claimed. The tracking savings claims 480,921 kWh annually. Program savings are due to the reduction in wattage when retrofitting baseline fixtures with LEDs and installation of controls..

The site contact reported that the occupancy for the building had been significantly reduced due to the COVID-19 impact. There are occupancy restrictions in the interior spaces, and foot traffic in the mall is generally less than a typical operating year. The evaluators conducted a non-operational visit which included photos of relevant lights, fixtures, and install locations. During the visit, the site evaluator visually confirmed a sample of lights in different usage areas and install locations.

The overall realization rate of energy savings for this project is 102.81%, primarily due to including HVAC interactivity which the tracking estimate did not include. The site tracking estimate was 480,921 kWh, 24.7 on peak summer kW, and 103.1 on peak winter kW. The evaluation estimate is 494,444 kWh, 33.3 on peak summer kW, and 103.1 on peak winter kW. The evaluation results are presented in Table 5-2.

Table 5-247. 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)
9994194	Retrofit Lighting	Tracked	480,921	36%	24.7	108.1
		Evaluated	494,444	65%	33.3	103.1
		Realization Rate	102.81%	156%	135%	95%
Totals		**Tracked**	**480,921**	**36%**	**24.7**	**103.1**
		Evaluated	**494,444**	**65%**	**33.3**	**103.1**
		Realization Rate	**102.81%**	**156%**	**135%**	**100%**

***Lighting and lighting controls savings were not separated and are shown combined.**

Explanation of Deviations from Tracking

The evaluated savings are 2.81% more than the applicant-reported savings due to the addition of HVAC interactivity which is included in the evaluator's lighting tool but not in the applicant's analysis. Further details regarding deviations from the tracked savings are presented in Section 3-4.

Recommendations for Program Designers & Implementers

There are no recommendations for this project.

Customer Alert

There are no customer alerts.

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.

Application Information and Applicant Savings Methodology

This section describes the applicant's description of the baseline and installed equipment, savings methodology, and the evaluation assessment of the savings calculation algorithm used by the applicant. Both applicant and evaluated approaches calculated energy savings based on on-site findings and assumptions. Project savings were primarily based upon the fixture wattage reduction.

Applicant Description of Baseline

The applicant classified the measure as a retrofit with the baseline as the existing condition. The baseline condition for the 581 fixtures was a mix of Metal Halide, High-Pressure Sodium, and T8 fixtures. Annual operating hours were split into usage groups of 3128, 5266, 4380, 1564, and 8760 hours. The applicant documentation does not state whether controls were present as a baseline condition. The

Applicant Description of Installed Equipment and Operation

The applicant proposed installing 581 LED lighting fixtures to replace the existing fixtures. Annual operating hours were consistent with the baseline assumed hours for fixture usage groups. Occupancy and daylighting control savings were claimed for some office spaces.

Applicant Energy Savings Algorithm

The applicant used the National Grid Lighting tool to estimate the tracking savings. Occupancy and daylighting controls were claimed for some spaces in the applicant documentation. The savings are calculated using the formulas shown below:

Baseline Fixture kWh = $\frac{Quantity_B * Wattage_B}{1000} * Applicant\ Operating\ Hours$

Proposed Fixture kWh = $\frac{Quantity_P * Wattage_P}{1000} * Applicant\ Operating\ Hours$

Fixture kWh Savings = $Baseline\ Fixture\ kWh\ - Proposed\ Fixture\ kWh$

Occupancy & Daylighting kWh Savings = $(Proposed\ Fixture\ kW) * Applicant\ Operating\ Hours * Hours\%$

Total kWh Savings = $Fixture\ kWh\ Savings + Control\ kWh\ Saving + Occupancy\ \&\ Daylighting\ kWh\ Savings$
Where,

Hours % = 32% reduction due to occupancy and daylighting sensors

Table 5-83. Tracking System Fixture Inputs and kWh SavingsTable 5-56. Tracking System Fixture Inputs and kWh Savings below shows the tracking system inputs and savings calculations for the lighting retrofit.

Table 5-248. Tracking System Fixture Inputs and kWh Savings

	A	B	C	D	E	F=A*B*E /1000	G=C*D*E/1000	I=F-G
Space Type	**Baseline Quantity**	**Baseline Watts per Fixture**	**Installed Quantity**	**Installed Watts per Fixture**	**Annual Hours**	**Baseline kWh**	**Installed kWh**	**kWh Fixture Savings**
Exterior	20	95	20	17	4,380	8,322	1,489	6,832
Exterior	3	295	3	55	4,380	3,876	723	3,153
Exterior	4	295	4	80	4,380	5,168	1,402	3,767
Exterior	1	295	1	86	4,380	1,292	377	915
Exterior	1	120	1	55	4,380	526	241	285
Exterior	25	120	25	28	4,380	13,139	3,066	10,073
Exterior	1	190	1	55	4,380	832	241	591
Exterior	16	190	16	60	4,380	13,314	4,205	9,110
Exterior	10	205	10	55	4,380	8,979	2,409	6,570
Exterior	1	205	1	20	4,380	898	88	810
Exterior	38	205	38	41	4,380	34,118	6,824	27,295
Exterior	94	675	94	250	4,380	277,896	102,924	174,971
Exterior	24	1080	24	300	4,380	113,523	31,534	81,989
Exterior	2	1080	2	215	4,380	9,460	1,883	7,577
Cinema/Common	26	60	26	22	5,266	8,215	3,012	5,203
Cinema/Common	8	295	8	83	5,266	12,428	3,497	8,931
Cinema/Common	20	52	20	16	5,266	5,477	1,685	3,792
Cinema/Common	14	52	14	19	5,266	3,834	1,401	2,433
Cinema/Common	94	190	94	16	5,266	94,053	7,920	86,133
Cinema/Common	3	205	3	24	5,266	3,239	379	2,860
Cinema/Common	46	76	46	23	5,266	18,410	5,572	12,839
Cinema/Common	17	100	17	11	5,266	8,952	985	7,968
Service Areas/Common	6	112	6	50	8,760	5,886	2,628	3,259
Mechanical Areas	27	112	27	50	1,564	4,730	2,112	2,618
Mechanical Areas	1	30	1	11	1,564	47	17	30
Mechanical Areas	4	190	4	41	1,564	1,189	257	932
Office Areas	14	60	14	23	3,128	2,628	1,007	1,621
Office Areas	61	27	61	16	3,128	5,152	3,053	2,099
Total	**581**		**581**			**665,585**	**190,929**	**474,656***

*Table does not include additional 6,156 kWh savings from occupancy and daylighting controls. The value reported in Table 3-2 includes control savings. Table 2-3 shows Evaluated Controls Savings.

Evaluation Assessment of Applicant Methodology

The evaluator deemed the applicant savings calculation methodology and assumptions to be reasonable. However, the evaluator notes that the applicant methodology does not include savings from HVAC interactivity.

Inspection

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

Summary of Findings

DNV GL conducted a non-operational visit to the facility on April 13th, 2020. The facilities manager familiar with the project showed the evaluator the relevant lights listed in the documentation. The evaluator verified a sample of lights in each space type / install location across the interior and exterior sections of the mall. The evaluator created a sample of about 50% of the lights claimed in the application grouped by location and operating hours. The evaluator was able to count and take photos of the relevant lights in the sample. The evaluator was able to verify lights in each location and operating hour group. The evaluator confirmed all lights in the targeted sample were installed and were able to verify an additional 25% of the total installed lights while on-site. Overall, the evaluator was able to verify 75% of the proposed lights as claimed in the application. Areas that were claimed to have occupancy and daylighting controls were confirmed to have functioning occupancy controls. The evaluator verified that occupancy and daylighting sensors were present in the applicable areas as claimed in the application. The site contact confirmed that those spaces had no prior controls before the fixtures were replaced. The site contact confirmed the hours and usage groups for each space type were accurate for a typical year. The contact noted that their operating schedule this year was not typical because of changes related to COVID-19 safety. The contact reported lesser hours in cinema spaces and less occupancy in the hallways. However, since this evaluation did not include on-site M&V metering and usage could not be verified, these claims could not be verified and could not be included as an evaluated discrepancy.

Evaluation Methods and Findings

Evaluation Description of Baseline

The evaluator reviewed the project files and interviewed the site contact to gather information on the baseline. The evaluator determined the lighting measure is a retrofit with a dual baseline measure, where the baseline would be the pre-existing fixtures identified in the lighting audit. The dual baseline for the analysis of lifetime savings follows the model where 1/3 lifetime is attributed to a baseline of the existing fixtures, and 2/3 will be assumed using a 60% of the baseline fixture savings for that remaining period regardless of existing fixture age or reported condition.

Evaluation Calculation Method

The evaluator calculated the savings using a similar approach to the applicant. The evaluator used the Massachusetts Custom Lighting tool to determine the evaluated savings. The savings algorithms used in the tool are as follows:

Baseline Fixture kWh = $\frac{Quantity_B * Wattage_B}{1000} * Evaluated\ Operating\ Hours\ without\ controls$

Proposed Fixture kWh = $\frac{Quantity_P * Wattage_P}{1000} * Evaluated\ Operating\ Hours\ without\ controls$

Fixture kWh Savings = $Baseline\ Fixture\ kWh - Proposed\ Fixture\ kWh$

Control kWh Savings = $Proposed\ Fixture\ kW * (Evaluated\ Operating\ Hours\ without\ controls - Evaluated\ EFL\ Operating\ Hours\ with\ controls)$

HVAC Interactive Fixture Savings = $(pre\ conn\ kW - post\ conn\ kW) * Coincident\ Occupied\ Cooling\ Hours * \frac{0.8}{Cooling\ COP}$

HVAC Interactive Controls Savings = $(post\ conn\ kW * (pre\ coincident\ occupied\ cooling\ hours - post\ coincident\ cooling\ hours) * 0.8)/(Cooling\ COP)$

Total kWh Savings = $Fixture\ kWh\ Savings + Occupancy\ Control\ kWh\ Savings + HVAC\ Interactive\ Fixture\ and\ HVAC\ Interactive\ Control\ Saving$

All spreadsheets used to estimate evaluation savings will be made available to the PAs for review at their request. For site cooling hours, the evaluator assumed cooling would only occur between May and October. For each hourly interval within that range of months in the 8760 model, if dry bulb temperature taken from local TMY3 data was greater than or equal to the setpoint of 55°F, then that hour was determined to be a cooling hour. Cooling hours that coincided with the lighting hours were used to determine total annual cooling savings. The cooling COP is assumed to be 2.9 for the packed unit that served the space. Table 2-2 shows the evaluation inputs and savings calculations for the fixtures.

Table 5-249. Evaluation Fixture Inputs and kWh Savings

Space Type	A Baseline Quantity	B Baseline Watts per Fixture	C Installed Quantity	D Installed Watts per Fixture	E Annual Pre Hours	F Connected kW Savings	G=A*B*E/1000 Baseline kWh	H=C*D*E/1000 Installed kWh	I=G-H kWh Fixture Savings	J % of Space Cooled	K Annual Cooling Hours	L Cooling COP	M=F*J*K*0.8/L Interactive Cooling Savings	N=I+M Total kWh Fixture Savings
Exterior	20	95	20	17	4,380	1.560	8,322	1,489	6,832	100%	1,111	2.9	473	7,306
Exterior	3	295	3	55	4,380	0.720	3,876	723	3,153	0%	1,111	2.9	0	3,153
Exterior	4	295	4	80	4,380	0.860	5,168	1,402	3,767	0%	1,111	2.9	0	3,767
Exterior	1	295	1	86	4,380	0.209	1,292	377	915	0%	1,111	2.9	0	915
Exterior	1	120	1	55	4,380	0.065	526	241	285	0%	1,111	2.9	0	285
Exterior	25	120	25	28	4,380	2.300	13,139	3,066	10,073	0%	1,111	2.9	0	10,073
Exterior	1	190	1	55	4,380	0.135	832	241	591	0%	1,111	2.9	0	591
Exterior	16	190	16	60	4,380	2.080	13,314	4,205	9,110	0%	1,111	2.9	0	9,110
Exterior	10	205	10	55	4,380	1.500	8,979	2,409	6,570	0%	1,111	2.9	0	6,570
Exterior	1	205	1	20	4,380	0.185	898	88	810	0%	1,111	2.9	0	810
Exterior	38	205	38	41	4,380	6.232	34,118	6,824	27,295	100%	1,111	2.9	1,890	29,185
Exterior	94	675	94	250	4,380	39.950	277,896	102,924	174,971	0%	1,111	2.9	0	174,971
Exterior	24	1080	24	300	4,380	18.720	113,523	31,534	81,989	0%	1,111	2.9	0	81,989
Exterior	2	1080	2	215	4,380	1.730	9,460	1,883	7,577	0%	1,111	2.9	0	7,577
Cinema/Common	26	60	26	22	5,266	0.988	8,215	3,012	5,203	100%	1,486	2.9	401	5,604
Cinema/Common	8	295	8	83	5,266	1.696	12,428	3,497	8,931	100%	1,486	2.9	688	9,619
Cinema/Common	20	52	20	16	5,266	0.720	5,477	1,685	3,792	100%	1,486	2.9	292	4,084
Cinema/Common	14	52	14	19	5,266	0.462	3,834	1,401	2,433	100%	1,486	2.9	187	2,620
Cinema/Common	94	190	94	16	5,266	16.356	94,053	7,920	86,133	100%	1,486	2.9	6,634	92,767
Cinema/Common	3	205	3	24	5,266	0.543	3,239	379	2,860	100%	1,486	2.9	220	3,080

Cinema/Common	46	76	46	23	5,266	2.438	18,410	5,572	12,839	100%	1,486	2.9	989	13,828
Cinema/Common	17	100	17	11	5,266	1.513	8,952	985	7,968	100%	1,486	2.9	614	8,581
Service Areas/Common	6	112	6	50	8,760	0.372	5,886	2,628	3,259	100%	1,943	2.9	197	3,456
Mechanical Areas	27	112	27	50	1,564	1.674	4,730	2,112	2,618	100%	450	2.9	205	2,824
Mechanical Areas	1	30	1	11	1,564	0.019	47	17	30	100%	450	2.9	2	32
Mechanical Areas	4	190	4	41	1,564	0.596	1,189	257	932	100%	450	2.9	73	1,005
Office Areas	14	60	14	23	3,128	0.518	2,628	1,007	1,621	100%	1,002	2.9	142	1,762
Office Areas	61	27	61	16	3,128	0.671	5,152	3,053	2,099	100%	1,002	2.9	183	2,283
Total	**581**		**581**			**104.81**	**665,585**	**190,929**	**474,656**				**13,191**	**487,847**

Table 5-3. Evaluation Controls Inputs and kWh Savings

	A	B	C	D=A*B/1000	E=C*D	F	G	H	I=D*F*G*0.8/H	J=E+X
Space Type	**Installed Quantity**	**Installed Watts per Fixture**	**Annual Hours Reduction**	**Connected kW**	**kWh Controls Savings**	**Percent of Space Cooled**	**Annual Cooling Hours Reduction**	**Cooling COP**	**Interactive Cooling Savings**	**Total kWh Controls Savings**
Cinema/Common	20	16	1,685	0.32	539	100%	425	2.9	37	576
Cinema/Common	94	16	1,685	1.50	2,534	100%	425	2.9	174	2,709
Cinema/Common	46	23	1,685	1.06	1,783	100%	425	2.9	123	1,906
Office Areas	14	23	1,001	0.32	322	100%	301	2.9	26	349
Office Areas	61	16	1,001	0.98	977	100%	301	2.9	80	1,057
Total	**581**			**43.71**	**6,156**				**441**	**6,597**

Final Results

The evaluated savings for the lighting project were slightly greater than the applicant-reported savings primarily due to a discrepancy stemming from heating and cooling interaction. Detailed values are shown in Table 5-196. Summary of Key Parameters, comparing changes in the baseline and proposed conditions for both the application and evaluation hours of use for each area.

Table 5-250. Summary of Key Parameters

Parameter	Tracking Value(s)	Evaluation Value(s)
Baseline Fixture Quantity	581	581
Installed Fixture Quantity	581	581
HVAC	Not Included	Heating: Warm Air Cooling: Packaged DX (COP 2.9)
Operating Hours	3128, 5266, 4380, 1564, and 8760 hours	3128, 5266, 4380, 1564, and 8760 hours

Table 5-251. Summary of Savings

ECM	Applicant Savings (kWh)	Evaluator Savings (kWh)
Lighting Retrofit	480,921	494,444

Explanation of Differences

The evaluation is 2.81% more than the applicant reported savings. Table 3-3 provides a summary of the differences between tracking and evaluated values.

Table 5-252. Summary of Energy Savings Deviations

End-use	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
Lighting	Interactive	HVAC Interactivity	+2.81%	**Increased Savings**- a difference of 13,632 kWh was determined by the inclusion of HVAC interactivity in the evaluator's savings algorithms.

Ancillary impacts

For this measure, electric HVAC interaction savings occur in retrofitting the fluorescent fixtures to LED. The tracking estimate did not include HVAC interactive effects. These effects resulted in an additional 13,632 kWh of savings.

RICE19L175

Report Date: June 1, 2021

Program Administrator	National Grid
Application ID(s)	9010772, 7467071
Project Type	Exterior lighting retrofit
Program Year	2019
Evaluation Firm	DNV
Evaluation Engineer	Ryan Brown
Senior Engineer	Stephen Carlson

DNV

Evaluated site summary and results

The evaluated project is for a large city where pre-existing non-LED streetlighting fixtures were replaced with LED fixtures and dimming controls. Per the application documentation, the project upgraded all streetlights throughout the city to LED lighting. The kWh reduction for this site is attributed to the fixture wattage reduction when retrofitting to LED. Further savings are achieved from the reduction in wattage due to scheduled dimming controls for all fixtures, which is programmed and managed through an EMS platform.

The evaluation for this site is a full scope measurement and verification site as the streetlights were not impacted by the COVID-19 pandemic. Lights still operated under normal parameters and dimmed schedules. The evaluator used the extensive EMS platform to capture trend data for a sample of fixtures, which were used to make operational adjustments in the evaluation analysis.

The evaluators modelled energy savings based on on-site parameters and EMS report dimming levels, which were vetted on-site during the in-person audit. The site tracking estimated energy savings of 1,070,627 kWh, 0.00 on peak summer kW and 96.0 on peak winter kW. The evaluated savings are estimated to be 1,025,640 kWh. The evaluation results are presented in Table 5-42.

Table 5-253. 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)
9010772/7467071	**Lighting retrofit**	**Tracked**	795,535	25%[82]	0.0	171.25
		Evaluated	737,745	21%	0.0	10.4
		Realization rate	93%	84%	N/A	11%
9010772/7467071	Lighting controls	Tracked	275,090	N.R.[1]	0.00	0.00
		Evaluated	291,431	7%	0.00	1.35
		Realization rate	106%	N/A	N/A	N/A
Total	**Total**	**Tracked**	**1,070,627**	**19%**	**0.00**	**171.25**
		Evaluated	**1,029,176**	**17%**	**0.00**	**11.7**
		Realization rate	**96%**	**89%**	**N/A**	**7%**

N.R = Not reported by program

Explanation of deviations from tracking

The evaluated savings are lower than the applicant reported savings, primarily due to a reduction in fixture operational hours based on EMS trend data. The evaluated peak kW savings are also lower than the applicant reported peak savings due to the low winter diversity factors calculated from the EMS derived lighting schedules. Further details regarding deviations from the tracked savings are presented in Section 3-1.

Recommendations for program designers and implementers

There are no recommendations at this time.

[82] Note the 25% on peak savings is for the full tracking estimate. There is not a separate tracking estimate for controls.

Customer alert

There are no customer alerts for this project.

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 information available. The project consisted of an exterior streetlighting retrofit throughout a large city.

Application information and applicant savings methodology

This section describes the application information, savings methodology provided by the applicant, and the evaluation assessment of the savings calculation algorithms used by the applicant. Both applicant and evaluated approaches calculated energy savings based on the lighting proposal, and on-site findings. Project savings were primarily based on the reduction in wattage when retrofitting pre-existing fixtures with LEDs and dimming controls.

Applicant description of baseline

The applicant classified the measure as a retrofit with a single baseline, where the baseline includes the pre-existing lighting fixtures operating without controls. The pre-existing fixtures include quantity 3,684, 50 W to 1,000 W high pressure sodium and mercury vapor fixtures operating at an assumed operating schedule of 4,175 annual hours.

Applicant description of installed equipment and operation

The proposed condition for the lighting measure consisted of a one for one retrofit where all 3,684 fixtures were replaced with LEDs throughout the city. The new fixtures ranged between 43 and 171 W and were proposed to operate for 4,175 annual hours, equivalent with the baseline. Each installed fixture was programmed into a city-wide EMS platform where all fixtures are scheduled to dim at specific levels based on the fixture wattage. The proposed control savings include a 1 kWh per fixture quantity penalty, which is attributed to the power draw due to the controls. It should be noted that upon the post inspection, a total of (8) fixtures were found to not be connected to the control system and therefore did not receive savings due to controls.

Applicant energy savings algorithm

The applicant calculated savings using a custom analysis spreadsheet. The lighting energy savings are calculated using the following formula:

Baseline Fixture kWh = $\frac{Quantity_B * Wattage_{\boldsymbol{B}}}{1000} * Applicant\ Operating\ Hours$

Proposed Fixture kWh = $\frac{Quantity_P * Wattage_{\boldsymbol{P}}}{1000} * Applicant\ Operating\ Hours$

Fixture kWh Savings = $Baseline\ Fixture\ kWh\ - Proposed\ Fixture\ kWh$

Control kWh Savings = $Proposed\ Fixture\ kWh * (1 - \%Operating\ Level_{Control})$

Note: There is an assumed 1 kWh draw for each fixture due to the controls. Also, the percent reduction value is different for all fixture groups. The applicant calculated savings by determining the hours spent at certain operating levels. The evaluator clarified the algorithm by reverse engineering the calculations and determining the average %reduction based on those differing operating levels. The 1 kWh draw is accounted for within the determined % operating level. Table 5-65. Control operating levels below shows the percent reduction value for each fixture group.

Table 5-254. Control operating levels

Baseline wattage	Average %Operating level	Average operating wattage
99 W	72%	71 W
43 W	65%	28 W
62 W	44%	27 W
171 W	89%	152 W

Table 5-66. Tracking System Lighting Inputs and kWh Savings below shows the tracking system inputs and savings calculations for the lighting retrofit. Additional details on the applicant algorithm could be found in the project files.

Table 5-255. Tracking System Lighting Inputs and kWh Savings - Fixtures

	A	B	C	D	E	F=A*B*E /1000	G=C*D*E/1000	I=F-G
Space Type	Baseline Quantity	Baseline Watts per Fixture	Installed Quantity	Installed Watts per Fixture	Annual Hours	Baseline kWh	Installed kWh	kWh Fixture Savings
Streetlighting	1	65	1	171	4,175	271	714	-443
Streetlighting	47	65	47	99	4,175	12,755	19,427	-6,672
Streetlighting	2532	65	2532	43	4,175	687,135	454,566	232,569
Streetlighting	79	65	79	62	4,175	21,439	20,450	989
Streetlighting	1	90	1	99	4,175	376	413	-38
Streetlighting	14	90	14	43	4,175	5,261	2,513	2,747
Streetlighting	1	90	1	62	4,175	376	259	117
Streetlighting	73	130	73	99	4,175	39,622	30,173	9,448
Streetlighting	356	130	356	43	4,175	193,223	63,912	129,311
Streetlighting	144	130	144	62	4,175	78,157	37,275	40,882
Streetlighting	1	1075	1	171	4,175	4,488	714	3,774
Streetlighting	4	1075	4	43	4,175	17,953	718	17,235
Streetlighting	2	455	2	99	4,175	3,799	827	2,973
Streetlighting	14	120	14	43	4,175	7,014	2,513	4,501
Streetlighting	1	120	1	62	4,175	501	259	242
Streetlighting	2	205	2	43	4,175	1,712	359	1,353
Streetlighting	372	295	372	99	4,175	458,173	153,760	304,413
Streetlighting	23	295	23	43	4,175	28,328	4,129	24,199
Streetlighting	19	295	19	62	4,175	23,401	4,918	18,483
Streetlighting	4	460	4	99	4,175	7,682	1,653	6,029
Streetlighting	2	460	2	43	4,175	3,841	359	3,482
Total	**3,692**		**3,692**			**1,595,507**	**799,912**	**795,595**[83]

[83] Fixture kWh savings are off (+60kWh) due to an admin error when inputting fixture application savings into the tracking system.

Table 5-256. Tracking System Lighting Inputs and kWh Savings – Controls

	A	B	C	D	E=(A*B)/1,000*C*(1-D)
Space Type	Installed Quantity	Installed Watts per Fixture	Annual Hours	%Operation	Controls kWh Savings
Streetlighting	1	171	4,175	0.89	80
Streetlighting	47	99	4,175	0.72	5,447
Streetlighting	2532	43	4,175	0.65	157,140
Streetlighting	79	62	4,175	0.45	11,328
Streetlighting	14	43	4,175	0.65	869
Streetlighting	1	62	4,175	0.45	143
Streetlighting	73	99	4,175	0.72	8,459
Streetlighting	356	43	4,175	0.65	22,094
Streetlighting	144	62	4,175	0.45	20,649
Streetlighting	4	43	4,175	0.65	248
Streetlighting	2	99	4,175	0.72	232
Streetlighting	14	43	4,175	0.65	869
Streetlighting	1	62	4,175	0.45	143
Streetlighting	2	43	4,175	0.65	124
Streetlighting	372	99	4,175	0.72	43,109
Streetlighting	23	43	4,175	0.65	1,427
Streetlighting	19	62	4,175	0.45	2,725
Total	**3,684**				**291,431**

Evaluation assessment of applicant methodology

The applicant correctly used the custom analysis tool for the lighting measure, and the evaluator determined the application calculation methodology reasonable as the proposed inputs were used correctly in the algorithms presented above based on site assumptions. The applicant calculated parent and child savings for the fixtures and controls portions of the project using two separate spreadsheets, one for fixtures and one for controls. A total of (8) fixtures were found not to be connected to the control system and therefore did not receive savings for controls.

On-site inspection

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

Summary of on-site findings

The evaluators conducted a site visit on May 10, 2021. During the site visit, the evaluators worked with an electrician and the lighting contractor to verify the streetlighting fixtures and their associated step dimming levels from the EMS. A summary of the on-site verification is provided in DNV interviewed the facility staff and verified the equipment installed onsite. DNV completed an initial site visit on 4/8/21 to visually verify and collect data on select measures.

Table 5-34 shows the verification method and result for each of the ten measures evaluated within this report.

Table 5-34.

Table 5-257. Measure verification

Measure Name	Verification Method	Verification Result
Streetlighting fixtures	Visual audit	Confirmed the installed lighting measure by counting a sample of fixtures and verifying the wattage of the fixture as posted underneath the fixture heads. A total of 724 fixtures were counted which equates to about 20% of the population.
Streetlighting dimming controls via the EMS	Visual audit and spot measurements using a Multimeter	Confirmed the operation of the step dimming schedules by taking spot measurements at a sample of streetlighting poles while throttling the dimmed levels of each fixture. The EMS shows that the lamps are regularly dimmed.

Prior to the site visit, the evaluator worked extensively with the main lighting contractor, who also manages the EMS platform for several cities in the state, as well as the PA review team to ensure all parameters were captured for the site visit. Given the wide breadth of data provided by the EMS platform, the team decided to primarily use EMS trend data for the evaluation analysis, but to spend the site visit confirming operational levels of the step dimming procedure. While on-site the evaluator had the lighting contractor on call to capture the V, A, and PF for each scheduled dimmed level via spot measurements at the fixture using a multimeter. The lighting contractor also vocalized the associated Wattage present on the EMS readings, which were found to match the W calculated using the equation W=V*A*PF[84]. The sample of fixtures were developed to ensure all control schedules were captured, which were found to be based on wattage. For this specific site, four fixture groups were developed based on wattage where controls schedules were the same within each fixture group but vary between others based on differing dimmed levels and hours at each dimmed level. The application file included information on which streets the fixtures are installed, which proved useful when planning the sample strategy for the on-site visit. The fixture sample groups are shown in Table 5-258. Fixture sample groups.

Table 5-258. Fixture sample groups

Group	Product Numbers	Quantity	Wattage	Dimming Step Description
1	BXSP1HOHT2ME100W40KULSVNQ9	494	99	99% output for 1,985 hours, 47% output for 2,190 hours

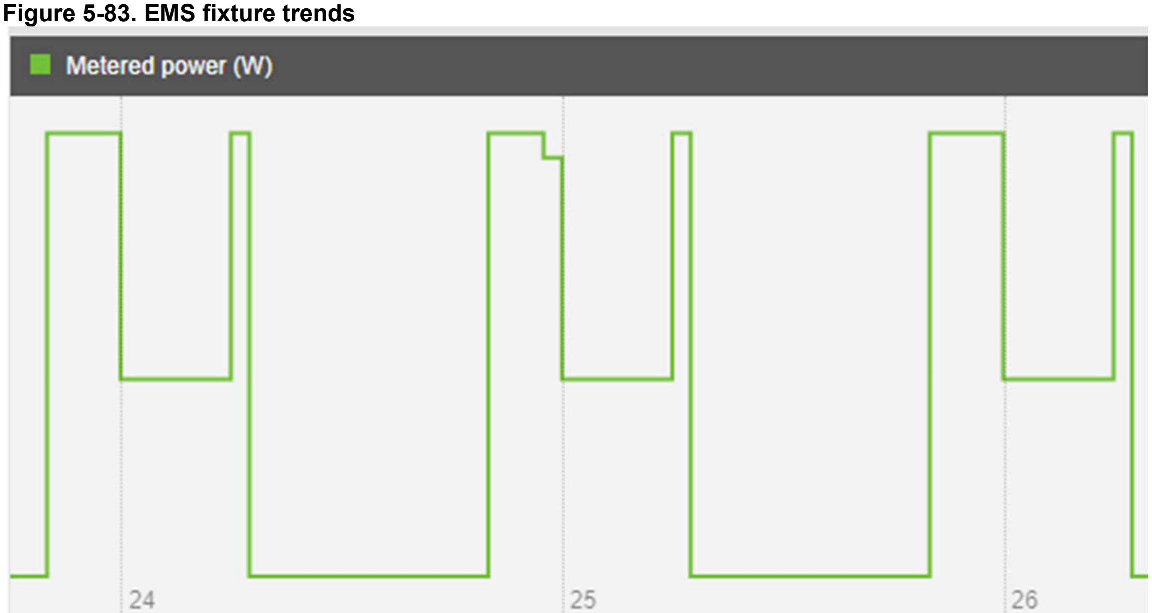
[84] Assumed a power factor of 0.98 for all readings.

Group	Product Numbers	Quantity	Wattage	Dimming Step Description
2	BXSPRA02FC-USN-42W	2,945	43	89% output for 1,985 hours, 43% output for 2,190 hours
3	BXSPRHOHT2ME60W40K&ULSVNQ9	244	62	61% output for 1,985 hours, 29% output for 2,190 hours
4	OSQAUA60DT40KULSVN	1	171	100% output for 1,985 hours, 79% output for 2,190 hours

While on-site, at least two lamps from each of the fixture groups were verified except for group 4 which only included one fixture.

Trend data including wattage and dimmed step levels for each matching fixture were downloaded to be used in the analysis. The following screenshot is an example of the EMS platform for one of the 43 W fixtures mentioned in the above table. Reports could be run to observe wattage fluctuations throughout the day, and a csv file can be pulled to show the periods of change. The screenshot in Figure 2-1 below, shows three days of fixture use. Up to 3 months of data could be downloaded.

Figure 5-83. EMS fixture trends



Spot measurements were conducted at a sample of 6 streetlights (anonymized for reporting purposes) as shown in

Table 5-259. Spot Measurements and EMS Readings below using a multimeter as mentioned above. Most of the measured readings were deemed reasonably close to the EMS readings. For example, in the table below the EMS reading for the fixture on Street 5 at 43% load was found to be 36 Watts while the spot reading was calculated to be 36.3 Watts. However, there are some readings that are not as close (compare Street 7 fixture's EMS and Spot readings). This could be due to the display limitation on multimeter's Amperage reading to only one decimal point (for example, on the Street 5 fixture, if we use 0.34 Amp instead of 0.5 Amp, the calculated spot measurement would be 41.2 Watts instead of 36.3 Watts). Therefore, the evaluator assumed the EMS readings for the sampled streetlights to be true or reasonably close to the actual power draw and deemed the EMS data reasonable to use for the evaluation analysis.

Table 5-259. Spot Measurements and EMS Readings

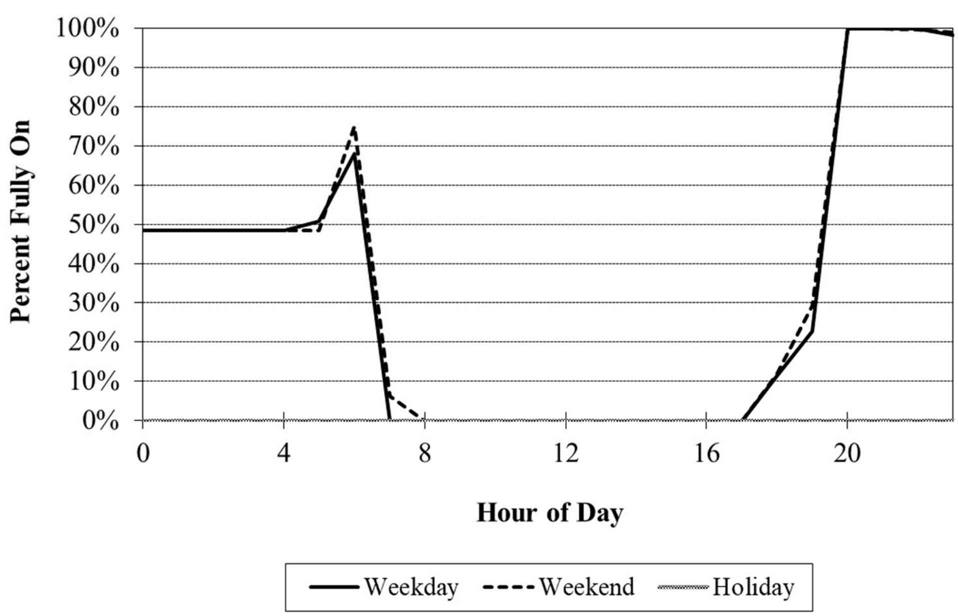
Street #	Rated Watt	EMS Reading 1		Spot Reading 1			EMS Reading 2		Spot Reading 2		
		Watt	Command	Voltage	Amp	Watt[85]	Command 2	Watt	Voltage	Amp	Watt
Street 1	99	100	90	120	0.8	96.9	38	48	120	0.3	36.3
Street 2	99	100	90	121	0.8	97.7	67	48	121	0.4	48.9
Street 3	42	37	67	118	0.3	35.7	31	16	118	0.1	11.9
Street 4	42	37	67	120	0.3	36.3	31	16	120	0.2	24.2
Street 5	62	36	43	120	0.3	36.3	21	19	120	0.2	24.2
Street 6	62	36	43	118	0.3	35.7	21	19	118	0.2	23.8
Street 7	171	176	100	122	1.5	184.7	50	136	122	1.2	147.8

The remainder of the site visit was spent auditing a quantified sample of the streetlighting population. The evaluator audited a total of 10% of the population (a total of 362 fixtures were found across 8 streets compared to the 378 stated in the application) to develop a ratio of audited lights over the applicant population for the audited street. This ratio equated to 95.8 %, which was applied to the remainder of the evaluation proposed quantity.

Measured and logged data

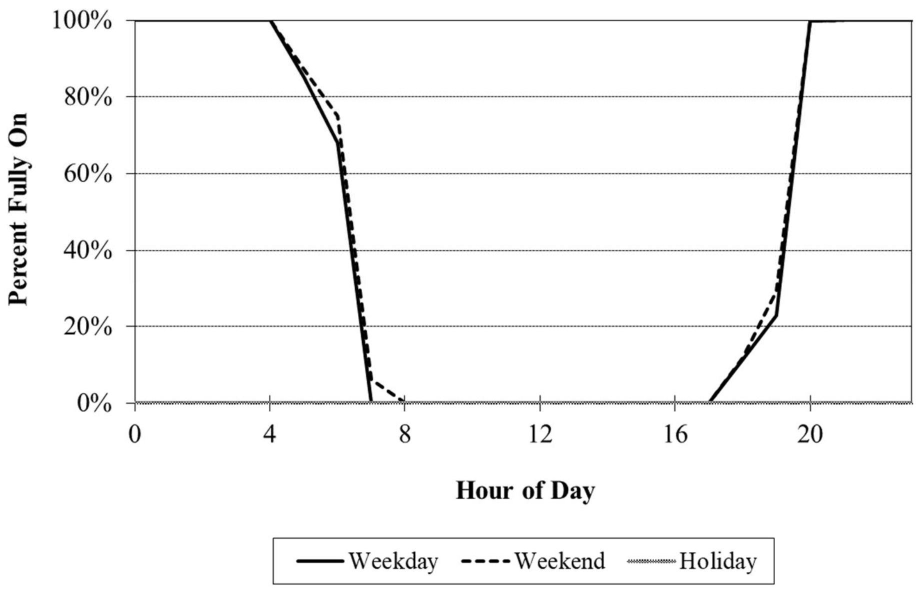
The evaluator used the EMS trend data to calculate an operating profile to show when the fixtures were in use and at what level of dimming. Trend hourly data was expanded to fit a weekly profile. The profiles depict an hourly percent on value that reflects the fixtures operation (on/off) and the percent of full load the fixture is operating for that hourly interval. For each hourly interval, this value was determined by taking the wattage trended at the hour and dividing it by the rated wattage of the fixture to reflect the dimming operation. An example of a logged operating schedule is shown below in Figure 5-29. Logged operating data – 39 W fixture.

Figure 5-84. Logged operating data – 43 W fixture



85 Watt = (Voltage*Amp*0.9998 + Voltage*Amp*0.98*.03); where 0.98 is the power factor and 3% was assumed to the %power drawn from the control system.

Figure 5-85. Baseline operating data – 43 W fixture



The figures above depict the operating profiles developed from the trend data, as well as an assumed baseline non-controlled schedule for the same fixture. The process for developing the baseline schedules will be discussed in the following section. For the analysis, the evaluator expanded the trend data set to an 8,760-operating profile.

Table 5-69. Trend data schedules lists the expanded operating profiles for each of the trended fixtures downloaded from the EMS, as well as the baseline and averaged schedules developed from the trend data.

Table 5-260. Trend data schedules

Schedule ID	Description	Streetlight	EFLH	On-Peak Hours
1	EMS hours	(99) Charles 0267	2,912	837
2	EMS hours	(62) Cleveland 0001	1,701	474
3	EMS hours	(42) Cleveland 0003	2,452	735
4	EMS hours	(62) Garfield 0001	1,729	478
5	EMS hours	(42) Garfield 0002	2,436	727
6	EMS hours	(171) Langberries 0003	3,600	839
7	EMS hours	(99) Minerals 0006	2,482	730
1B	EMS baseline hours	(99) Charles 0267 BL	3,990	838
2B	EMS baseline hours	(62) Cleveland 0001 BL	3,697	730
3B	EMS baseline hours	(42) Cleveland 0003 BL	3,896	809
4B	EMS baseline hours	(62) Garfield 0001 BL	3,700	731
5B	EMS baseline hours	(42) Garfield 0002 BL	3,891	806
6B	EMS baseline hours	(171) Langberries 0003 BL	4,040	839
7B	EMS baseline hours	(99) Minerals 0006 BL	3,895	806
8	Average	99 W Schedule	2,697	783
8B	Average Baseline	99 W BL Schedule	4,046	839
9	Average	62 W Schedule	1,715	476
9B	Average Baseline	62 W BL Schedule	4,040	839
10	Average	42 W Schedule	2,444	731
10B	Average Baseline	42 W BL Schedule	4,040	839

Evaluation methods and findings

This section describes the evaluator methods and findings.

Evaluation description of baseline

The evaluator reviewed the project files and interviewed the lighting contractor to gather information on the baseline. The evaluator determined the lighting measure is a retrofit with a single baseline, where the baseline would be the pre-existing fixtures identified in the lighting audit.

Baseline schedules for dimmed fixtures were developed from EMS trend data assuming that for every hour the fixtures were operating, regardless of dimming level, they would have been operating at 100% output for that hour in the baseline condition. 100% output is equal to the rated max wattage of each fixture.

Evaluation calculation method

The evaluator calculated the savings using a similar approach to the applicant. Trend EMS data was used to determine the operation schedules and effective full load hours for all sampled streetlights. Data was drawn from the EMS and expanded to fit an 8,760-model based on trends in the data. The custom savings equations are presented below:

Baseline Fixture kWh = $\frac{Quantity_{\boldsymbol{B}} * Wattage_{\boldsymbol{B}}}{1000} * Evaluated\ Operating\ Hours\ without\ controls$

Proposed Fixture kWh = $\frac{Quantity_{\boldsymbol{P}} * Wattage_{\boldsymbol{P}}}{1000} * Evaluated\ Operating\ Hours\ without\ controls$

Fixture kWh Savings = $Baseline\ Fixture\ kWh\ - Proposed\ Fixture\ kWh$

Control kWh Savings = $Proposed\ Fixture\ kW\ * (Evaluated\ Operating\ Hours\ without\ controls - Evaluated\ EFL\ Operating\ Hours\ with\ controls)$

Total kWh Savings = $Fixture\ kWh\ Savings + Control\ kWh\ Savings$

All spreadsheets used in the estimation of evaluation savings will be made to the PAs for review at their request.

Final Results

The evaluated savings for the street lighting project were less than the applicant reported savings primarily due to a change in annual operating hours for the fixtures. Other parameters that influenced evaluated savings include the reduction in operating hours due to controls, installed fixture quantity, and a tracking documentation error. Main factors impacting savings are shown Table 5-70.

Table 5-261. Summary of key parameters

	Applicant		Evaluation	
Fixture group	**Baseline Hours**	**Proposed Hours**	**Baseline Hours**	**Proposed Hours**
99 W	4,175	3,004	4,046	2,697
62 W	4,175	1,862	4,040	1,715
43 W	4,175	2,732	4,040	2,444
171 W	4,175	3,710	4,040	3,600

Table 5-71. Evaluation fixture inputs and kWh savings and Table 5-72. Evaluation controls inputs and kWh savings below show the evaluation inputs and savings calculations for the lighting fixtures and controls respectively.

Table 5-262. Evaluation fixture inputs and kWh savings

	A	B	C	D	E	F	G=A*B*E /1000	H=C*D*E/1000	I=G-H
Space Type	Baseline Quantity	Baseline Watts per Fixture	Installed Quantity	Installed Watts per Fixture	Annual Hours	Connected kW Savings	Baseline kWh	Installed kWh	kWh Fixture Savings
Streetlighting	45	65	45	99	4,046	-1.530	11,838	18,030	-6,192
Streetlighting	1	90	1	99	4,046	-0.009	349	384	-35
Streetlighting	70	130	70	99	4,046	2.167	36,772	28,003	8,769
Streetlighting	2	455	2	99	4,046	0.682	3,526	767	2,759
Streetlighting	356	295	356	99	4,046	69.826	425,224	142,702	282,522
Streetlighting	4	460	4	99	4,046	1.383	7,130	1,534	5,595
Streetlighting	1	65	1	171	4,040	-0.102	252	662	-410
Streetlighting	2425	65	2425	43	4,040	53.346	636,809	421,274	215,536
Streetlighting	76	65	76	62	4,040	0.227	19,869	18,952	917
Streetlighting	13	90	13	43	4,040	0.630	4,875	2,329	2,546

	A	B	C	D	E	F	G=A*B*E /1000	H=C*D*E/1000	I=G-H
Space Type	Baseline Quantity	Baseline Watts per Fixture	Installed Quantity	Installed Watts per Fixture	Annual Hours	Connected kW Savings	Baseline kWh	Installed kWh	kWh Fixture Savings
Streetlighting	1	90	1	62	4,040	0.027	348	240	108
Streetlighting	341	130	341	43	4,040	29.661	179,071	59,231	119,840
Streetlighting	138	130	138	62	4,040	9.378	72,433	34,545	37,888
Streetlighting	1	1075	1	171	4,040	0.866	4,159	662	3,498
Streetlighting	4	1075	4	43	4,040	3.953	16,638	666	15,972
Streetlighting	13	120	13	43	4,040	1.032	6,500	2,329	4,171
Streetlighting	1	120	1	62	4,040	0.056	464	240	224
Streetlighting	2	205	2	43	4,040	0.310	1,586	333	1,254
Streetlighting	22	295	22	43	4,040	5.551	26,253	3,827	22,426
Streetlighting	18	295	18	62	4,040	4.240	21,687	4,558	17,129

	A	B	C	D	E	F	G=A*B*E /1000	H=C*D*E/1000	I=G-H
Space Type	Baseline Quantity	Baseline Watts per Fixture	Installed Quantity	Installed Watts per Fixture	Annual Hours	Connected kW Savings	Baseline kWh	Installed kWh	kWh Fixture Savings
Streetlighting	2	460	2	43	4,040	0.799	3,560	333	3,227
Total	**3,536**		**3,536**			**182**	**1,479,346**	**741,600**	**737,745**

Table 5-263. Evaluation controls inputs and kWh savings

	A	B	C	D=A*B/1000	E=C*D
Space Type	Installed Quantity	Installed Watts per Fixture	Annual EFL Hours Reduction	Connected kW	kWh Controls Savings
Streetlighting	45	99	1,349	4.46	6,013
Streetlighting	1	99	1,349	0.09	128
Streetlighting	70	99	1,349	6.92	9,339
Streetlighting	2	99	1,349	0.19	256
Streetlighting	356	99	1,349	35.27	47,593
Streetlighting	4	99	1,349	0.38	512
Streetlighting	2425	43	1,597	104.27	166,471
Streetlighting	13	43	1,597	0.58	920
Streetlighting	341	43	1,597	14.66	23,406

	A	B	C	D=A*B/1000	E=C*D
Space Type	**Installed Quantity**	**Installed Watts per Fixture**	**Annual EFL Hours Reduction**	**Connected kW**	**kWh Controls Savings**
Streetlighting	4	43	1,597	0.16	263
Streetlighting	13	43	1,597	0.58	920
Streetlighting	2	43	1,597	0.08	131
Streetlighting	22	43	1,597	0.95	1,512
Streetlighting	2	43	1,597	0.08	131
Streetlighting	76	62	1,597	4.69	7,489
Streetlighting	1	62	1,597	0.06	95
Streetlighting	138	62	1,597	8.55	13,651
Streetlighting	1	62	1,597	0.06	95
Streetlighting	18	62	1,597	1.13	1,801
Streetlighting	1	171	1,597	0.16	261
Streetlighting	1	171	1,597	0.16	261
Total	**3,536**			**183**	**291,431**

Explanation of differences

The evaluated savings are less than the tracked savings. Table 5-51 provides a summary of the differences between tracking and evaluated values.

Table 5-264. Summary of deviations

End-use	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
Lighting controls	Operation	Annual hours	+1%	Increase in savings (-14,883 kWh) due to the reduced impact on operational schedule due to dimming controls.
Lighting fixtures	Operation	Annual hours	-2%	Decrease in savings (-50,443 kWh) due to the change in baseline fixture operational hours.
Lighting fixtures	Quantity	Quantity	-3%	Decrease in savings (-33,676 kWh) due to the change in quantity. The evaluator found that there were less fixtures installed for the sampled streets compared to tracking.

Ancillary impacts

There are no ancillary impacts associated with this measure as the streetlighting fixtures are exterior.

RICE19L177

Report Date: July 22, 2021

Program Administrator	National Grid	
Application ID(s)	9020546, 7236613	
Project Type	Exterior lighting retrofit	
Program Year	2019	
Evaluation Firm	DNV	
Evaluation Engineer	Jeff Zynda	
Senior Engineer	Srikar Kaligotla	

Evaluated site summary and results

The evaluated project is for a small city where pre-existing high-pressure sodium streetlighting fixtures were replaced with LED fixtures and dimming controls. Per the application documentation, the project upgraded streetlights throughout the city to LED lighting. The kWh reduction for this site is attributed to the fixture wattage reduction when retrofitting to LED. Further savings are achieved from the reduction in wattage due to scheduled dimming controls for all fixtures, which is programmed and managed through an EMS platform.

The evaluation for this site is a full scope measurement and verification site as the streetlights were not impacted by the COVID-19 pandemic. Lights still operated under normal parameters and dimmed schedules. The evaluator used the extensive EMS platform to capture trend data for a sample of fixtures, which were used to make operational adjustments in the evaluation analysis.

The evaluators modelled energy savings based on on-site parameters and EMS reported dimming levels, which were vetted on-site during the in-person audit. The site tracking estimated energy savings of 450,543 kWh, 0.00 on peak summer kW and 49.7 on peak winter kW. The evaluated savings are estimated to be 439,643 kWh. The evaluation results are presented in Table 5-42.

Table 5-265. 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)
9020546,7236613	Lighting retrofit	**Tracked**	369,737	25%	0.0	109.7
		Evaluated	349,088	18%	0.0	0.0
		Realization rate	94.4%	70.8%	N/A	0.0%
	Controls	Tracked	80,806	25%	0.0	0.0
		Evaluated	90,555	2%	0.0	0.0
		Realization rate	112.1%	9.3%	N/A	N/A
Total	**Total**	**Tracked**	**450,543**	**25%**	**0.0**	**109.7**
		Evaluated	**439,643**	**15%**	**0.0**	**0.0**
		Realization rate	**97.6%**	**58.1%**	**N/A**	**0.0%**

N/A = Not applicable

Explanation of deviations from tracking

The evaluated savings are lower than the applicant reported savings, primarily due to a decrease in fixture operating hours, which is partially offset by an increase in the equivalent full load (EFL) hour reduction between the baseline fixtures without controls and the installed fixtures with dimming controls based on EMS trend data.. The evaluated winter peak kW savings are also lower than the applicant reported winter peak savings due to the low winter diversity factors calculated from the EMS derived lighting schedules. Further details regarding deviations from the tracked savings are presented in Section 3-1.

Recommendations for program designers and implementers

There are no recommendations currently.

Customer alert

There are no customer alerts for this project.

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 information available. The project consisted of an exterior streetlighting retrofit throughout a small city.

Application information and applicant savings methodology

This section describes the application information, savings methodology provided by the applicant, and the evaluation assessment of the savings calculation algorithms used by the applicant. Both applicant and evaluated approaches calculated energy savings based on the applicant supplied information and on-site findings. Project savings were primarily based on the reduction in wattage when retrofitting pre-existing high-pressure sodium fixtures with LEDs and dimming controls.

Applicant description of baseline

The applicant classified the measure as a retrofit with a single baseline, where the baseline includes the pre-existing lighting fixtures operating without controls. The pre-existing fixtures include 1,084 high-pressure sodium fixtures operating with wattages ranging from 65 watts to 460 watts and an assumed operating schedule of 4,175 annual hours.

Applicant description of installed equipment and operation

The proposed condition for the lighting measure consisted of a one for one retrofit where all 1,084 fixtures were replaced with LEDs throughout the city. The new fixture wattages ranged from 54 watts to 171 watts and were proposed to operate for 4,175 annual hours, equivalent with the baseline. Most (1,035) of the installed fixtures and 11 pre-existing LED fixtures were programmed into a city-wide EMS platform where all fixtures were assumed to dim by one of five dimming percentages ranging from 17% to 89% of the proposed fixture wattage. The proposed control savings include an annual 1 kWh per fixture penalty, which is attributed to the power draw of the controls.

Applicant energy savings algorithm

The applicant calculated savings using a custom analysis spreadsheet. The lighting energy savings are calculated using the following formula:

Baseline Fixture kWh = $\frac{Quantity_B * Wattage_{\boldsymbol{B}}}{1000} * Applicant\ Operating\ Hours$

Proposed Fixture kWh = $\frac{Quantity_P * Wattage_{\boldsymbol{P}}}{1000} * Applicant\ Operating\ Hours$

Fixture kWh Savings = $Baseline\ Fixture\ kWh\ - Proposed\ Fixture\ kWh$

Control kWh Savings = $(Proposed\ Fixture\ kW * (1 - \%\ Operating\ Level_{Control}) - (Quantity * 1kWh)$

The percent reduction value is different for all fixture groups. The applicant calculated savings by determining the hours spent at certain operating levels. The evaluator clarified the algorithm and determined the average percent reduction based on those differing operating levels. Table 5-65. Control operating levels below shows the percent reduction value for each fixture group.

Table 5-266. Control dimming levels

Baseline wattage	Controlled Fixture Quantity	Average Percent Operating level	Average operating wattage
54 W	874	74%	40 W
99 W	59	71%	71 W
137 W	92	75%	103 W
137 W	4	17%	23 W
171 W	13	17%	29 W
171 W	4	89%	152 W

Table 5-66. Tracking System Lighting Inputs and kWh Savings below shows the tracking system inputs and savings calculations for the lighting retrofit. Additional details on the applicant algorithm could be found in the project files.

Table 5-267. Tracking System Lighting Inputs and kWh Savings

	A	B	C	D	E	F=A*B*E /1000	G=C*D*E/1000	H[86]	I=F-G	J=H+I
Space Type	Baseline Quantity	Baseline Watts/ Fixture	Installed Quantity	Installed Watts/ Fixture	Annual Hours	Baseline kWh	Installed kWh	Control kWh Savings	kWh Fixture Savings	kWh Total Savings
Street Lighting	1	65	1	54	4,175	271	225	0	46	46
Street Lighting	49	295	49	99	4,175	60,351	20,253	5,774	40,097	45,871
Street Lighting	36	295	36	137	4,175	44,339	20,591	5,148	23,748	28,896
Street Lighting	7	295	7	54	4,175	8,622	1,578	0	7,043	7,043
Street Lighting	2	295	2	171	4,175	2,463	1,428	1,183	1,035	2,219
Street Lighting	9	460	9	99	4,175	17,285	3,720	1,060	13,565	14,625
Street Lighting	61	460	61	137	4,175	117,153	34,891	9,903	82,262	92,165
Street Lighting	4	460	4	54	4,175	7,682	902	0	6,780	6,780
Street Lighting	4	460	4	171	4,175	7,682	2,856	311	4,826	5,137
Street Lighting	618	90	618	54	4,175	232,218	139,331	35,921	92,887	128,809
Street Lighting	1	130	1	99	4,175	543	413	118	129	247
Street Lighting	1	130	1	137	4,175	543	572	0	-29	-29
Street Lighting	271	130	271	54	4,175	147,088	61,098	14,880	85,990	100,870
Street Lighting	20	190	20	54	4,175	15,865	4,509	0	11,356	11,356
Street Lighting	11	171	11	171	4,175	7,853	7,853	6,507	0	6,507
Total	**1,095**		**1,095**			**669,958**	**300,222**	**80,806**	**369,737**	**450,543**

[86] These values include a 1 kWh reduction per controlled fixture to account for the power draw for each fixture due to controls.

Evaluation assessment of applicant methodology

The applicant correctly used the custom analysis tool for the lighting measure, and the evaluator determined the application calculation methodology reasonable as the proposed inputs were used correctly in the algorithms presented above based on site assumptions.

On-site inspection

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

Summary of on-site findings

The evaluators conducted a site visit on May 10, 2021. During the site visit, the evaluators worked with an electrician and the lighting contractor to verify the streetlighting fixtures and their associated step dimming levels from the EMS. A summary of the on-site verification is provided in DNV interviewed the facility staff and verified the equipment installed onsite. DNV completed an initial site visit on 4/8/21 to visually verify and collect data on select measures.

Table 5-34 shows the verification method and result for each of the ten measures evaluated within this report.

Table 5-34.

Table 5-268. Measure verification

Measure Name	Verification Method	Verification Result
Streetlighting fixtures	Visual audit	Confirmed the installed lighting measure by counting a sample of 95 fixtures (~9%) across 10 different streets and verifying the wattage of the fixture as posted underneath the fixture heads on 10 different fixtures.
Streetlighting dimming controls via the EMS	Visual audit and spot measurements using a Multimeter	Confirmed the operation of the step dimming schedules by taking spot measurements at a sample (6) of streetlighting poles while modulating the dimmed levels of each fixture. The EMS data that was provided showed when and to what wattage the fixtures were dimmed.

Prior to the site visit, the evaluator worked extensively with the main lighting contractor, who also manages the EMS platform for several cities in the state, as well as the PA review team to ensure all parameters were captured for the site visit. Given the wide breadth of data provided by the EMS platform, the team decided to primarily use EMS trend data for the evaluation analysis, but to spend the site visit confirming operational levels of the step dimming procedure. While on-site, the evaluator had the lighting contractor on call to capture the volts (V) and amps (A) for each scheduled dimmed level via spot measurements at the fixture using a multimeter. The lighting contractor also vocalized the associated Wattage (W) present on the EMS readings, which were found to match the W calculated using the equation W=V*A*PF[87]. For this specific site, the six fixture groups shown in Table 5-258. Fixture sample groups were developed based on wattage where controls schedules were based on differing dimmed levels and hours at each dimmed level. The application file included information on which streets the fixtures are installed, which proved useful when planning the sample strategy for the on-site visit.

Table 5-269. Fixture sample groups

[87] Assumed a power factor of for all readings 0.98.

Group	Product Number	Quantity	Wattage	Baseline Hours	Average % Operating Level	EFL Hours
1	BXSPR-B-HT-S2ME-A-40K-UL-SV-N-Q9	874	54	4,175	74%	3,080
2	BXSP1-HO-HT-2ME-100W-40K-UL-SV-N-Q9	59	99	4,175	71%	2,975
3	BXSPC-HT-2ME-F-40K-UL-SV-N-Q9	92	137	4,175	75%	3,124
4	BXSPC-HT-2ME-F-40K-UL-SV-N-Q9	4	137	4,175	17%	710
5	OSQ-A-UA-60D-T-40K-UL-SV-N	13	171	4,175	17%	710
6	OSQ-A-UA-60D-T-40K-UL-SV-N	4	171	4,175	89%	3,715

Trend data including wattage and dimmed step levels for each matching fixture were downloaded to be used in the analysis. These trend data were then validated using the spot measurements taken on-site using the multimeter as explained below.

Spot measurements were conducted at a sample of 6 streetlights (anonymized for reporting purposes) as shown in the

Table 5-68 below using a multimeter as mentioned above. Most of the measured readings were deemed reasonably close to the EMS readings. For example, in the table below the EMS reading for the fixture on Street 1 at 100% load (no dimming) was found to be 62 Watts while the spot reading was calculated to be 61.1 Watts. However, there are some readings that are not as close (compare Street 5 fixture's EMS and Spot readings for Command 2). This could be due to the display limitation on multimeter's Amperage reading to only one decimal point (for example, on the Street 1 fixture, if we use 0.54 Amp instead of 0.5 Amp, the calculated spot measurement would be 66.0 Watt instead of 61.1 Watt). Therefore, the evaluator assumed the EMS readings for the sampled streetlights to be true or reasonably close to the actual power draw.

Table 5-270: Spot Measurements and EMS readings

Street #	Rated Watt	EMS Reading 1		Spot Reading 1			EMS Reading 2		Spot Reading 2		
		Watt	Command	Voltage	Amp	Watt[88]	Command 2	Watt	Voltage	Amp	Watt
Street 1	54	62	100%	121	0.5	61.1	30%	26	121	0.2	24.4
Street 2	54	62	100%	119	0.5	60.1	30%	26	119	0.2	24.0
Street 3	99	101	100%	116	0.9	105.4	38%	48	119	0.5	57.7
Street 4	99	100	100%	120	0.8	96.9	38%	48	120	0.4	48.5
Street 5	171	161	100%	124	1.3	162.7	40%	81	124	0.7	87.6
Street 6	171	181	100%	118	1.4	166.8	40%	81	118	0.7	83.4

The remainder of the site visit was spent auditing a quantified sample of the streetlighting population. The evaluator audited a total of 9% (95 fixtures across 10 streets) of the population to develop a ratio of audited lights over the applicant population for the audited street, which was applied to the remainder of the evaluation proposed quantity.

Measured and logged data

The evaluator used the EMS trend data to calculate an operating profile to show when and at what dimming level the fixtures were used. Hourly trend data was expanded to fit a weekly profile. The logged operating profile in Figure 5-29. Logged operating data – 39 W fixture depicts the average percent of full load for each hour. For each hourly interval, this value was determined by taking the wattage trended at the hour and dividing it by the rated wattage of the fixture to reflect the dimming operation. Figure 5-30 shows the average percent of full load for each hour in the baseline condition. Since the baseline fixtures did not have dimming controls, this figure also represents the average percent on for each hour.

Figure 5-86. Logged operating data – 54 W fixture

[88] Watt = (Voltage*Amp*0.98 + Voltage*Amp*0.98*.03); where 0.98 is the power factor and 3% was assumed to the %power drawn from the control system.

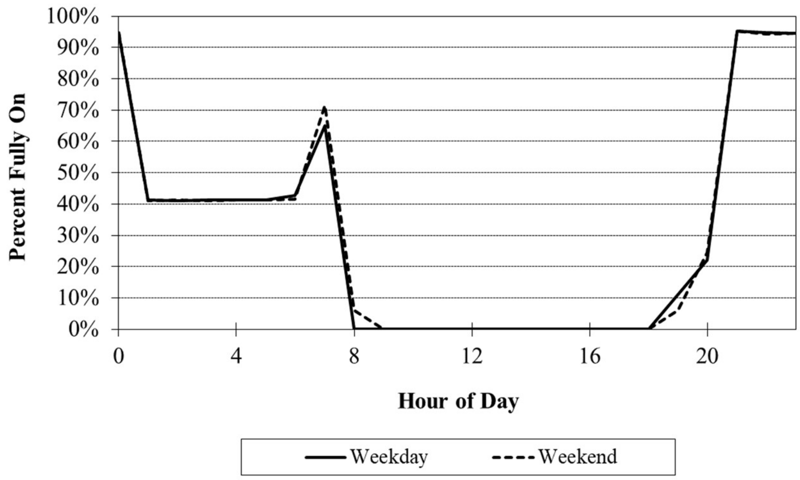
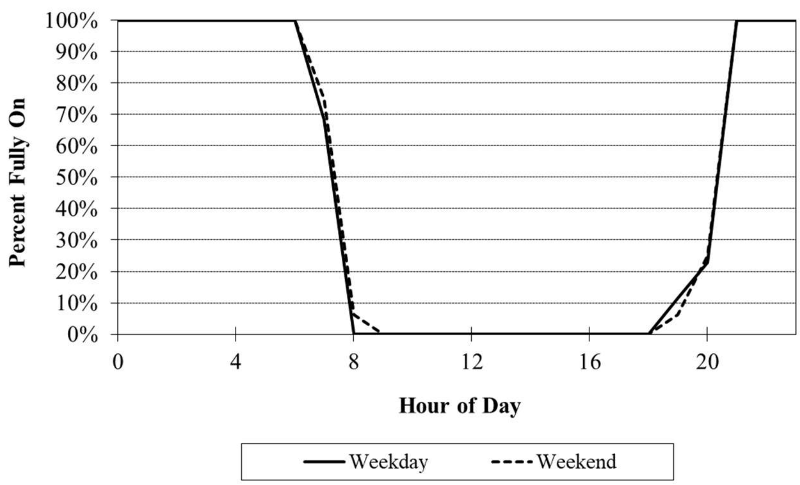


Figure 5-87. Baseline operating data – 54 W fixture



Trend data for 9 individual streetlights sampled across the city at three different rated wattages were downloaded from the vendor's EMS website. For the analysis, the evaluator expanded the trend data set to an 8,760-operating profile.

Table 5-69. Trend data schedules lists the expanded operating profiles for each of the trended fixtures downloaded from the EMS, as well as the baseline and averaged schedules developed from the trend data. The average max watts for each fixture type from the EMS data have been applied as the evaluation installed watts in this analysis.

Table 5-271. Trend data schedules

Schedule ID	Description	(Fixture Wattage) Streetlight	Max Watts from EMS data	EFLH	On-Peak Hours
1	EMS hours	(54) Ayer 0002	63	2,586	720
2	EMS hours	(171) Broad 0127	174	2,938	728
3	EMS hours	(54) Central 0006	60	2,646	720
4	EMS hours	(171) Cross 0022	175	2,866	727
5	EMS hours	(171) Dexter 0051	166	2,810	721
6	EMS hours	(99) Higginson 0002	105	2,853	743
7	EMS Hours	(99) Lonsdale 0103	101	2,848	743
8	EMS Hours	(54) Tremont 0004	60	2,683	728
9	EMS Hours	(99) Washington 0011	102	2,840	740
10	EMS Hours	(137) Broad 0079	153	2,557	531
1B	EMS baseline hours	(54) Ayer 0002 Baseline	63	4,035	759
2B	EMS baseline hours	(171) Broad 0127 Baseline	174	4,035	759
3B	EMS baseline hours	(54) Central 0006 Baseline	60	4,035	759
4B	EMS baseline hours	(171) Cross 0022 Baseline	175	4,035	759
5B	EMS baseline hours	(171) Dexter 0051 Baseline	166	4,035	759
6B	EMS baseline hours	(99) Higginson 0002 Baseline	105	4,035	759
7B	EMS baseline hours	(99) Lonsdale 0103 Baseline	101	4,035	759
8B	EMS baseline hours	(54) Tremont 0004 Baseline	60	4,035	759
9B	EMS baseline hours	(99) Washington 0011 Baseline	102	4,035	759
10	EMS baseline hours	(137) Broad 0079 Baseline	153	3,712	544
11	Average	54 Watt Schedule	61 (Average)	2,658	723
11B	Average Baseline	54 Watt Baseline Schedule	61 (Average)	4,035	759
12	Average	99 Watt Schedule	103 (Average)	2,847	742
12B	Average Baseline	99 Watt Baseline Schedule	103 (Average)	4,035	759
13	Average	171 Watt Schedule	172 (Average)	2,840	726
13B	Average Baseline	171 Watt Baseline Schedule	172 (Average)	4,035	759

Evaluation methods and findings

This section describes the evaluator methods and findings.

Evaluation description of baseline

The evaluator reviewed the project files and interviewed the lighting contractor to gather information on the baseline. The evaluator determined the lighting measure is a retrofit with a single baseline, where the baseline would be the pre-existing fixtures identified in the site documentation without controls.

EFL hours were converted from EMS kW data, assuming that fixtures would have been operating at full output, which is equal to being on 100% for that hour. The evaluator used the rated wattage of each specific fixture to represent 100% output, so anything less would represent a dimmed schedule. Baseline schedules for controlled fixtures were developed assuming that for every hour the fixtures were operating based on the EMS trend data, regardless of dimming level, they would've been operating at 100% output for that hour in the baseline condition.

Evaluation calculation method

The evaluator calculated the savings using a similar approach to the approach used by the applicant. EMS trend data was used to determine the operation schedules and effective full load (EFL) hours for all sampled streetlights. Data was drawn from the EMS and expanded to fit an 8,760-model based on trends in the data. The custom savings equations are presented below:

Baseline Fixture kWh = $\frac{Quantity_B * Wattage_B}{1000} * Evaluated\ Operating\ Hours\ without\ controls$

Proposed Fixture kWh = $\frac{Quantity_P * Wattage_P}{1000} * Evaluated\ Operating\ Hours\ without\ controls$

Fixture kWh Savings = $Baseline\ Fixture\ kWh\ - Proposed\ Fixture\ kWh$

Control kWh Savings = $Proposed\ Fixture\ kW\ * (Evaluated\ Operating\ Hours\ without\ controls - Evaluated\ EFL\ Operating\ Hours\ with\ controls)$

Total kWh Savings = $Fixture\ kWh\ Savings + Control\ kWh\ Savings$

All spreadsheets used in the estimation of evaluation savings will be made to the PAs for review at their request.

Final Results

The evaluated savings for the lighting project are lower than the applicant reported savings primarily due a decrease in fixture operating hours, which is partially offset by an increase in the equivalent full load (EFL) hour reduction between the baseline fixtures without controls and the installed fixtures with dimming controls based on EMS trend data. Installed fixture quantities were found to be consistent with the application. Main factors impacting savings are shown Table 5-70.

Table 5-272. Summary of key parameters

		Applicant			Evaluation		
Fixture group	Qty of Controlled Fixtures	Baseline Hours	Proposed EFL Hours	EFL Hour Reduction	Baseline Hours	Proposed EFL Hours	EFL Hour Reduction
54 Watt	874	4,175	3,080	1,095	4,035	2,658	1,376
99 Watt	59	4,175	2,975	1,200	4,035	2,847	1,188
137 Watt	96	4,175	3,023	1,152	3,712	2,557	1,155
171 Watt	17	4,175	1,417	2,758	4,035	2,782	1,195

Table 5-71. Evaluation fixture inputs and kWh savings and Table 5-72. Evaluation controls inputs and kWh savings below show the evaluation inputs and savings calculations for the lighting fixtures and controls respectively.

Table 5-273. Evaluation fixture inputs and kWh savings

	A	B	C	D	E	F	G=A*B*E /1000	H=C*D*E/1000	I=G-H
Space Type	Baseline Quantity	Baseline Watts per Fixture	Installed Quantity	Installed Watts per Fixture	Annual Hours	Connected kW Savings	Baseline kWh	Installed kWh	kWh Fixture Savings
Street Lighting	1	65	1	54	4,035	0.011	262	218	44
Street Lighting	49	295	49	99	4,035	9.604	58,319	19,571	38,747
Street Lighting	7	295	7	54	4,035	1.687	8,331	1,525	6,806
Street Lighting	2	295	2	171	4,035	0.248	2,380	1,380	1,001
Street Lighting	9	460	9	99	4,035	3.249	16,703	3,595	13,108
Street Lighting	4	460	4	54	4,035	1.624	7,423	871	6,552
Street Lighting	4	460	4	171	4,035	1.156	7,423	2,760	4,664
Street Lighting	618	90	618	54	4,035	22.248	224,399	134,639	89,760
Street Lighting	1	130	1	99	4,035	0.031	524	399	125
Street Lighting	271	130	271	54	4,035	20.596	142,135	59,041	83,095
Street Lighting	20	190	20	54	4,035	2.720	15,331	4,357	10,974
Street Lighting	36	295	36	137	3,712	5.688	39,416	18,305	21,111
Street Lighting	61	460	61	137	3,712	19.703	104,145	31,017	73,128
Street Lighting	1	130	1	137	3,712	-0.007	482	508	-26
Total	**1,095**		**1,095**			**88.558**	**634,864**	**285,776**	**349,088**

Table 5-274. Evaluation controls inputs and kWh savings

	A	B	C	D=A*B/1000	E=C*D
Space Type	**Installed Quantity**	**Installed Watts per Fixture**	**Annual EFL Hours Reduction**	**Connected kW**	**kWh Controls Savings**
Street Lighting	49	99	1,188	4.85	5,761
Street Lighting	9	99	1,188	0.89	1,058
Street Lighting	1	99	1,188	0.10	118
Street Lighting	618	54	1,376	33.37	45,932
Street Lighting	256	54	1,376	13.82	19,027
Street Lighting	2	171	1,195	0.34	409
Street Lighting	4	171	1,195	0.68	817
Street Lighting	11	171	1,195	1.88	2,247
Street Lighting	36	137	1,155	4.93	5,695
Street Lighting	60	137	1,155	8.22	9,492
Total	**1,046**			**69.10**	**90,555**

Explanation of differences

The evaluated savings are lower than the tracked savings. Table 5-51 provides a summary of the differences between tracking and evaluated values.

Table 5-275. Summary of deviations

End-use	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
Lighting fixtures	Operation	Annual hours	-4.6%	Decrease in savings due to the reduction in baseline fixture operational hours.
Lighting controls	Operation	Annual hours	+2.2%	Increase in savings due to a greater impact on operational schedule due to dimming controls.

Ancillary impacts

There are no ancillary impacts associated with this measure as the streetlighting fixtures are exterior.

RICE19N014

Application ID(s)	7864915, 9674245, 9171306, 7257791	
Project Type	C&I Retrofit	
Program Year	2019	
Evaluation Firm	DNV	DNV
Evaluation Analysis Type	Full M&V	
Evaluation Engineer	HJ Wang, Joe St. John	
Senior Engineer	Stephen Carlson	

Evaluated Site Summary and Results

The 250,000 ft building hosts offices and an on-site data center with four conditioned floors, a mechanical penthouse and below-grade parking structures and was built in 1988. The building is typically occupied Monday through Friday from 7:00 am to 5:00 pm. The 4th floor is partially occupied after 5:00 pm, with some staff remaining until 6:00 pm to 7:00 pm. The lower level with the cafeteria and vending areas is unoccupied after 4:00 pm. The building is primarily served by two natural gas condensing boilers for heating and two 300-ton water-cooled centrifugal chillers for cooling.

Due to the complexity of the measure and time constraints limiting the metering period, DNV only evaluated the high impact control upgrades and winter cooling measure and assumed the same realization rate for the non-evaluated measures. Some measures associated with 7257791, 9171306 and 9674245 were not evaluated but represented only 11% of the total savings at this site.

The measures installed include:

<u>7257791/9171306: Retro-commissioning (RCx) and control upgrade.</u>

The list below describes all the installed control upgrade as follows:

a. AHU scheduling. The applicant reported 168,401 kWh/yr savings as a result of reduced ventilation load during unoccupied hours from fan energy, cooling and heating energy (Evaluated)

b. Repair airside economizer. The applicant reported 47,569 kWh/yr savings after repairing the malfunctioning economizer in AHU-1, 2N, 2S, and 4N (Not evaluated)

c. AHU static pressure reset. The applicant reported 5,888 kWh savings by reducing the fan energy consumption during the part-load condition. (Not evaluated)

d. Hot water temperature reset. The measure reduces hot water temperature based on outdoor air temperature (OAT) when less heating load is needed, increasing condensing boiler efficiency and reducing natural gas usage. The applicant reported 64 kWh/yr savings. (Not evaluated)

e. Chilled water (CHW) temperature reset. The measure allows for higher chilled-water temperature based on OAT when the cooling load is small and increases chiller efficiency. The applicant reported 90,253 kWh/yr savings. (Evaluated)

f. Condenser water (CW) temperature reset. The measure allows lower condensing water temperature, which increases the chiller efficiency. The applicant reported 82,867 kWh/yr savings. (Evaluated)

The applicant reported total savings of 395,042 kWh for the RCx measures, 86% of which is evaluated. The realization rate for the evaluated RCx-HVAC control measure is 60%, primarily because the assumption used in the applicant's calculation for building load is different from the evaluated findings. Additionally, the evaluated demand savings is significantly lower than the applicant's claim. It appears the applicant's used different peak hours than the Rhode Island Technical Resource Manual (RI TRM). The measures should show minimal savings during the peak demand period because the measures only reduce energy use during the unoccupied period.

<u>7864915: Installing 30-ton chiller for data center and utilize free cooling in winter.</u>

This measure eliminated the need to run the large 300-ton chillers in winter with hot gas bypass, saving energy. Applicant originally calculated savings assuming installing a new 30-ton chiller and utilizing free cooling in winter and claimed 219,905 kWh/yr savings. However, upon interviewing the site contact and reviewing the metered data, there is no free cooling implemented in winter. The evaluated savings are 115,968 kWh/yr, corresponding to 53% realization rate. Additionally, the evaluated summer demand impact is 0 kW because the new 30-ton chiller will not operate during the summer peak, and the 300-ton chillers will handle both space cooling load from the office and the data center.

<u>9674245: VAV control and Temperature setback during unoccupied hours for the second floor.</u>

The measure reduces the heating and cooling load during unoccupied hours and therefore reduces corresponding energy consumption. The applicant reported 13,342 kWh annual savings. Due to the small amount of savings, DNV did not evaluate this measure. Instead, DNV applies the realization rate for all evaluated measures to the un-evaluated measures.

DNV contacted the site and confirmed that there are no operational changes due to the pandemic and thus started with a full EM&V analysis with on-site metering. The metered data also confirmed the building operation is normal and there is no impact from the pandemic.

The evaluation results are presented in Table 1-1.

Table 5-276. 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)
7257791/ 9171306	RCx - HVAC control (evaluated)	Tracked	341,521	23%	11.2	39.8
		Evaluated - ops	203,240	49%	0.5	0.4
		Realization Rate	60%	128%	4%	1%
7864915	New 30-ton chiller for winter load	Tracked	219,905	19%	15	47.0
		Evaluated - ops	115,968	43%	0	27.1
		Realization Rate	53%	226%	0%	58%
Totals Evaluated (Ops)		**Tracked**	561,426	21%	26.2	86.8
		Evaluated - ops	319,208	47%	0.5	27.5
		Realization Rate	57%	219%	2%	32%
7257791/ 9171306	RCx - HVAC control (Not evaluated)	Tracked	53,521	52%	1.8	6.2
		Evaluated – non-ops	30,430	81%	-0.2	1.5
		Realization Rate	57%	156%	-11%	24%
9674245	VAV control and setback (Not evaluated)	Tracked	13,342	50%	3.1	0.8
		Evaluated – non-ops	7,586	75%	0.1	0.3
		Realization Rate	57%	89%	2%	80%
Totals (Evaluated and not evaluated)		**Tracked**	628,289	17%	31.08	93.81
		Evaluated - ops	357,224	50%	0.4	29.3
		Realization Rate	57%	294%	1%	31%

Explanation of Deviations from Tracking

The applicant's assumptions for building load are different from the evaluated findings. The applicant assumed a building load percentage based on the outdoor temperature. However, based on metered data, the assumption overestimated the building load and, therefore, increased the control upgrade's savings. Additionally, DNV identified that 7257791/ 9171306 double-counted the temperature setback during unoccupied hours for AHU-2N, which is also claimed via measure 9674245. Therefore, DNV removed the double-counted savings from measure 7257791/9171306. For measure 7864915, DNV discovered that free-cooling in winter was never implemented based on the on-site visit and the interview with the site contact. This resulted in a 46% reduction in savings for this measure.

Recommendations for Program Designers & Implementers

Review savings calculation to avoid double-counting or claiming savings for measures that have not been installed. Controls projects should also include more detailed commissioning to verify all measures are working as installed.

Customer Alert

There were no customer alerts.

Evaluated Measures

The following measures were installed:

7257791/9171306: RCx - HVAC control

1. Air handler schedule optimization with an optimal start

Per the application, this measure will implement the operating schedules of the existing AHUs with better controlled occupancy schedules of the associated spaces. Savings are derived from the reduced AHU fan operating hours. The total claimed savings for this measure is 168,401 kWh annually.

2. Repair airside economizer and optimize ventilation control

This measure will eliminate the existing fixed mixed air temperature setpoint and allow the economizer dampers of all existing AHU to utilize the economizer setting to minimize space cooling and heating. In addition, this measure will also repair the outside air dampers and actuators of AHU 1, 2N, 2S and 4N to provide minimum ventilation and proper economizer functionality. Energy savings are derived from the reduced heating and cooling energy resulting from proper economizer operation and a reduction in the minimum outside air quantity where applicable. The total claimed savings for this measure is 47,569 kWh annually.

3. Air handler static pressure reset

Instead of fixed static pressure setpoint between 0.5 to 1 in. WC., among different AHUs, this measure will allow the BAS to determine the optimal static pressure setpoint. The discharge air static pressure reset will also be based on the return air or average space temperature. In order to avoid the potential of these two control strategies fighting each other, the BAS will be programmed with a sequence to prioritize one of them. The total claimed savings for this measure is 5,888 kWh annually.

4. Hot Water System supply temperature reset

The hot water supply temperature is proposed to reset between 160 °F and 130 °F based on outside air temperatures of between 30°F and 65°F, comparing to the pre-existing reset temperature was 180 °F to 145 °F. Energy saving is derived from the higher efficiency of a condensing boiler at low-load and low-return temperatures when the return water is below the dew point temperature of the combustion gases, causing condensation of the water vapor produced during combustion. The total claimed savings for this measure is 64 kWh annually.

5. Chilled water system supply temperature reset

Instead of a fixed leaving CHW temperature (44°F) setpoint, this measure will implement the outside air temperature reset control to allow the leaving CHW temperature setpoint to rise from 44°F to 52°F for outside air temperatures between 70 °F and 50 °F, respectively. The energy savings are derived from a higher leaving water temperature setpoint reducing the chilled water ΔT across the chiller to increase the chiller efficiency for a given load. The total claimed savings for this measure is 90,253 kWh annually.

6. Condenser water system supply temperature reset

Instead of a fixed leaving CW temperature (83°F) setpoint, this measure will implement a new sequence of operations that maintains a leaving CW temperature set point equal to the outside air wet-bulb temperature plus 7.5°F. The range of leaving CW temperature setpoint would be bounded between 55°F and 83°F. The savings are achieved from controlling the tower fans to maintain their design approach temperature allowing the towers to provide the coldest CW temperatures to the chillers, maximizing the chiller efficiency, without overworking the tower fans themselves. The total claimed savings for this measure is 82,867 kWh annually.

7864915: New 30-ton Chiller for winter cooling

Installing a new 30-ton chiller with a remote air-cooled condenser, new CHW pumps, piping and controls in the central plant to provide process load cooling during the winter. Adding the free-cooling feature eliminates the need for mechanical chiller operation when outside air conditions are around 45°F or below during the winter season. A new 50-ton dry cooler would be mounted on the roof, and a new flat plate heat exchanger and associated pumping systems would be installed in the mechanical room. The total claimed savings for this measure is 219,905 kWh annually. (Evaluator notes: free cooling was not implemented)

9674245: VAV control upgrades and night temperature setback

VAV control upgrades and night temperature setbacks. The total claimed savings for this measure is 13,342 kWh annually.

Application Information and Applicant Savings Methodology

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

Applicant Description of Baseline

The applicant classified all the measures as a retrofit with a single baseline

7257791/9171306: RCx - HVAC control

1. Air handler schedule optimization with an optimal start

The baseline operation schedule for all units is shown in Figure 5-88. When the system is on, the fan will operate continuously and provide minimum ventilation when the economizer is not in operation. When the system is off, the fan will remain off, and no space cooling or heating is provided.

Existing Typical Schedule of Operation				
AHU	Existing Weekday		Existing Weekend	
	Start	End	Start	End
1	ON	ON	ON	ON
2N	ON	ON	ON	ON
2S	4:00	17:30	OFF	OFF
3N	4:00	17:30	OFF	OFF
3S	4:30	17:30	OFF	OFF
4N	4:00	19:30	OFF	OFF
4S	3:00	19:00	OFF	OFF
B1	3:30	18:30	OFF	OFF
B2	ON	ON	ON	ON

Figure 5-88 Applicant Baseline Schedule

2. Repair airside economizer and optimize ventilation control

All AHUs are commanded to economize using a comparative dry bulb algorithm with a high dry bulb limit temperature of 72°F. Additionally, OA dampers of AHU 1, 3N and 2S do not function and provide little to no outside air to the building. OA dampers of AHU 2N and 4N appear to be malfunctioning and provide more than the required ventilation.

3. Air handler static pressure reset

The supply fans of existing AHUs 1, 2S, 3S, 4S, B1 and B2 control to maintain a fixed static pressure setpoint ranging between 0.5 in. WC and 1.0 in. WC.

4. Hot water system supply temperature reset

Facility heating load is met by (2) Viessmann Vitocrossal 2,702,000 Btu/h (input) natural gas-fired condensing hot water boilers that each have a combustion efficiency of approximately 87%. The boilers operate in a lead/lag configuration and modulate as required to maintain the hot water supply temperature setpoint. The HW supply temperature currently is programmed to reset between 180 °F and 145 °F based on outside air temperatures of 30°F and 65°F, but the applicant noted that the boilers didn't respond properly to the hot water supply temperature setpoint command that the BAS initiated and the HW supply temp is a constant 180°F.

5. Chilled water system supply temperature reset

In the baseline situation, the Carrier Evergreen chillers control was maintained at a fixed 44 °F leaving the CHW temperature setpoint whenever enabled.

6. Condenser water system supply temperature reset

In the baseline situation, the cooling towers are controlled to maintain a fixed leaving CW temperature setpoint of 83°F whenever the towers are enabled.

7864915: New 30-ton Chiller

In the baseline situation, the chilled water plant runs year-round due to a need for cooling in the data center and 3-4 small communication rooms. The chilled water plant is also currently providing chilled water to the air handlers due to operational issues with the AHU economizers. Therefore, no free cooling feature was included in the baseline situation.

9674245: VAV control upgrades and night temperature setback

No temperature setback for the second-floor units in the baseline situation.

In addition to the description above, Table 5-277 shows other key parameters used in the applicant's baseline system.

Table 5-277. Applicant baseline key parameters

		BASELINE		
Measure	**Parameter**	**Value(s)**	**Source of Parameter Value**	**Note**
7257791/9171306: RCx - HVAC control	300-ton chiller full load efficiency	0.75 kW/ton	TA study estimate	Both measures use the same chiller plant.
7864915: New 30-ton Chiller	300-ton chiller full load efficiency	0.75 kW/ton	TA study estimate	
7257791/9171306: RCx - HVAC control	Supply fan HP	AHU-1: 40 AHU-2N: 15 AHU-2S: 25 AHU-3N: 15 AHU-3S: 25 AHU-4N: 15 AHU-4S: 20 AHU-B1: 7.5 AHU-B2: 20 Total: 182.5 HP	Nameplate	
7257791/9171306: RCx - HVAC control	Exhaust/Return fan HP	AHU-1: 15 AHU-2N: 7.5 AHU-2S: 7.5 AHU-3N: 10 AHU-3S: 5 AHU-4N: 3 AHU-4S: 5 AHU-B1: 7.5 AHU-B2: 5 Total: 65.5 HP	Nameplate	

7257791/9171306: RCx - HVAC control	Motor efficiency	91%-94.5% depending on motor size	NEMA Premium Efficiency Requirement	
9674245: Temperature setback	Thermostat setpoint	Cooling: 72F Heating: 70F	TA study estimate	

Applicant Description of Installed Equipment and Operation

This section describes the proposed condition assumed in the application analysis. It only discusses the original analysis's assumptions, not any information gained through this evaluation.

7257791/9171306: RCx - HVAC control

1. Air handler schedule optimization with an optimal start

The proposed operation schedule for all units is shown in Figure 5-89 below. When the system is on, the fan will operate continuously and provide minimum ventilation when the economizer is not in operation. When the system is off, the fan will cycle on and off based on space cooling and heating load and supply no ventilation.

Proposed Typical Schedule of Operation				
AHU	Existing Weekday		Existing Weekend	
	Start	End	Start	End
1	ON	ON	ON	ON
2N	6:00	17:30	OFF	OFF
2S	7:00	17:30	OFF	OFF
3N	7:00	17:30	OFF	OFF
3S	7:00	17:30	OFF	OFF
4N	7:00	19:30	OFF	OFF
4S	7:00	19:00	OFF	OFF
B1	3:30	15:30	OFF	OFF
B2	5:00	17:00	OFF	OFF

Figure 5-89 Applicant Proposed Schedule

2. Repair airside economizer and optimize ventilation control

This measure eliminates the mixed air temperature setpoint and allows the economizer dampers of all existing air handlers to control the discharge air temperature setpoint less the estimated fan heat (0.5°F to 1°F). This measure also proposes to repair the outside air dampers and/or actuators of AHU 1, 2N, 2S, and 4N to provide minimum ventilation and proper economizer functionality.

3. Air handler static pressure reset

In the proposed case, the BAS would control to determine the optimal static pressure setpoint to meet the space loads at minimum fan energy. The new static pressure control sequence would allow the BAS to vary each AHU's static pressure setpoint between a maximum and minimum value. Supply discharge pressure reset would be based on the return air or average space temperature. It is assumed that the reset can be employed to reduce the static pressure setpoint from its current programmed maximum to a minimum value of 0.5 in. WC for each respective air handling unit.

4. Hot water system supply temperature reset

This control upgrade proposes reducing the hot water supply temperature reset temperatures to maximize the efficiency of the existing condensing boilers. The HW supply temperature is proposed to reset between 160 °F and 130 °F based on outside air temperatures (OAT) of 30°F and 65°F, respectively. The temperature will modulate linearly in between 30°F and 65°F OAT.

5. Chilled water system supply temperature reset

For this measure, it was proposed that the CHW temperature setpoint would reset linearly between 44°F and 52°F for outside air temperatures between 70 °F and 50 °F, respectively.

6. Condenser water system supply temperature reset

In the proposed case for this measure, a new sequence of operation would be implemented to control the cooling tower fans to maintain a leaving CW temperature set point equal to the outside air wet-bulb temperature plus 7.5°F, which is a design approach temperature for an evaporative cooling tower. The leaving CW temperature setpoint would be bounded to always be between 55°F and 83°F.

7864915: Free cooling in winter

The proposed case for this measure is primarily to add a new 30-ton chiller and a 50-ton dry cooler to allow free winter cooling for the data center and avoid running the 300-ton chillers with hot gas bypass, which is very inefficient. Free cooling will be enabled when OAT is lower than 45°F.

9674245: VAV control upgrades and night temperature setback

The unoccupied setpoint is setback to 64°F for heating and 80°F for cooling for second-floor VAV zones. The occupied hours are from 6 am-6 pm Monday through Friday.

In addition to the description above, Table 5-278**Table 5-277** shows other key parameters used in the applicant's proposed system.

Table 5-278: Application proposed key parameters

		PROPOSED		
Measure	**Parameter**	**Value(s)**	**Source of Parameter Value**	**Note**
7864915: New 30-ton Chiller	30-ton Chiller full load efficiency	0.78 kWh/ton	Equipment Specs	
9674245: Temperature setback	Thermostat setpoint	Occupied hours: Cooling: 72F Heating: 70F Unoccupied hours: Cooling: 80F Heating: 64F	TA assumption	

Applicant Energy Savings Algorithm

7257791/9171306: RCx - HVAC control

Applicant used trend data, in combination with 8,760 hourly Excel spreadsheet models developed from Providence TMY3 weather data to calculate energy savings:

1. Air handler schedule optimization with an optimal start

The applicant linearly extrapolated the cooling load based on the outdoor temperature, and the cooling load is used to determine the required airflow cfm based on the indoor and supply air enthalpy difference. The cooling load is assumed to be 100% of the capacity when OAT is 85F or above and 0 when OAT is 50F. The heating load linearly increases from 0 to 100% of the heating capacity when OAT drops from 50F to 0F. In addition, the supply airflow rate is checked against the minimum outdoor air cfm to ensure the system will provide minimum outdoor air requirement at all times. The supply air cfm and outdoor air cfm is then used to determine the fan energy use as follows:

Fan full load power [kW] = Fan BHP [HP] x 3.412 [kW/HP] /Motor Efficiency/VFD Efficiency

Fan hourly power [kW] = [(Supply air cfm/ Design cfm)^3*]x Fan full load power [kW]*

The applicant used a similar approach for the proposed model, except that the system will shut off during the scheduled off period.

The ventilation load is calculated as follows:

*Ventilation Load [kBtu/hr] = 4.5[lbs dry air/cfm-hr] x (Outdoor Air Enthalpy [Btu/lbs dry air] - Indoor Air Enthalpy [Btu/lbs dry air]) * Ventilation Rate [cfm] x Ventilation Schedule / 1000*

The corresponding cooling energy use for ventilation is

Ventilation hourly cooling energy *[kW] = Ventilation Load [kBtu/hr]] / 12[kBtu/Ton] * Chiller Efficiency [kW/ton]*

The cooling energy savings plus the interactive savings from reduction in fan heat is calculated using the chiller efficiency as follows:

*Hourly interactive cooling savings [kW] = Min [(Baseline Supply Fan Power [kW] - Post Supply Fan Power [kW]) * 3.412 [kBtuh/kW] * [Hourly Cooling load [tons/hr] / 12 [kbtuh/ton] x Average Chiller Efficiency [kW/ton], Baseline Total Hourly Cooling Energy]*

Hourly savings [kW] = Hourly interactive cooling savings [kW] + Baseline *Supply Fan Power [kW]* - Post *Supply Fan Power [kW]* + Baseline *Exhaust Fan Power [kW]* - Post *Exhaust Fan Power [kW]* + Baseline ventilation hourly cooling energy *[kW]* - Post ventilation hourly cooling energy *[kW]*

2. Repair airside economizer and optimize ventilation control

Trend data, in combination with 8,760 hourly spreadsheet models developed from Providence TMY3 weather files, were used to calculate energy savings. Energy savings are derived from the reduced heating and cooling energy resulting from proper economizer operation and a reduction in the minimum outside air quantity where applicable. The model used trend data to calculate the optimal outside air damper position based on the required mixed air temperature to minimize external cooling and heating.

$$X_{OAD} = {}^{T_{RA} - T_{MA}}\!/_{T_{RA} - T_{OA}}$$

$$T_{MA} = T_{DA} - T_{SF}$$

Where;

T_{OA} is the trended outside air temperature,

X_{OAD} is the percent outside air damper position, and

T_{RA} is the trended return air temperature,

T_{MA} is the mixed air temperature,

T_{DA} is the discharge air temperature setpoint and

T_{SF} is the estimated temperature rise due to fan motor heat dissipation.

For AHU 1 and AHU 2S, since both provided inadequate quantities of outside air to the building in the baseline situation, the heating and cooling energy penalty will be considered in the saving calculation due to the increase in ventilation.

3. Air handler static pressure reset

The savings were calculated by estimating the baseline annual fan energy using the current static pressure setpoints and the post-case using the proposed static pressure setpoints.

4. Hot water, chilled water and condensing water reset

For the hot water, chilled water, and condenser water temperature reset, the applicant used the eQUEST energy model with the cooling and heating load calculated from the other measures to account for interactive effects.

7864915: Free cooling in winter

The energy savings associated with this measure were estimated using a weather-based bin spreadsheet that models the existing central plant and air-cooled chiller operation.

The applicant developed the base model to determine existing operation energy use using 300-ton chillers with a minimum 10% turn-down ratio. The applicant assumes the cooling load is 300 tons when the temperature bin is above 87.9F and decreases linearly to 10 tons when the OAT bin is 48.5°F. The central chiller and associated pumps and cooling tower will operate at a minimum turn-down ratio with artificial load from hot gas bypass and data center load for the baseline case.

For the proposed case, the applicant assumed the dry cooler could provide free cooling when the temperature is below 48.5F, and the 30-ton chiller is used when the dry cooler cannot provide enough cooling for the data center. The difference between the baseline and proposed energy consumption is the measure savings. The detailed calculation steps can be found in the savings calculation spreadsheet.

9674245: VAV control upgrades and night temperature setback

The savings for this measure is as follows

If the system is in heating mode

Hourly Heating load [kBtu/hr] = Envelop Loss [kBtu/hr] + Ventilation Load [kBtu/hr] + Infiltration Load (Assume only occurs if there is no mechanical ventilation) [kBtu/hr] – Internal Load [kBtu/hr]

Whereas

Envelope Loss [kBtu/hr] = U-value x Envelope Area x (Indoor Setpoint – OAT)

*Ventilation Load [kBtu/hr] = 1.08 [(Btu/h) * °F / cfm] x (Indoor Setpoint – OAT) * Ventilation Rate [cfm] x Ventilation Schedule / 1000 [kBtuh/Btuh]*

*Infiltration Load [kBtu/hr] = 1.08 [(Btu/h) * °F / cfm] x (Indoor Setpoint – OAT) * Infiltration Rate [cfm] x (1-Ventilation Schedule) / 1000 1000 [kBtuh/Btuh]*

Internal Load [kBtu/hr] = Equipment Load at given hour [kBtu/hr] + Lighting Heat Gain at given hour [kBtu/hr] + Occupancy Heat Gain at given hour [kBtu/hr]

The heating airflow is

Heating Airflow [cfm] = Heating Load [kBtu/hr] x 1000 / [1.08 x (VAV Box Supply Air Temperature – AHU Supply Air Temperature]

If the system is in cooling mode,

Hourly Cooling load [kBtu/hr] = Envelop Loss [kBtu/hr] + Ventilation Load [kBtu/hr] + Infiltration Load [kBtu/hr] + Internal Load [kBtu/hr]

Whereas

Envelope Loss [kBtu/hr] = U-value x Envelope Area x (OAT - Indoor Setpoint)

*Ventilation Load [kBtu/hr] = 4.5[units] x (Outdoor Air Enthalpy [Btu/lbs dry air] - Indoor Air Enthalpy [Btu/lbs dry air]) * Ventilation Rate [cfm] x Ventilation Schedule / 1000*

*Infiltration Load [kBtu/hr] = 1.08[(Btu/h) * °F / cfm] x (Outdoor Air Enthalpy [Btu/lbs dry air] - Indoor Air Enthalpy [Btu/lbs dry air]) * Infiltration Rate [cfm] x (1-Ventilation Schedule) / 1000*

Cooling airflow = Hourly Cooling load [kBtu/hr] / System Design Capacity [kBtu/hr] x System design airflow [cfm]

The hourly cooling energy is

*Hourly cooling energy [kW] = Hourly Cooling load [kBtu/hr] / 12 [kBtu/Ton] * Average Chiller Efficiency [kW/ton]*

The actual AHU supply airflow is

AHU airflow [cfm]= Max (Cooling airflow [cfm], Heating airflow [cfm], Ventilation airflow [cfm], Minimum AHU airflow [cfm])

The Exhaust Fan Power is

Exhaust Fan Power [kW] = (Ventilation Airflow / Exhaust Design Airflow)$^{2.7}$ x Exhaust Full Load Power

Whereas the Exhaust full load power is the same as the applicant's calculation

The Supply Fan Power for the baseline case is

Baseline Supply Fan Power [kW] = (AHU Airflow / Supply Fan Design Airflow)$^{2.7}$ x Supply Fan Design Full Load Power

The Supply Fan Power for the post-installation case is

Post Supply Fan Power [kW] = (AHU Airflow / Supply Fan Design Airflow)$^{2.8}$ x Supply Fan Design Full Load Power

The slight change in the exponent is to accounts for the static pressure reset.

The interactive cooling energy savings from fan heat is

*Hourly interactive cooling savings [kW] = Min [(Baseline Supply Fan Power [kW] - Post Supply Fan Power [kW]) * 3.412, Hourly Cooling load [kBtu/hr]] / 12 x Average Chiller Efficiency [kW/ton]*

Hourly savings [kW] = Hourly interactive cooling savings [kW] + Baseline *Supply Fan Power [kW]* - Post *Supply Fan Power [kW]* + Baseline *Exhaust Fan Power [kW]* - Post *Exhaust Fan Power [kW]* + Baseline Hourly cooling energy *[kW]* - Post Hourly cooling energy *[kW]*

The annual energy savings are the sum of the hourly savings.

Evaluation Assessment of Applicant Methodology

DNV generally agrees with the applicant's calculation for the measures. However, for measure 7864915, the evaluator confirmed that the free cooling was not implemented and therefore recalculated the savings without that component. Additionally, DNV removed the double-counted savings for the second-floor temperature setback in measure 7257791/9171306.

On-site Metering

This section provides details on the tasks performed during the on-site visit. DNV installed meters and conducted an on-site verification of the system installed. The following section provides a summary of the findings.

Summary of On-site Findings

DNV interviewed the facility staff and verified the equipment installed on-site. DNV performed a visual inspection of equipment on 3/18/21 to ensure it matches the applicant's descriptions. DNV also verbally confirmed space conditions and equipment operation with the facility staff, as shown in Table 5-34

Table 5-279. Measure Verification

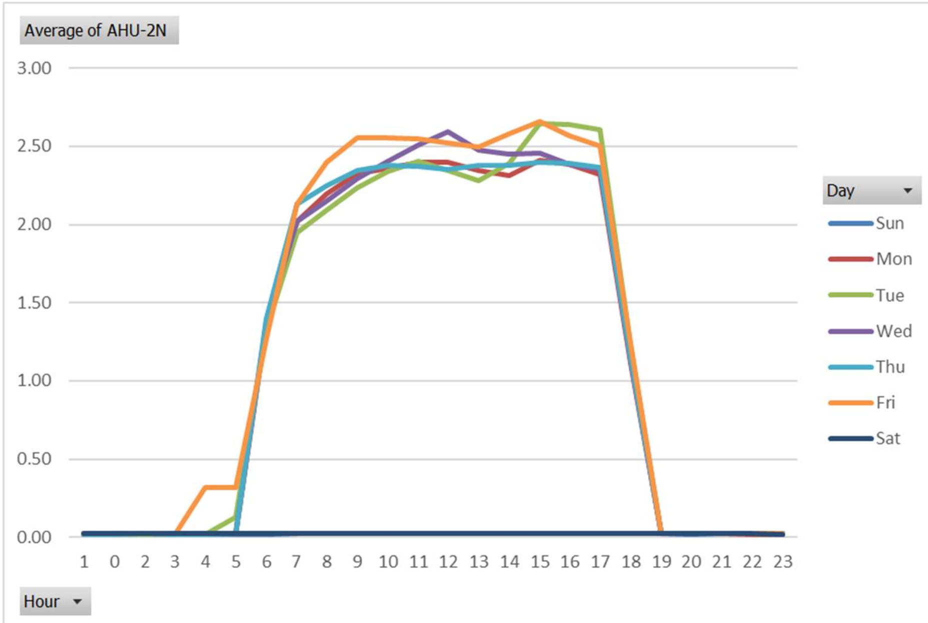
Measure Name	Verification Method	Verification Result
7257791/9171306: RCx - HVAC control	Verify the scheduling, VAV controls are operating properly	Confirmed the system operates properly
7257791/9171306: RCx - HVAC control	Verify pressure reset, supply air hot water, chilled water and condensing water temperature reset are implemented	Confirmed
7257791/9171306: RCx - HVAC control	Verify economizer control has been repaired	Confirmed
7864915: New 30-ton Chiller	Verify winter free cooling is implemented	Upon discussion with the site contact, DNV found a new 30-ton chiller installed to handle the data center and other winter cooling load instead of free cooling via a dry cooler. Therefore, the measure was not implemented as the original measure. However, there are still savings using a dedicated 30-ton chiller rather than running the 300-ton chiller with hot gas bypass.
9674245: Temperature setback	Verify temperature setback is implemented on second-floor spaces	Confirmed

Table 5-35 shows the installed logger, metering period and the parameters they monitor.

Table 5-280. Logger Information

Data Logger Type	Parameter	Time Interval	Duration
DENT Elite kW Logger	AHU-2N Supply fan kW	5 mins	3/18/21 - 5/20/21
DENT Elite kW Logger	AHU-2S Supply fan kW	5 mins	3/18/21 - 5/20/21
WattNode kW Logger	AHU-B2 Supply fan kW	5 mins	3/18/21 - 5/20/21
DENT Elite kW Logger	Chiller #1 kW	5 mins	3/18/21 - 5/20/21
DENT Elite kW Logger	Chiller #2 kW	5 mins	3/18/21 - 5/20/21
DENT Elite kW Logger	Pony chiller (30-ton) compressor kW	5 mins	3/18/21 - 5/20/21
DENT Elite kW Logger	Pony chiller (30-ton) condenser fan kW	5 mins	3/18/21 - 5/20/21
HOBO amp logger	Condenser pump 1	5 mins	3/18/21 - 5/20/21
HOBO amp logger	Condenser pump 2	5 mins	3/18/21 - 5/20/21
DENT Elite kW Logger	Cooling tower 1	5 mins	3/18/21 - 5/20/21
HOBO amp logger	Cooling tower 2	5 mins	3/18/21 - 5/20/21
Temperature logger	Chilled water leaving water temperature	5 mins	3/18/21 - 5/13/21
Temperature logger	Chilled water entering water temperature	5 mins	3/18/21 - 5/13/21

The following shows the metered data of the loggers mentioned above. Figure 5-90 shows the average supply fan power of AHU-2N and AHU-B1 for a different day of the week. Both fans appear to be operating only from 5 am-8 pm during weekdays. It appears the fan is completely shut down during unoccupied periods.



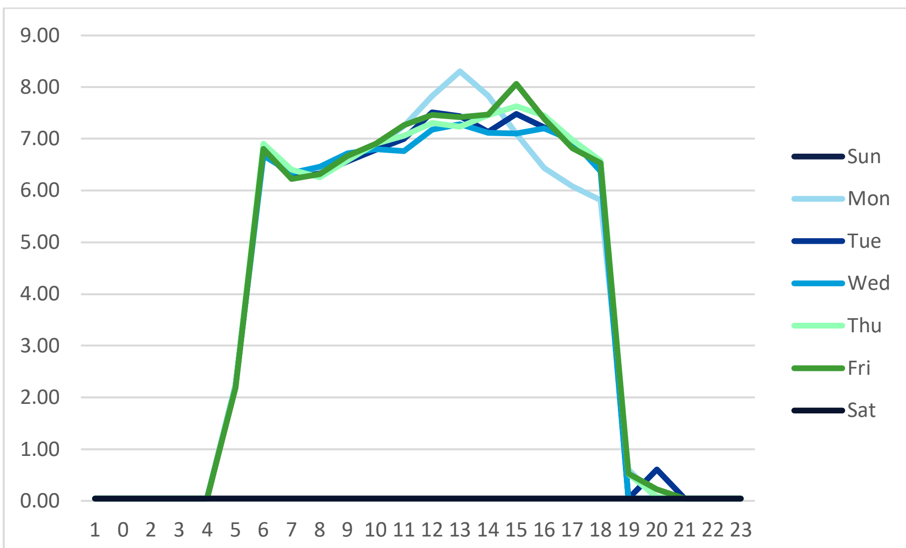


Figure 5-90 Metered AHU-2N and AHU-B2 supply fan power

Similarly, the average chilled water temperature differential hourly profile for a different day of the week is plotted in Figure 5-91. The temperature differential is calculated as

Delta T [F]= Chilled Water Leaving Water Temperature (CHW LWT) [F] - Chilled Water Entering Water Temperature (CHW EWT) [F]

The LWT and EWT are measured before and after the main chillers (300 ton), excluding the new 30-ton chiller. When the temperature differential is below zero, it means the chiller compressor is on and vice versa. It shows the chiller is operating during 7 am-7 pm every day. This is slightly different from the metered AHU-2N and AHU-B2 fan operation because, per Figure 5-89, AHU-1 operates on weekends and requires the chiller to run. As expected, Figure 5-92 shows the temperature differential decreases further as OAT increases due to higher cooling load at higher OAT.

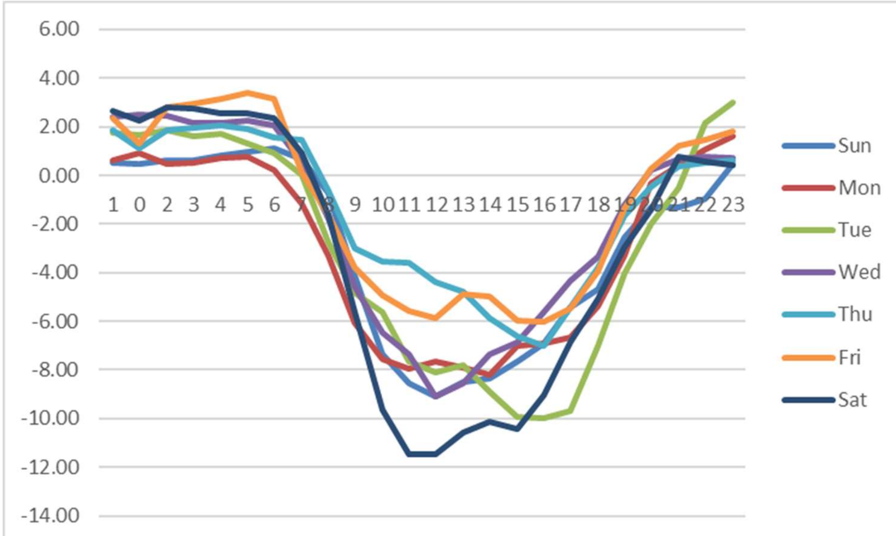


Figure 5-91 Metered Chilled Water Temperature Differential

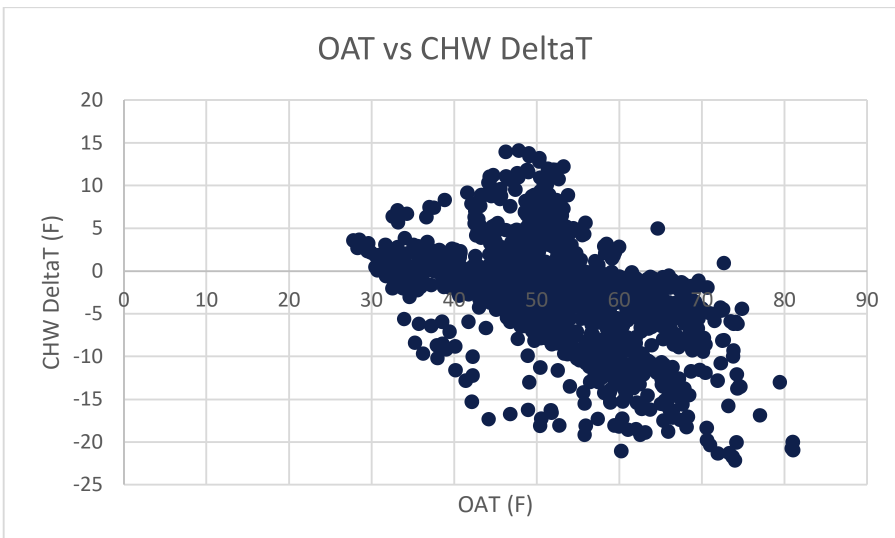


Figure 5-92 Chilled Water Temperature Differential vs. OAT

DNV also metered the 300-ton chiller power. However, it appears the readings for both chillers are incorrect as the power for Chiller 1 is always zero and for Chiller 2 is around 10 kW for the majority of the time and then decreases to -30 kW at the end of the metering period. Therefore, DNV did not use the metered chiller power for the analysis. Figure 5-93 and Figure 5-94 show the 30-ton chiller power versus OAT. The metered data shows the 30-ton chiller was only on for a certain time. This is more likely during unoccupied hours or low OAT when there was minimal load on the main chillers. In the calculation, DNV assumes when the building load is smaller than 15 ton (minimum turndown ratio for the 300-ton chillers), the 30-ton chiller will be used.

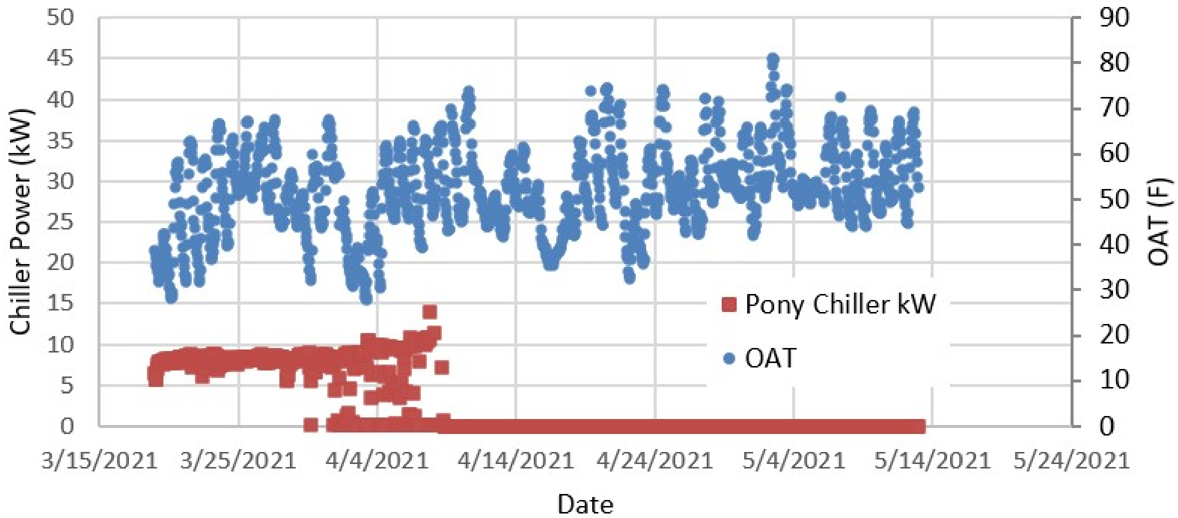


Figure 5-93 30-ton Chiller Power vs OAT (Time Series)

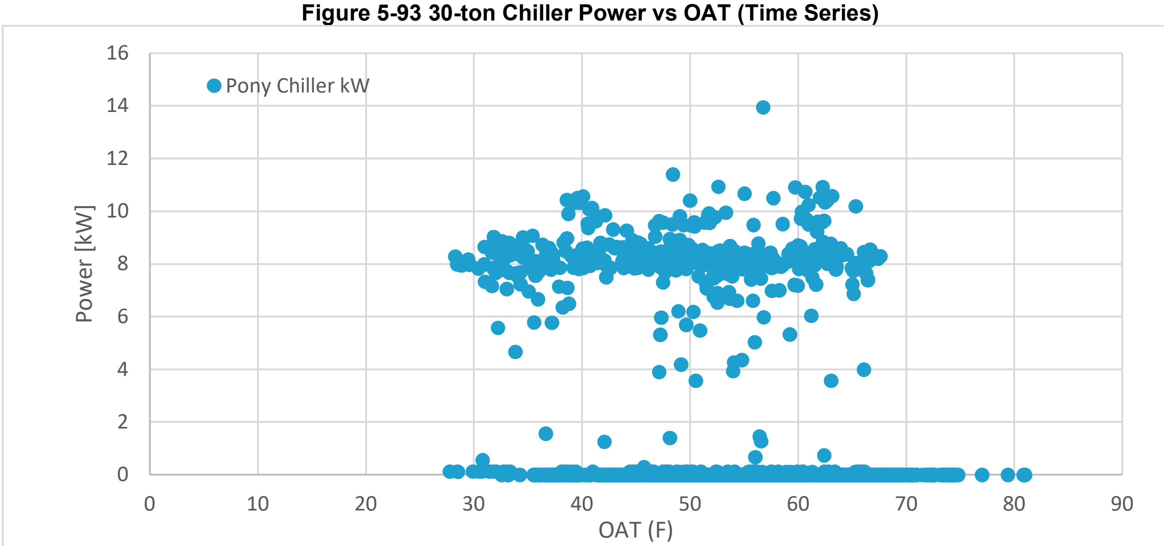


Figure 5-94 30-ton Chiller Power vs OAT

Evaluation Methods and Findings

Evaluation Description of Baseline

The evaluator reviewed the project files and interviewed the site contact to gather information on the baseline. DNV determined the all the measures are retrofit and using existing conditions as the baseline is appropriate.

Evaluation Calculation Method

7257791/9171306: RCx and control upgrade

AHU scheduling

The evaluator created an hourly analysis model to simulate the building HVAC system consumption by first estimating the cooling and heating load from the building envelope loss, infiltration and ventilation load and internal heat gain from lighting, plug load and occupancy load based on the typical office building. The key parameters are shown in Table 5-281. The site indicated the trend data is not readily available due to a cybersecurity breach. Therefore, DNV used metered data to determine the thermostat setpoint and fan operation. For each hour, the space load is calculated as

If the system is in heating mode

Hourly Heating load [kBtu/hr] = Envelop Loss [kBtu/hr] + Ventilation Load [kBtu/hr] + Infiltration Load (Assume only occurs if there is no mechanical ventilation) [kBtu/hr] – Internal Load [kBtu/hr]

Whereas

Envelope Loss [kBtu/hr] = U-value x Envelope Area x (Indoor Setpoint – OAT)

Ventilation Load [kBtu/hr] = 0.075 [lb/ft^3] 0.24 [Btu/lb-°F]*60 [min/hr] x (Indoor Setpoint – OAT) * Ventilation Rate [cfm] x Ventilation Schedule / 1000 [kBtu/Btu]*

Infiltration Load [kBtu/hr] = 0.075 [lb/ft^3] 0.24 [Btu/lb-°F]*60 [min/hr] x (Indoor Setpoint – OAT) * Infiltration Rate [cfm] x (1-Ventilation Schedule) / 1000 [kBtu/Btu]*

Internal Load [kBtu/hr] = Equipment Load at given hour [kBtu/hr] + Lighting Heat Gain at given hour [kBtu/hr] + Occupancy Heat Gain at given hour [kBtu/hr]

The heating airflow is

Heating Airflow [cfm] = Heating Load [kBtu/hr] x 1000 / [1.08 x (VAV Box Supply Air Temperature – AHU Supply Air Temperature]

If the system is in cooling mode,

Hourly Cooling load [kBtu/hr] = Envelop Loss [kBtu/hr] + Ventilation Load [kBtu/hr] + Infiltration Load [kBtu/hr] + Internal Load [kBtu/hr]

Whereas

Envelope Loss [kBtu/hr] = U-value x Envelope Area x (OAT - Indoor Setpoint)

*Ventilation Load [kBtu/hr] = 4.5[units] x (Outdoor Air Enthalpy [Btu/lbs dry air] - Indoor Air Enthalpy [Btu/lbs dry air]) * Ventilation Rate [cfm] x Ventilation Schedule / 1000 [kBtu/Btu]*

Infiltration Load [kBtu/hr] = 0.075 [lb/ft^3] 0.24 [Btu/lb-°F]*60 [min/hr] x (Outdoor Air Enthalpy [Btu/lbs dry air] - Indoor Air Enthalpy [Btu/lbs dry air]) * Infiltration Rate [cfm] x (1-Ventilation Schedule) / 1000 [kBtu/Btu]*

Cooling airflow = Hourly Cooling load [kBtu/hr] / System Design Capacity [kBtu/hr] x System design airflow [cfm]

The hourly cooling energy is

*Hourly cooling energy [kW] = Hourly Cooling load [kBtu/hr] / 12000[Btu/Ton] * Average Chiller Efficiency [kW/ton]*

During occupied hours,

The actual AHU supply airflow is

AHU airflow [cfm]= Max (Cooling airflow [cfm], Heating airflow [cfm], Ventilation airflow [cfm], Minimum AHU airflow [cfm])

During unoccupied hours,

Based on the metered data and interview with the site contact, the cfm, cooling and heating load are zero.

The Exhaust Fan Power is

Exhaust Fan Power [kW] = (Ventilation Airflow / Exhaust Design Airflow)$^{2.7}$ x Exhaust Full Load Power

Whereas the Exhaust full load power is the same as the applicant's calculation

The Supply Fan Power for the baseline case is

Baseline Supply Fan Power [kW] = (AHU Airflow / Supply Fan Design Airflow)$^{2.7}$ *x Supply Fan Design Full Load Power*

The Supply Fan Power for the post-installation case is

Post Supply Fan Power [kW] = (AHU Airflow / Supply Fan Design Airflow)$^{2.8}$ *x Supply Fan Design Full Load Power*

The slight change in the exponent is to accounts for the static pressure reset.

The interactive cooling energy savings from fan heat is

*Hourly interactive cooling savings [kW] = Min [(Baseline Supply Fan Power [kW] - Post Supply Fan Power [kW]) * 3.412 [kBtuh/kW] * [Hourly Cooling load [tons/hr] / 12 [kbtuh/ton] x Average Chiller Efficiency [kW/ton], Baseline Total Hourly Cooling Energy]*

Hourly savings [kW] = Hourly interactive cooling savings [kW] + Baseline *Supply Fan Power [kW]* - Post *Supply Fan Power [kW]* + Baseline *Exhaust Fan Power [kW]* - Post *Supply Fan Power [kW]* + Baseline Hourly cooling energy *[kW]* - Post Hourly cooling energy *[kW]*

The annual energy savings are the sum of the hourly savings for each AHU. The total savings for the AHU scheduling is

The savings result from the change in the scheduling of the ventilation rate, thermostat setpoint, supply air temperature reset, static pressure reset and interactive cooling energy savings from a reduction in fan heat.

Table 5-281: Key parameters for evaluator's model

Parameter	Value(s)	Source of Parameter Value	Note
Lighting	1.04 W/ft2	ASHRAE 90.1	For the hourly schedule, please refer to the analysis spreadsheet.
Equipment	0.80 W/ft2	DNV estimate for a typical office building	
Occupants load	200 sqft/person. 420 BTUH/person.	ASHRAE 90.1	
Envelope	Wall: R-13 Roof: R-19 Window: U-0.57	ASHRAE 90.1 (2004) for metal building	
Thermostat setpoint	Baseline Cooling:72F Post-installation: Cooling: 70F (occupied); 80F (unoccupied)	Return air temperature measurement	
	Baseline Heating:70F Post-installation: Heating: 70F (occupied); 64F (unoccupied)		

Ventilation schedule	Refer to Figure 5-88 and Figure 5-89	TA study/Site interview
VAV box supply air temperature in heating	95F	TA Study

Chilled water temperature reset/Condenser temperature reset

DNV uses the load calculated from the previous step plus the rest of the building load for the remaining building areas. DNV used the chiller efficiency curve for a standard variable speed chiller with the following efficiencies under different operating conditions, as shown in Figure 5-95.

Variable speed chiller efficiency

Entering condenser water temperature (Fahrenheit)	Chiller efficiency (kW/ton)						
	25% Load	38% Load	50% Load	63% Load	75% Load	88% Load	100% Load
85	0.73	0.65	0.57	0.56	0.55	0.57	0.59
80	0.62	0.55	0.48	0.48	0.49	0.51	0.53
75	0.52	0.46	0.41	0.42	0.42	0.45	0.47
70	0.43	0.39	0.35	0.36	0.37	0.39	0.42
65	0.37	0.33	0.29	0.3	0.31	0.34	0.37
60	0.28	0.26	0.25	0.26	0.27	0.3	0.32

Figure 5-95 Chiller Efficiency (ASHRAE 90.1 2010)

The chiller energy use is calculated as

Chiller hourly energy use [kW] = Chiller hourly load [kBtu] /12 x Corresponding Efficiency [kW/ton]

For the baseline, the condensing water (CW) temperature is maintained at 84F regardless of outdoor temperature. The condensing temperature is 7.5F below the outdoor wet-bulb temperature for the proposed case, with a lower bound of 55F and an upper bound of 83F.

For the savings of chilled water temperature reset, DNV used the rule of thumb savings that 1F chilled water decrease equals 1% efficiency increase, and the chilled water temperature is controlled based on outdoor temperature as in Figure 5-96.

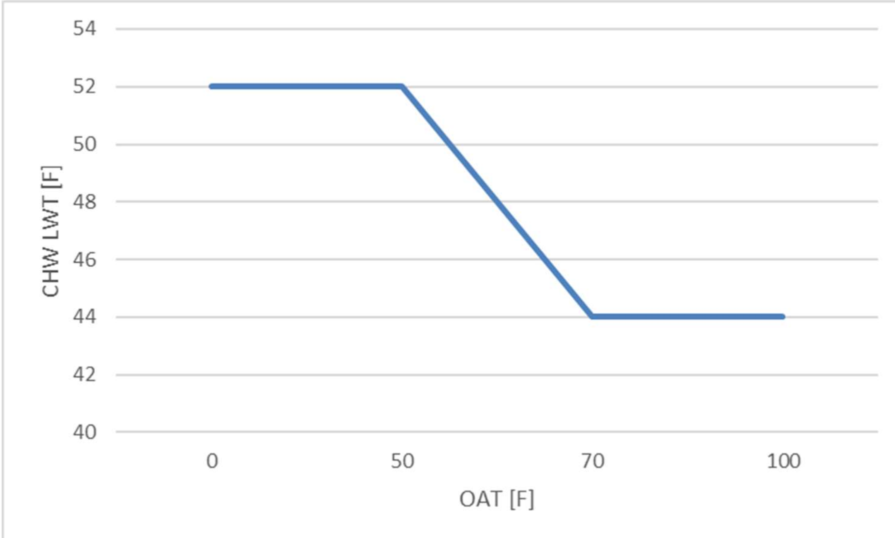


Figure 5-96 CHW LWT Reset Schedule

The total savings is the sum of the CHW reset and CW reset for each hour.

7864915: Installing 30-ton chiller

As discussed in the previous section, a new 30-ton chiller was installed to handle the winter cooling load for the data center. Instead of using a 300-ton chiller with hot gas bypass, artificially increasing the cooling load chiller can operate above the minimum turn-down ratio. DNV utilized the same calculation method as the applicant, except removing the savings from free cooling with the dry cooler. The baseline energy usage is the same, and for the post-installation case, all the winter cooling load is added to the new 30-ton chiller.

Final Results

Explanation of Differences

The applicant's assumptions for building load are different from the evaluated findings. The applicant assumed a building load percentage based on the outdoor temperature. However, based on metered data, the assumption overestimated the building load and, therefore, increased the control upgrade's savings. Additionally, DNV identified that 7257791/ 9171306 double-counted the temperature setback during unoccupied hours for AHU-2N, which is also claimed via measure 967425. Therefore, DNV removed the double-counted savings from measure 7257791/ 9171306. For measure 7864915, DNV discovered that free-cooling in winter was never implemented based on the on-site visit and the interview with the site contact. This results in a 46% reduction in savings for this measure. Table 5-51 provides a summary of the differences between tracking and evaluated values.

Table 5-282. Summary of Deviations

Measure	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
7257791/ 9171306	Operation	Heating and cooling load	-14%	Savings decreases because the applicant assumed cooling and heating load based on OAT. This oversimplified the load estimate because the cooling and heating load is not linearly related to outdoor temperature. The building internal load does not vary based on outdoor condition, but rather vary based on building operation schedule. Since majority of the savings come from the part load condition, DNV calculated the load based on internal gain, envelope losses and their schedules at each hour to more accurately calculate the hourly load at part load condition.

7257791/ 9171306	Administrative	Temperature setback	-1%	Doubled counted savings for night setback in measure 7257791/ 9171306 and 9674245
7864915	Technology	No free cooling in winter	-28%	No free cooling was implemented per on-site findings. The savings only come from running a new 30-ton chiller to avoid running the large 300-ton chiller with hot gas bypass.
	Final RR			**57%**

Ancillary impacts

Measures 7257791/9171306 and 9674245 also save natural gas consumption by reducing the heating load during unoccupied hours and increased boiler efficiency through hot water reset. DNV calculated the ancillary natural gas savings to be 15,899 therms/yr.

RICE19N015

Report Date: 04/23/2021

Program	RICE2019	
Application ID(s)	9511271	
Project Type	Existing Building Retrofit	
Program Year	2019	
Evaluation Firm	DNV	DNV
Evaluation Type	Full M&V	
Evaluation Engineer	Kristen Schleier	
Senior Engineer	Srikar Kaligota	

Evaluated Site Summary and Results

This is a small franchised restaurant. The proposed measure consisted of installing demand defrost controls on the fan coil units of a walk-in freezer and walk-in cooler at a chain restaurant location. The defrost controls reduce energy in two ways. The first way is by reducing the number and total duration of the defrost cycle, which reduces the energy use by the electric resistance defrost heater. The second way is through the reduction in the cooling load on the refrigeration system, since the refrigeration system no longer has to remove as much heat from unnecessarily defrost cycles. The controller has a self-learning algorithm. Most controllers use a design that is fixed to a time related event. This controller customizes itself to the individual evaporator and determines when the system requires defrosting using temperature sensors on the evaporator coil and analyzing when defrost is necessary.

During the recruitment process, the evaluator discovered the site to be closed and out of business. The business closed prior to March 2020 and the closure was unrelated to the COVID pandemic. The measure operated for less than one year. Because of the nature and timing of the business closure, no savings will be applied for this site.

The evaluation results are presented in Table 1-1.

Table 5-283: Evaluation Results Summary

PA Application ID	Measure Name		Annual Electric Energy (kWh)	Summer On-Peak Demand (kW)	Winter On-Peak Demand (kW)	% On Peak
9511271	Refrigeration Retrofit	Tracked	1,405	0.16	0.16	48%
		Evaluated	0	0	0	0%

Realization Rate	0%	0%	0%	0%

Explanation of Deviations from Tracking

The evaluated reported savings are zero because the business is closed, prior to March 2020 with no impact from the Pandemic.

Recommendations for Program Designers & Implementers

There are no recommendations currently.

Customer Alert

There are no customer alerts.

Evaluated Measures

The measure involves installing demand defrost controls on the fan coil units of a walk-in freezer and walk-in cooler.

Application Information and Applicant Savings Methodology

The site installed an electronically operated defrost controller to reduce the walk-in cooler and freezer energy consumption. The applicant savings calculation methodology involved estimating the kWh consumption per defrost cycle for both the freezer and the cooler. The savings estimates were based on values and algorithms obtained from the RI Technical Reference Manual (TRM)[89]. The savings for this measure was broken down as shown in the table below:

[89] http://rieermc.ri.gov/wp-content/uploads/2019/10/py2019-ri-trm.pdf

Savings Type	Annual kWh Savings	% Savings
Defrost heater Savings	970.5	69%
Reduced Cooling Load Savings	434.8	31%
Total Savings	**1,405**	**100%**

Applicant Description of Baseline

The applicant baseline was described as the pre-existing system, i.e., the existing walk-in freezer and cooler operating with no defrost controls. The measure consisted of installing the new add-on controller. The calculations (based on the RI TRM) assume that the baseline operating hours are 973 (based on four defrost cycles per day, 365 days/year for 40 minutes per defrost cycle) and that the post-case defrost hours are 65% of 973 or 632 hours/year[89]. The measure was classified as a retrofit with an add-on.

The following table shows the key inputs used in the applicant savings calculation methodology:

Table 5-284. Applicant baseline key parameters

			BASELINE	
Measure	**Parameter**	**Value(s)**	**Source of Parameter Value**	**Note**
Demand Defrost Controls	Defrost Cycles/day	4 cycles/day	RI TRM	
Demand Defrost Controls	Defrost Cycle Time	40 Minutes	RI TRM	
Demand Defrost Controls	Operating Hours (Defrost Cycle)	973 hours/year	RI TRM	

Applicant Description of Installed Equipment and Operation

The applicant documentation describes the proposed defrost control as a microprocessor-driven controller with sensors that can control the system with precision and accuracy that is superior to mechanical controls. The sensors provide feedback from the system to allow the logic to learn from the performance and adapt the control sequence.

Table 5-285: Application proposed key parameters

			PROPOSED	
Measure	**Parameter**	**Value(s)**	**Source of Parameter Value**	**Note**
Demand Defrost Controls	Defrost Cycles/day	4	RI TRM	
Demand Defrost Controls	Defrost Cycle Time	40 Minutes	RI TRM	
Demand Defrost Controls	Operating Hours (Defrost Cycle)	632 hours/year	RI TRM	

Applicant Energy Savings Algorithm

The applicant used the algorithms found in the RI TRM (Technical Reference Manual) to estimate savings. Those algorithms are provided below.

$$Total\ Savings = Defrost\ Heater\ Savings + Reduced\ Cooling\ Load\ Savings$$

$$Defrost\ Heater\ Savings = kW_{Defrost} \times DRF\ \times Hours$$

$$Reduced\ Cooling\ Load\ Savings = Defrost\ Heater\ Savings\ \times RefrigEff \times \frac{3{,}412\ \frac{Btu}{hr}}{kW} \times \frac{ton}{12{,}000\frac{Btu}{hr}}$$

Where,

$$kW_{Defrost} = Load\ of\ electric\ defrost: site\ specific: 2.8488\ kW$$

$DRF = Defrost\ reduction\ factor - pecent\ reduction\ in\ defrosts\ requred\ per\ year : 35\%$DRF =
Defrostreductionfactor − pecentreductionindefrostsrequredperyear: 35%[89]
$Hours = Number\ of\ hours\ defrost\ occurs\ over\ a\ year\ without\ the\ defrost\ controls: 973\ hours$Hours =
Numberofhoursdefrostoccursoverayearwithoutthedefrostcontrols: 973hours[89]
$RefrigEff = Efficiency\ of\ typical\ refrigeration\ system\ \left(\frac{kW}{ton}\right): 1.6$**Error! Digit expected.**[89]

So, with the above numbers:

$$Defrost\ Heater\ Savings = 2.8488\ kW \times 35\% \ \times 973\ Hours = 970.5\ kWh$$

$$Reduced\ Cooling\ Load\ Savings = 970.5\ kWh\ \times 1.6\frac{kW}{ton} \times \frac{3{,}412\ \frac{Btu}{hr}}{kW} \times \frac{ton}{12{,}000\frac{Btu}{hr}} = 434.8\ kWh$$

$$Total\ Savings = \ 970.5\ \text{kWh}\ +\ 434.8\ \text{kWh} = 1{,}405.3\ \text{kWh}$$

Here, the 973 hours comes from assuming that the baseline defrost strategy involves four defrost cycles per day, 365 days/year for 40 minutes per defrost cycle

The total kWh savings for this measure was estimated to be 1,405 kWh.

Evaluation Assessment of Applicant Methodology

The evaluator agrees with the analysis approach used by the applicant.

Onsite Inspection

Summary of Site Visit Findings and Metering

Table 5-4: Measure Verification

Measure Name	Verification Method	Verification Result
HVAC/Refrigeration Retrofit	Verify measure quantity, schedule, control, and kw.	The measure is not in operation as facility is closed for business.

Measured and Logged Data

No measures were logged, due to business closure.

Final Results

This section will summarize the evaluation results determined in the analysis above. The evaluator's estimated savings values result from observed changes to the applicant's pre and post-cases.

PA Application ID	Measure Name		Annual Electric Energy (kWh)	Summer On-Peak Demand (kW)	Winter On-Peak Demand (kW)	% On Peak
9511271	Refrigeration Retrofit	Tracked	1,405	0.16	0.16	48%
		Evaluated	0	0	0	0%
		Realization Rate	0%	0%	0%	0%

Explanation of Differences

The evaluation savings are zero for this site as the measure is not operating currently and facility is closed for business permanently.

RICE19N047

Report Date: 6/4/2021

Application ID(s)	8662026
Project Type	New Construction
Program Year	2019
Evaluation Firm	DMI
Evaluation Engineer	Bennett Rose
Senior Engineer	Jay Robbins

Evaluated Site Summary and Results

This evaluation site is a light industrial production facility. The new construction project that is being evaluated considers the installation of a new compressed air system to serve a process CAIR load. The site required more CAIR capacity and installed a new system with greater capacity to serve the process loads. The pre-existing air compressor was purchased in 2005.

The installed system includes one (1) 100HP variable speed compressor and one (1) 100HP load/no load compressor. The compressors are air-cooled and oil-injected. The system is controlled so that the variable speed compressor handles the load until it is loaded 100% at which point the load/ no-load compressor will serve the base load and the variable speed compressor will trim the load. The proposed case system also includes an integrated refrigerated air dryer and four zero-loss condensate drains. The baseline system considered for the project includes one (1) 200-HP load/no load compressor. The compressor quantity has an unusually significant impact on savings for this application due to the airflow during non-production periods.

The operation at this site was not impacted by COVID. The evaluation conducted a full metering and verification approach because the operation of the installed equipment was not impacted by COVID and the site was comfortable with the evaluator conducting an in-person site visit and metering.

The savings claimed by the applicant for this project are 246,842 kWh.

The evaluation results are presented in Table 1-1.

Table 5-286. 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)
8662026	High Efficiency Air Compressors w/ zero-loss condensate drains	Tracked	246,842	45%	36.1	0
		Evaluated - ops	490,935	28.6%	55.4	58.6
		Realization Rate	198.9%	63.6%	153.0%	-
Totals		**Tracked**	**246,842**	**45%**	**36.1**	**0**
		Evaluated - ops	**490,935**	**28.6%**	**55.4**	**58.6**
		Realization Rate	**198.9%**	**63.6%**	**153.0%**	**-**

Explanation of Deviations from Tracking

The evaluated savings are significantly higher than the applicant savings due to the baseline compressor operation during non-production periods. There is a very low airflow load during non-production periods that wasn't included in the applicant analysis. Since the non-production periods amount to 6,000 hours per year, this is potentially a significant oversight. With the baseline compressor quantity being only one compressor, instead of two compressors installed in the proposed case, the baseline compressor is very lightly loaded at less than 5% load during these 6,000 hours. With a minimum unloaded operating power of 68 kW, the baseline compressor uses significant energy during non-production periods, increasing savings well above the applicant estimate. The baseline assumptions regarding compressor quantity and operation are discussed in detail below.

Recommendations for Program Designers & Implementers

There are no recommendations currently.

Customer Alert

There is an opportunity for additional energy savings. The site has a manually controlled damper that enables the facility to exhaust compressor waste heat outside or to the production floor. According to the site, because it is inconvenient to manipulate the damper which is on the roof of the compressor room, the compressor waste heat is not recovered. An opportunity for additional savings would be to install a more conveniently located wall switch to change the damper position when the production floor needs to be heated.

There is continuous compressed air demand during non-production hours. The evaluator's understanding is that there is no production equipment operating during these periods. Unless this demand is related to a small amount of process equipment that runs 24/7, the expectation is that this compressed air demand is related to leaks when compressed air may not be needed at all. If this is the case, shutting off the compressors during off hours when no process equipment is running will provide significant energy savings. Based on the evaluation analysis the projected savings would be as much as 55,157 kWh.

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 one (1) 100HP variable speed compressor and one (1) 100HP load/no load compressor with integrated cycling dryers and zero-loss condensate drains to serve a process CAIR load.

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.

Applicant Description of Baseline

This measure is classified by the applicant as a new construction project. This classification is based on the motive of the customer for implementing the project. The customer required more compressed air capacity and installed a new compressed air system to achieve the required capacity of the facility. The baseline system is a 200-HP load/no load air compressor with a non-cycling refrigerated air dryer.

Table 2-1 summarizes the key baseline parameters assumed by the applicant.

Table 5-287. Applicant Baseline Key Parameters

			BASELINE	
Measure	**Parameter**	**Value(s)**	**Source of Parameter Value**	**Note**
ECM 1	Operating Hours	Monday-Friday, 5AM-3PM, 50 weeks per years	TA Study	
	Weekly Operating Hours	99 Hours/week	TA Study	
	Annual Operating Hours	4,950 hours	TA Study	
	Air Compressor Capacity	One (1) 200 HP load/no load (905 cfm @ 125 PSI)	TA Study	
	Peak CAIR Load (CFM)	901.1 CFM	TA Study	
	Air Dryer Nominal Capacity	7.4 kW @ 100% Flow 7.2 kW @ 10% Flow	TA Study	
	Demand associated with not having zero-loss drains	2.7 kW	TA Study	
	Average Condensate Drain Airflow per drain	3 CFM	TA Study	
	Average Base Case Compressed Air System Demand	79.5 kW	TA Study	

Applicant Description of Installed Equipment and Operation

The installed equipment is one (1) 100-HP variable speed compressor and one (1) 100-HP load/no-load compressor with integrated air dryers. The variable speed compressor will be controlled to handle the compressed air load of the facility and modulate speed up until the compressor is loaded 100%. At this point, the load/no load compressor will cycle on and the variable speed compressor will modulate speed to trim the compressed air load as required to maintain the compressed air pressure setpoint of the facility. The facility also installed four zero-loss condensate drains.

Table 2-2 summarizes the key proposed case parameters assumed by the applicant.

Table 5-288: Application Proposed Key Parameters

			PROPOSED	
Measure	**Parameter**	**Value(s)**	**Source of Parameter Value**	**Note**
ECM 1	Operating Hours	Monday-Friday, 5AM-3PM, 50 weeks per years	TA Study	
	Weekly Operating Hours	99 Hours/week	TA Study	
	Annual Operating Hours	4,950 hours	TA Study	
	Air Compressor Capacity	One (1) 100 HP variable speed and One (1) 100 HP Load/No Load 418cfm @ 135psi each	TA Study	
	Air Dryer	Integrated (i.e. included in air compressor performance)	TA Study	
	Average Condensate Drain Airflow	0 CFM	TA Study	
	Average Proposed Case Compressed Air System Demand	29.7	TA Study	

Applicant Energy Savings Algorithm

The annual savings analysis for this project is based on a week of compressed air flow data. The data appears to be CAIR airflow data collected in 10 second intervals indicating that the site may have a CAIR flow meter in place.

The base case compressor performance is calculated based on Compressed Air Challenge performance curve assuming a baseline CAIR storage capacity of 2 gal/CFM. The performance curve is adjusted based on the CAGI rated no load kW of the base case compressor model. The applicant adjusts the full load compressor demand based on the rated performance and the actual operating compressed air pressure (125 psi) at the facility using the following equation. This same equation is used for both the base and proposed case.

$$Operating\ kW = 0.995^{Rate\ \ Pressure\ psi - Operati\ \ \ Pressure\ psi} * Rated\ kW$$

The performance curve is used to calculate base case compressor demand according to the metered compressed air flow data. The base compressor performance curve is as follows:

$$\%kW\ input(\%\ Load) = 0.3716x^3 - 1.2771x^2 + 1.61x + 0.2987$$

The base case includes a refrigerated non-cycling air dryer. The air dryer performance is based on manufacturer performance data. The manufacturer data includes rated kW at full flow (7.4 kW) and rated kW at 10% flow (7.2 kW). It is assumed that the part load performance curve is linear between these two specified points.

The proposed case variable speed compressor performance is based on manufacturer data scaled based on the CAIR pressure at the facility which is 125 psi. The proposed case trim compressor performance curve is as follows:

$$kW\ input(\%\ Load) = 0.0001x^2 + 0.1592x + 10.2708$$

The proposed case base load compressor will only operate when fully loaded at 85.8 kW.

The savings analysis assumes that the proposed case compressors have integrated cycling dryers and that the dryer demand is captured in the performance data for the proposed case air compressors.

Zero loss drain savings are calculated by applying an average demand penalty to the base case system. Savings assume an average base case leakage rate of 3 CFM per drain, with a total of 4 drains, and an average compressor performance of 0.2231 kW/CFM based on the proposed case variable speed compressor. The 0.2231 kW/CFM is the average of the compressor performance data points, not the average compressor airflow. This results in an average base case demand of 2.7 kW associated with drain leakage.

The base case and proposed case performance curves are applied to the compressed air flow trend data. The average base and proposed system demand over the trend period are projected over 99 weekly hours for 50 weeks/year (assuming 2 weeks shutdown) to calculate annual savings. The note next to the input for weekly hours says "M-F 5am-3pm" as the basis for 99 hours/week. This value is an input and it is unclear how it was calculated.

The applicant calculates peak demand savings based on the time of day, day of week averages for the base and proposed compressor. Summer peak savings compare the base and proposed average compressor demand from 1PM-5PM Monday through Friday, and Winter Peak demand savings compare the base and proposed case demand from 5PM-7PM Monday through Friday.

Evaluation Assessment of Applicant Methodology

Operating hours assumption is Monday through Friday from 5AM to 3PM; however, the applicant uses 99 hours per week as an input value for their annual projection. Based on the operating hours described, the weekly hours assumed by the applicant should be 50 hours per week.

The way that the applicant's saving analysis is structured does not consider savings outside of production hours. The trends used by the applicant show that there is compressed air flow outside of production hours; the compressor operated continuously for the 7-day metering period. It is unclear why the applicant has not included these hours in the savings projection.

Site Visit

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

Summary of Site Visit Findings

The evaluator visited the site on 3/18/2021 to conduct a site interview, observe the installed equipment, and install power meters on the two air compressors. The evaluator returned to the site on 5/5/2021 to retrieve the meters. The site visit findings are as follows:

-The compressed air usage during operating hours is slightly lower than assumed by the applicant.

-The compressor staging sequence is operating as expected by the applicant.

-The four (4) zero-loss drains are installed as expected.

-The customer was initially interested in installing a 200-HP constant speed compressor to serve their facility and the project was implemented in response to an increase in compressed air load at the facility associated with venturi vacuum pumps.

-There are no plant shutdowns according to the site interview. The site has various machines for various processes and is able to accomplish maintenance on different machines as needed without shutting down the entire plant. Although there is no scheduled plant shut down, the evaluator assumes that the compressed air system will require some annual maintenance and has maintained the 50 weeks per year operating hours assumption.

-The compressed air pressure setpoint is 115 psi.

-There is a manual damper on the roof of the compressed air room that allows the exhaust air to be sent either outside or into the production space. According to the site, the damper is always in the same position and sends the exhaust air outside because changing the damper position would require a worker to climb onto the roof the compressed air room.

Table 5-289. Measure Verification

Measure Name	Verification Method	Verification Result
High Performance Air compressors and Dryers with Zero-Loss Drains	On-site verification with kW metering of two new air compressors	The equipment was installed as expected, the average compressed air load and compressed air pressure setpoint are less than assumed in the TA study.

Evaluation Methods and Findings

This section describes the evaluator methods and findings.

Evaluation Description of Baseline

The site interview confirmed the motivation for the project being an increase in needed capacity and the pre-existing air compressor was purchased and installed in 2005. Based on these findings, the evaluator agrees with the classification of this project as new construction. The site interview also confirmed that the customer initially wanted to install one 200-HP constant speed compressor. A vendor email was included with the applicant documentation stating that the customer was encouraged to install two smaller compressors instead of one larger compressor, with the promise of incentive contribution from National Grid. The baseline load/no load compressor is consistent with the compressed air Industry Standard Practice (ISP) memo[90]. The ISP memo does not address compressor quantity; the assumption is that equal airflow capacity is an acceptable baseline.

The baseline compressor quantity has an unusually large impact on savings for this application. Based on the metered data collected by the evaluator, the baseline load/no load compressor would be operating at no-load conditions for the majority of the time - 6,000 hours per year during non-production periods. Changing the baseline compressor quantity to two load/no load compressors would reduce savings by 40% due to the lower zero-flow demand of a two-compressor system (i.e. one compressor with half the capacity and half the zero-flow demand with the second compressor off).

[90] ISP STUDY FINDINGS – AIR COMPRESSORS AND COMPRESSED AIR DRYERS - https://ma-eeac.org/wp-content/uploads/AirCompressors_ISP_Memo_final.pdf

The savings sensitivity raises the question of whether or not comparing a two-compressor system to a one compressor system of matching capacities is reasonable. In the absence of the energy program, if the customer had installed the single load/no-load compressor, the increase in electrical costs may have encouraged the customer to implement a schedule to shut down the compressed air plant during non-production periods. The evaluator's understanding is that there is no production equipment operating during non-production hours, so the airflow is due entirely to compressed air leaks and the site should be able to shut down the plant entirely.

Evaluation Calculation Method

The evaluator collected metered kW data for the two installed air compressors. Although the meters were collected on 5/5/2021, the meter installed on the trim compressor ran out of memory on 4/1/2021. The metering period used for the evaluation is 3/18/2021-4/1/2021. It is unclear why the trim compressor meter stopped collecting data as the meter was set up to allow over three months of data collection.

The base load compressor was off at the time of the meter installation. While the meter appeared to be properly installed, it was found that the B and C phases were mismatched when the meter was retrieved. The base load compressor demand is calculated based on the linear relationship between phase 1 amperage and power sum kW of the trim compressor (R^2 value of 0.9977) and accounting for the drive burden of the VFD of the trim compressor (3% of the Nameplate HP) using the following equation. This methodology provides an estimated compressor kW that is very similar to the compressor CAGI data (within 1%) at the loaded operating condition.

$$Base\ Load\ Compressor\ kW = 2.9822 * Base\ Load\ Compressor\ Phase\ 1\ Amps – 0.4208 – 100\ HP * 3\% * 0.746 \frac{kW}{HP}$$

To ensure that the two weeks that data was collected is representative of the total metering period and useful for projecting annual operation, the evaluator is able to compare the runtime during the metering period to the run hours tallied on the compressor controls interface.

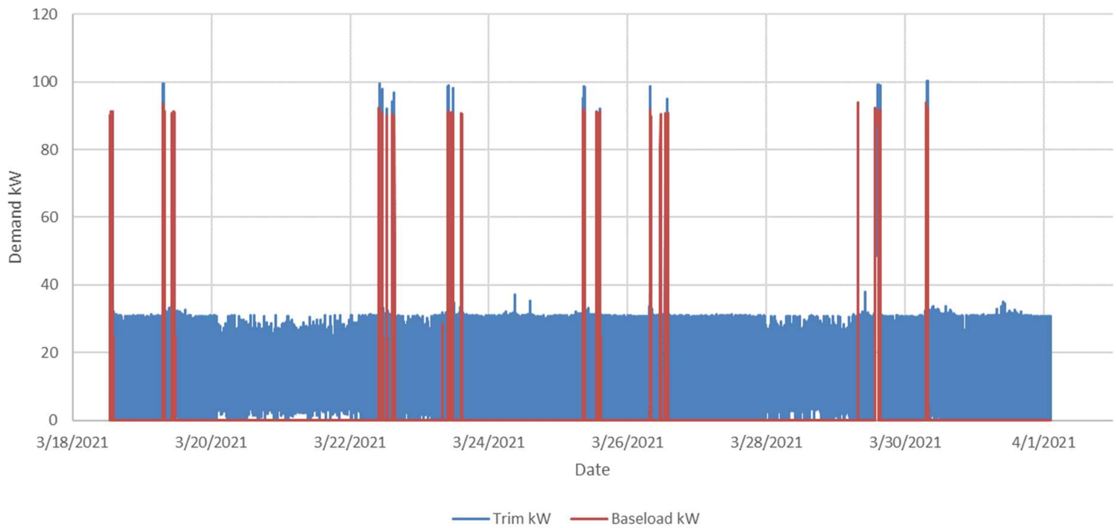
The trim compressor lifetime run hours at the time of the meter install were 7,893; the run hours at meter pickup were 8,285. Over the 1,152-hour period between these two observations (3/18/21-5/5/21), this results in 34% runtime. Accounting for cycling, the total runtime during the time period that metered data was collected is 38.6%. This finding supports that the two-week metered data period used for the evaluation analysis is reflective of typical operation. The exact install date of the compressors is unclear, but the install likely happened between 2/8/19 based on the equipment and labor invoice and 3/26/19 based on the signed post inspection form. Based on this installation time frame, the runtime of the trim compressor over its lifetime is between 42% and 45%. The low-end figure is within 10% of the runtime during the two-week period that the evaluation analysis is based on. Considering all of this evidence, the two-week metered data used for the evaluation analysis appears to be reflective of typical compressor operation at the site.

The evaluation analysis is based on the two-week metering period in which both power meters were recording. The load/no-load power meter continued to operate for a total of 7 weeks, in which the load/no-load compressor did operate more often; 5.3% of the seven-week period compared to 2.9% of the two-week period. The additional operation occurred primarily during shifts in which production went late, generally a couple of hours beyond the usual 3PM shutdown time. The additional baseload compressor operation does increase the airflow load profile, and therefore the baseline compressor usage. The extent of the increase cannot be quantified without coincident VFD compressor data, but assuming the same % VFD compressor load as the two-week period would increase savings by 6% beyond the evaluation savings. Since the average VFD compressor load would likely be somewhat less due to serving a smaller trim load during baseload compressor operation, the potential impact on savings would likely be less than a 6% increase in evaluated savings. To be conservative and not having the concurrent data all seven weeks we used just the two weeks of concurrent data which will result in slightly lower savings than likely occurred.

Lifetime % runtime for both the VFD and baseline compressor is higher than the seven-week evaluation metering periods by approximately 10%. This could be the result of more production, atypical operation during startup, or the compressor install date may be earlier than what was estimated based on the project documentation. Regardless of the lifetime runtime hours, the site interview does indicate that the seven-week period observed during the evaluation metering is a good representative period of typical operation, including increases or decreases due to COVID.

The raw data is presented in Figure 2-1.

Figure 2-1. Raw Metered Data



The metered data and the same CAGI data and operating pressure adjustment used by the applicant is used to interpolate the compressed air flow profile at the site during the metering period. Since the operating pressure was observed to be 115 psi, the formula used to adjust the CAGI compressor performance data is as follows:

$$Operating\ kW = 0.995^{Rated\ Pressure\ psi - Operating\ Pressure\ psi} * Rated\ kW$$

Table 2-4 shows the performance data used for the trim compressor and the impact of the operating pressure adjustment. It is assumed that below the lowest rated airflow, the trim compressor cycles on and off at minimum speed. The rated kW at zero-flow airflow of the trim compressor is 0 kW.

Table 2-4. Trim Compressor Performance

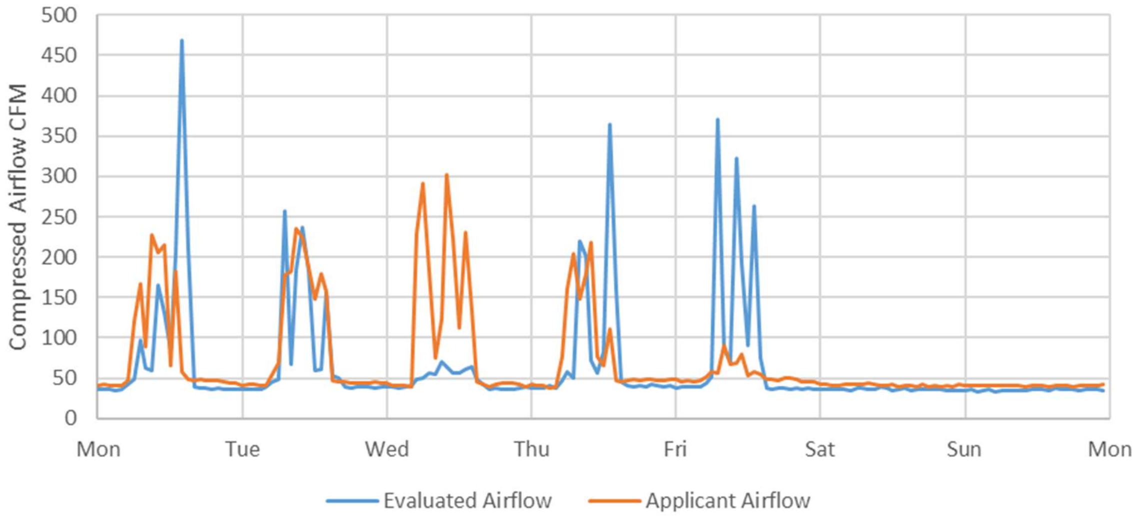
Airflow	CAGI kW @ 135 psi	Adjusted kW @ 115 psi
417.9	93.0	84.1
371.3	82.4	74.5
315.4	70.3	63.6
268.1	60.6	54.8
214.6	50.0	45.2
162.6	40.2	36.4
113.3	30.4	27.5

The base load compressor performance is adjusted based on the observed compressor operating pressure. The adjustment result is 462.1 CFM at full load demand (90.2 kW). The rated no flow demand of the base load compressor is 23.3 kW. The average airflow of the base load compressor when the metered kW is between the full load and no-load demand is calculated by linearly interpolating between the two points.

The baseline system performance data based on CAGI data used by the applicant is used by the evaluator to project baseline compressed air system kW demand. The baseline system demand includes the same assumptions for zero-loss drain savings and refrigerated dryer operation as described in Section 2.2.2. The operational pressure adjustment changes the baseline full load kW from 175.5 kW to 166.9 kW. The same formula to calculate base compressor demand described in the applicant methodology section is used by the evaluator.

The evaluated annual projection is based on the average weekly operation of the compressed air system during the metering period. The figure below compares the average weekly compressed airflow profile resulting from the evaluated metered data and the compressed airflow profile from the applicant’s analysis.

Figure 2-2. Weekly Compressed Airflow Summary



The variability in compressed air demand on a day-to-day basis is reflective of the variability in process loads at the site. The applicant’s trend data indicates a lower demand on Friday and the evaluator’s metered data indicates a lower demand on Wednesday. The site operates various processes according to production demand and both the applicant and evaluation projections account for this variability.

Baseline compressor power is calculated for the same estimated airflow and observed operating pressure as the installed compressors using CAGI performance data. This calculation is performed at the one-minute interval data, then summarized in the 24x7 models.

The applicant analysis only considers the average compressor demand during operating hours; however, the metered data shows that there is compressed air demand during unoccupied hours as well. The evaluator’s understanding is that this demand is related to compressed air leaks and that there are no overnight processes at the facility that require continuous compressed airflow. The evaluation analysis includes the unoccupied period operation, which was calculated in a 24x7 model to account for peak periods.

The baseline compressor operates at an average of 4.4% load during these non-production periods. In the energy model, this baseline compressors operates at the unloaded minimum power of ~52 kW for a significant number of hours, with very brief periods of operation at the loaded condition (~167 kW) for a fraction of the one-minute intervals. The baseline compressor never turns off to zero kW in the energy model. The evaluation assumes that the baseline compressor would be controlled such that it would turn off after 15 minutes of unloaded operation, which does not ever occur in the estimated one-minute airflow intervals.

The applicant’s analysis assumes that the facility shuts down two weeks per year. The feedback from the site is that there are no scheduled shutdowns because the site has a variety of equipment and processes that they are able to stagger maintenance as needed throughout the year. It is still expected that the applicant will need to maintain the compressed air system so this assumption is not adjusted by the evaluator. The evaluated annual projection is summarized in Table 2-4.

Table 2-5. Evaluator Annual Projection

Line	Parameter	Value	Units	Basis
1	Weekly Production Hours	50	Hours	Metered Data
2	Annual Production Weeks	50	Weeks	Assumes 2 week shut down for compressor maintenance per year
3	Annual Production Hours	2,500	Hours	Line 1 x Line 2
4	Annual Off-Hours	5,924	Hours	8,760 hours - 336 shutdown hours - Line 3
5	Base Production Demand	83.4	kW	CAGI based projection
6	Base Off-Hour Demand	68.5	kW	CAGI based projection
7	Installed Production Demand	27.2	kW	Metered Data
8	Installed Off-Hour Demand	9.3	kW	Metered Data
9	Base kWh	614,133	kWh	Line 5 x Line 3 + Line 6 x Line 4
10	Installed kWh	123,198	kWh	Line 7 x Line 3 + Line 8 x Line 4
11	Annual Savings	490,935	kWh	Line 9 - Line 10
12	Summer Peak Savings	55.4	kW	Savings 1PM-5PM M-F
13	Winter Peak Savings	58.6	kW	Savings 5PM-7PM M-F

Final Results

This section will summarize the evaluation results determined in the analysis above. Table 3-1 provides a summary of the key savings input parameters comparing the inputs used by the applicant for the tracking savings and the inputs resulting from the evaluation.

The tracking values shown below are based on the model inputs, which do not agree with the metered data that the applicant collected. That is, the metered data did demonstrate the unoccupied hours operation of the compressors, but that operation was not used as an input in the savings calculation.

Table 5-290. Summary of Key Parameters

	BASELINE		PROPOSED / INSTALLED	
Parameter	Tracking Value(s)	Evaluation Value(s)	Tracking Value(s)	Evaluation Value(s)
Weekly Production Hours	Monday – Friday 5AM-3PM 99 hours/week	Monday – Friday 5AM-3PM 50 hours/week	Monday – Friday 5AM-3PM 99 hours/week	Monday – Friday 5AM-3PM 50 hours/week
Operating Weeks/Year	50	50	50	50
Annual Production Operating Hours	4,950	2,500	4,950	2,500
Annual Nonproduction Operating Hours	0	6,260	0	6,260
Compressed Air Pressure	125 psi	115 psi	125 psi	115 psi
Production CAIR Flow	136.3 CFM	122.4 CFM	136.3 CFM	122.4 CFM
Non-Production CAIR flow	43.0 CFM* (0 CFM)	38.8 CFM	43.0 CFM* (0 CFM)	38.8 CFM
Average Production Demand	79.5	86.1	29.7	27.2
Average Non-Production Demand	0	72.3	0	9.3

*Tracking 'Non-Production CAIR Flow' is based on the applicant metering data. The analysis did not account for operation during these non-production periods.

Explanation of Differences

This section describes the key drivers behind any difference in the application and evaluation estimates, annual kWh savings, percent on-peak kWh saving, and demand savings. Table 3-2 provides a summary of the differences between tracking and evaluated values.

Table 5-291. Summary of Deviations

Measure	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
App ID 0001	Methodology	Weekly operating hours	-49.5%	**Decreased Savings –** The applicant acknowledges the production schedule of Monday-Friday from 5AM-3PM. This results in 50 hours/week but for some reason the applicant uses 99 hours/week in their analysis.
	Methodology	Off-Hours Operation	+119.6%	**Increased savings –** The metered data and the trend data used by the applicant demonstrate that there is compressed air demand during off-hours. Accounting for compressor operation during off hours increases savings.
	Operational	Compressed Airflow Profile	+37.0%	**Increased savings –** The metered data shows that the compressed airflow profile during production hours is less than assumed by the applicant. Although the production hours savings decreased, the off hours savings increased resulting in a net increase in energy savings.
	Operational	Compressed Air Pressure	-8.2%	**Decreased Savings** – The compressed air pressure at the facility is 115 psi, not 125 psi. This adjustment decreases the average baseline system demand.
		Final RR		**198.9%**

The applicant is inconsistent in describing and quantifying the production hours at the facility. The input for weekly operating hours is 99 hours per week and the operating hours are described as Monday through Friday from 5AM-3PM. Monday-Friday 5AM-3PM results in 50 hours per week, not 99 hours per week. Adjusting the applicant's weekly hours input based on the description decreases savings.

The applicant's data and the evaluator's data indicate that there is compressed air demand outside of the production hours of the site. The compressor plant operates during these off-hours and they are not included in the annual savings. Accounting for energy savings during off-hours significantly increases the savings, especially with a baseline compressor quantity of one.

Adjusting the analysis to reflect the compressed air demand observed by the evaluator decreases the savings.

The compressed air pressure was found to be 115 psi, not 125 psi as expected by the applicant. This discrepancy decreases savings.

Ancillary Impacts

The site has the ability to use compressor waste heat for space heating in the winter and, according to the site, does not do so due to the inconvenience of the manual damper location. No heating savings were claimed by the applicant, so this finding has no impact on claimed savings. There is an opportunity for gas savings at this site by making the damper control strategy more convenient to utilize compressor waste heat for space heating. The heating systems that would be impacted by this change are gas-fired infrared heaters located on the production floor.

RICE19N060

Report Date: 5/26/21

Application ID(s)	8556355	
Project Type	C&I Retrofit	
Program Year	2019	
Evaluation Firm	DNV	
Evaluation Analysis Type	Full M&V	
Evaluation Engineer	HJ Wang	
Senior Engineer	Olav Hegland	

Evaluated Site Summary and Results

The facility is a medium-sized office building with approximately 23,600 sqft office space and 52,000 sqft of unconditioned garage space. The building was built in 2002 and all equipment is original. The building is typically occupied from Monday through Friday from 7:30 AM to 6:30 PM. The office space is served by a 60-ton rooftop unit that is connected to 36 fan-powered VAV boxes (FPB) for individual space control. The building uses natural gas as the primary heating source for the VAV system.

The retrofit measure is to implement building controls and test and repair the malfunctioning VAV boxes. The controls upgrade includes:

a. Ventilation scheduling and temperature setbacks
b. Optimal start
c. Static pressure reset
d. Discharge air temperature reset

The electric savings primarily come from the cooling and fan savings from reduced ventilation requirement and temperature setback during unoccupied hours and fan part-load energy savings due to static pressure reset. In addition, the upgraded controls also reduce natural gas heating energy use which is incentivized through the RI Gas program. The customer claimed 64,250 kWh/yr electric energy savings, 4.8 kW for summer demand savings and an increase in winter demand by 0.9 kW.

DNV conducted onsite metering and hourly analysis and verified the electric savings to be 81,308 kWh/yr, corresponding to a 127% gross realization rate. The primary reason for the difference is that the applicant's calculation did not explicitly include the savings from static pressure reset, ventilation scheduling and its associated exhaust fan energy savings and cooling energy savings. The applicant assumed a reduction in space load, however, it is unclear if the reduction is only due to temperature setback or also includes other control upgrades. Additionally, the applicant didn't account for the fan heat interactive effect on the cooling energy savings. On the other hand, the verified demand savings is significantly lower than the applicants because the control upgrade primarily generates savings during unoccupied hours. There are minimal savings during the on-peak period since both existing and post-installation scenarios operate near full load conditions. The applicant calculation used the bin method, which will not accurately capture the demand savings instead of hourly analysis done by DNV. During the pandemic period, the building schedule (7:30 AM – 6:30 PM Monday thru Friday) appears to be the same based on the metering data and site interview. DNV uses TMY3 weather data (Providence, RI) and normal operating conditions to calculate the annual savings under normal operating conditions. A full EM&V analysis was done because the site contact confirmed it is safe for an onsite visit, and the operation is not affected by the pandemic.

The evaluation results are presented in Table 1-1.

Table 5-292. 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)
8556355	HVAC control	Tracked	64,250	75%	4.80	-0.90
		Evaluated - ops	81,308	43%	0.15	0.48
		Realization Rate	127%	73%	3%	-54%
Totals		**Tracked**	64,250	75%	4.80	-0.90
		Evaluated - ops	81,308	43%	0.15	0.48
		Realization Rate	127%	73%	3%	-54%

Explanation of Deviations from Tracking

The evaluated savings are higher than the applicant's savings because the applicant's calculation did not include the savings from static pressure reset, ventilation scheduling, and associated exhaust fan energy savings and cooling energy savings. Additionally, the applicant didn't account for the fan heat interactive effect on the cooling energy savings. On the other hand, the metered data indicated the outdoor temperature reset does not follow the control strategy in the TA report. Therefore DNV excludes the savings from supply air temperature reset. The verified demand savings are significantly lower than the applicants because the control upgrade primarily generates savings during unoccupied hours. There are minimal savings during the on-peak period since both existing and post-installation scenarios operate near full load conditions. The applicant calculation uses the bin method, which will not accurately capture the demand savings instead of hourly analysis done by DNV.

Recommendations for Program Designers & Implementers

None.

Customer Alert

There were no customer alerts.

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 upgrading the building controls and test and repair malfunctioning VAV boxes. The controls upgrade includes:

a. Ventilation scheduling and temperature setbacks

b. Optimal start

c. Static pressure reset

d. Discharge air temperature reset

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.

Applicant Description of Baseline

Per the applicant, baseline control conditions were as follows: a front-end workstation was not purchased for the BAS at the time of the building's construction, nor has one been installed since then. The result is an HVAC system that had controls but no way for the end-users to operate them. The RTU's operation could only be viewed and adjusted at the unit's keypad on the roof. There was no visibility into the DDC controls for the terminal boxes, nor was there any ability to implement schedules or adjust setpoints. To ensure that the building remains comfortable, office area HVAC equipment was operated continuously, with no night setback. Discharge air temperature setpoints were adjusted manually at the RTU and were rarely changed. The operation of the economizer dampers was unclear. The RTU provided a fixed duct static pressure to the fan-powered boxes regardless of box damper position and it was not possible to see whether boxes were maintaining their airflow setpoints. Because of weather variability, the HW pumps ran whenever there was a risk of the outside air temperature dropping into the 40s or 30s at night or on weekends, regardless of the daytime temperatures. Table 5-277 shows the key parameters used in the applicant's baseline system.

Table 5-293. Applicant baseline key parameters

Measure	Parameter	BASELINE Value(s)	BASELINE Source of Parameter Value	Note
EEM #1 HVAC control	Chiller average efficiency	1 kW/ton	TA study estimate	
EEM #1 HVAC control	Supply fan BHP	34 BHP	Nameplate	
EEM #1 HVAC control	Supply fan motor efficiency	93%	Nameplate	
EEM #1 HVAC control	Supply fan full load CFM	14,000	Nameplate	
EEM #1 HVAC control	Exhaust fan BHP	15 BHP	Nameplate	
EEM #1 HVAC control	Exhaust fan motor efficiency	91%	Nameplate	
EEM #1 HVAC control	Exhaust fan full load CFM	2,800	Nameplate	
EEM #1 HVAC control	Ventilation schedule	Always provide min OA regardless of building occupancy.	TA study estimate	
EEM #1 HVAC control	Space load	Assumed 50% (occupied hours)/56% (unoccupied hours) of design cooling load at 95F outdoor air temperature (OAT) and 30% (occupied hours)/23% (unoccupied hours) design load at 55F OAT Assumed 0% heating load at 55F OAT and 100% heating load at 0F OAT for both occupied and unoccupied hours	TA assumption	It is unclear why the applicant assumed a higher load for an unoccupied period at 95F OAT.
EEM #1 HVAC control	Thermostat setpoint	Cooling: 75F Heating: 70F	TA assumption	

Applicant Description of Installed Equipment and Operation

This section describes the proposed condition assumed in the application analysis. It only discusses the original analysis's assumptions, not any information gained through this evaluation.

Table 5-294: Application proposed key parameters

		PROPOSED		
Measure	**Parameter**	**Value(s)**	**Source of Parameter Value**	**Note**
EEM #1 HVAC control	Ventilation schedule	Always provide min OA regardless of building occupancy.	TA study estimate	
EEM #1 HVAC control	Space load	Assumed 45% (occupied hours)/10% (unoccupied hours) of design cooling load at 95F outdoor air temperature (OAT) and 30% (occupied hours)/10% (unoccupied hours) design load at 55F OAT Assumed 0% heating load at 55F OAT and 100% heating load at 0˚F OAT for both occupied and unoccupied hours	TA assumption	The assumption of reduced cooling load during an unoccupied period compared to the baseline is the main reason for savings.
EEM #1 HVAC control	Thermostat setpoint	Cooling: 75F Heating: 70F	TA assumption	

Applicant Energy Savings Algorithm

Applicant savings were estimated using a bin model with TMY3 weather data for Providence, RI. The applicant's algorithm is as follows:

For the baseline model, the applicant assumed a higher space cooling load during unoccupied hours than occupied hours, as shown in Table 5-277. The cooling load is linearly extrapolated based on the outdoor temperature and is used to determine the required airflow cfm based on the indoor and supply air enthalpy difference. In addition, the supply airflow rate is checked against the minimum outdoor air cfm to ensure the system will provide minimum outdoor air requirement at all times. The supply air cfm and outdoor air cfm is then used to determine the fan energy use as

Fan full load power [kW] = Fan BHP [HP] x 3.412 [kW/HP] /Motor Efficiency

Fan hourly power [kW] = [0.3 x (Supply air cfm/ Design cfm) + 0.7 x (Supply air cfm/ Design cfm)$^{2.8}$]x Fan full load power [kW]

The applicant used a modified fan power law equation to account for the efficiency losses at part load conditions.

The applicant used a similar approach for the proposed model, except assuming a lower space cooling load during unoccupied hours, as shown in Table 5-278. DNV interpreted this as an assumption to account for temperature setback during unoccupied hours and ventilation schedule. However, it is unclear why the applicant did not modify the setpoint temperature and ventilation rate for unoccupied hours directly in the proposed model.

Evaluation Assessment of Applicant Methodology

DNV generally agrees with the applicant's calculation. However, the applicant's calculation did not include the savings from static pressure reset and ventilation schedule changes. Additionally, the applicant didn't account for the fan heat interactive effect on the cooling energy savings. To properly calculate the demand impact and scheduling, DNV used hourly calculation, which can more accurately account for the savings from scheduling than using a Bin-method.

Onsite Metering

This section provides details on the tasks performed during the onsite visit. DNV installed meters and conducted an onsite verification of the system installed. The following section provides a summary of the findings.

Summary of Onsite Findings

DNV interviewed the facility staff and verified the equipment installed onsite. DNV perform a visual inspection of equipment on 3/18/21 to ensure it matches the applicant's descriptions. DNV also verbally confirmed space conditions and equipment operation with the facility staff and confirmed BMS system trending capability. However, the customer informed DNV upon meter retrieval that the BMS system had a cybersecurity breach and could not provide trend data. Therefore, DNV relies on TA study and metered results to conduct savings calculations.

Table 5-295. Measure Verification

Measure Name	Verification Method	Verification Result
HVAC control	Verify the scheduling, VAV controls are operating properly	Confirmed the system operation and schedule via customer interview Occupied period: 7:30 AM-6:30 PM Monday to Friday OA schedule: Minimum OA during the occupied period. No OA for the rest of the time except for economizer operation Temperature setback: Cooling: 72F (occupied); 76F (unoccupied) Heating: 70F (occupied); 66F (unoccupied)

Table 5-35 shows the installed logger, metering period and the parameters they monitor.

Table 5-296. Logger Information

Data Logger Type	Parameter	Time Interval	Duration
kW Logger	Supply fan kW	5 mins	3/18/21 - 5/13/21
kW Logger	Exhaust fan kW	5 mins	3/18/21 - 5/13/21
Temperature logger	Supply air temperature	5 mins	3/18/21 - 5/13/21
Temperature logger	Return air temperature	5 mins	3/18/21 - 5/13/21
Temperature logger	Outdoor air temperature	5 mins	3/18/21 - 5/13/21

DNV installed two power loggers to monitor the supply and exhaust kW. However, the exhaust fan kW did not show the correct readings; therefore, the exhaust data was discarded. Since there is no trend data available for the airflow cfm, DNV GL used the metered supply airflow power to approximate the airflow using the power law equation with an exponent of 2.8. Figure 5-90 shows the relation between supply airflow rate versus OAT. During the metering period, the OAT ranged from 28F to 80F, covering moderate heating and cooling scenarios. The figure shows the CFM modulate between 8700 CFM to close to 12,000 CFM with a short period of time reaching 1500 CFM, which might be an anomaly. The lowest CFM occurs when OAT is around 55F and during unoccupied hours, indicating the balance point temperature is around 55F in unoccupied mode.

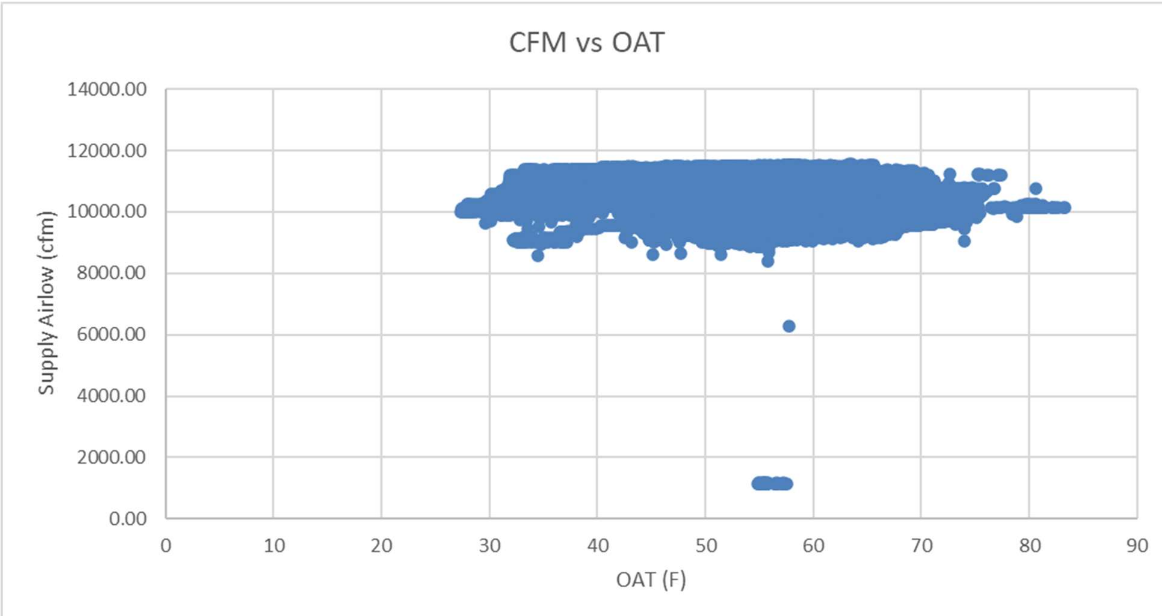


Figure 5-97 Supply CFM vs. OAT

Figure 2-2 below shows that the metered supply air temperature (SAT) varies from 72˚F to around 52˚F. This indicated the supply air temperature is not constant at 55F, which indicated there is a certain supply air reset strategy implemented, but it does not follow the outdoor air temperature reset as in the TA report as:

SAT = 55F when OAT >= 85F

SAT = 65F when OAT <= 25F and

SAT modulates linearly when OAT is from 85F to 25F

To be conservative, DNV excludes the savings from outdoor temperature reset.

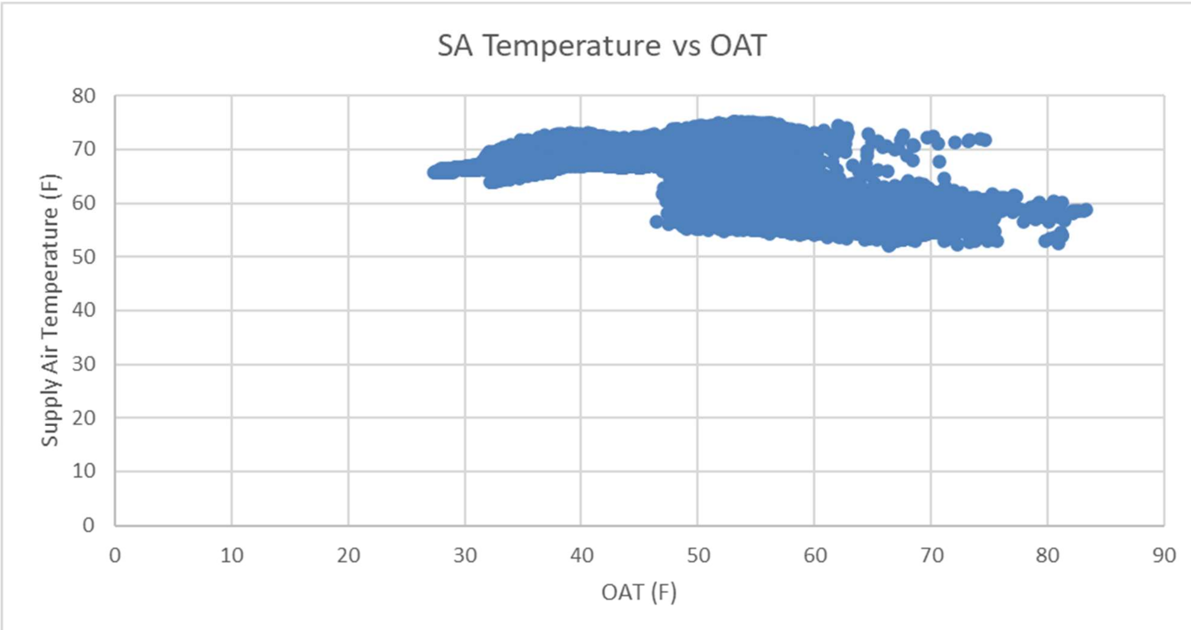


Figure 5-98 Supply Air Temperature vs. OAT

The return air temperature measurement can be used as a proxy for the room temperature. Figure 5-100 shows the metered return air temperature and averaged daily profile shows the return air temperature is around 72˚F during occupied hours from 8 AM to 6 PM Monday to Friday and around 70˚F from 8 AM to 6 PM during the weekend. The return air temperature is around 70˚F between 6 PM to 8 AM the next day. Note that the average daily profile includes heating and cooling mode, with the majority being in heating mode. Therefore, DNV used the schedule in Table 5-34 based on the site contact's response.

Figure 5-96 Metered Return Air Temperature

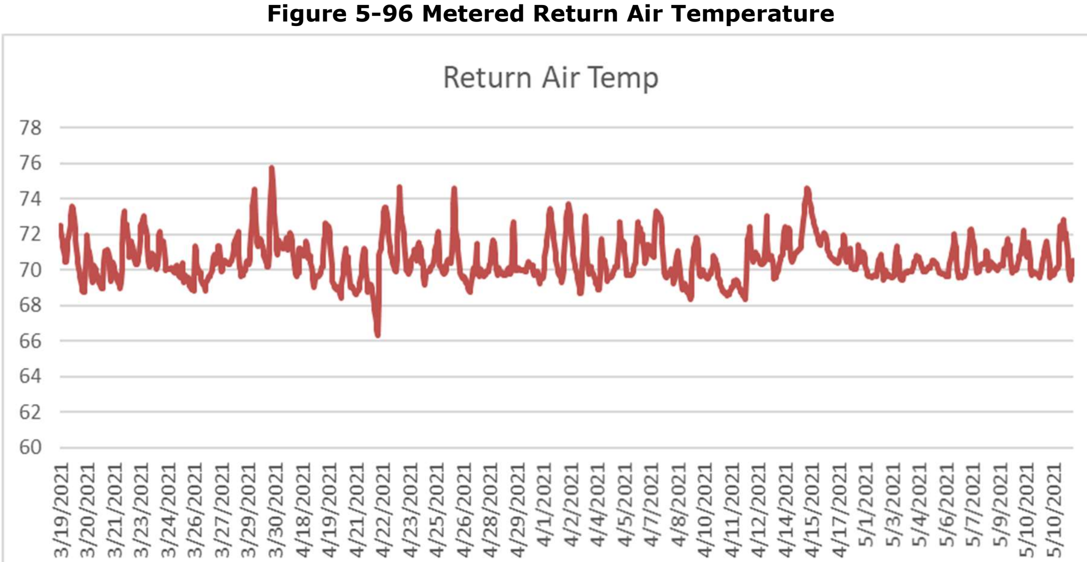
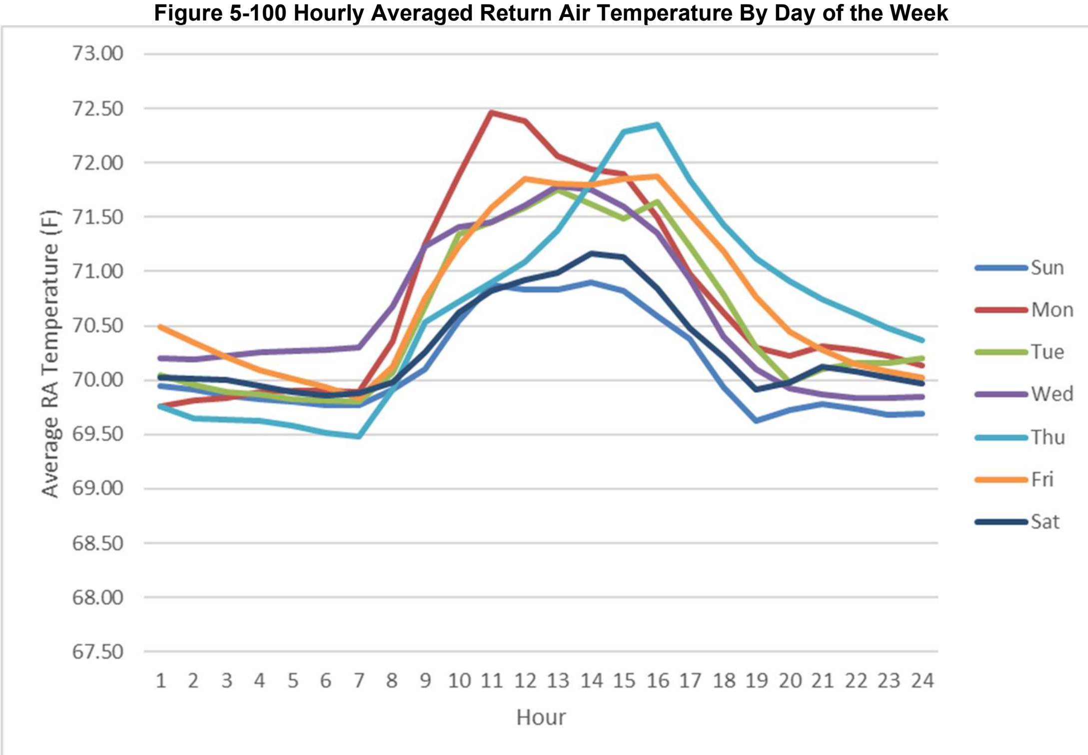


Figure 5-100 Hourly Averaged Return Air Temperature By Day of the Week



Evaluation Methods and Findings

Evaluation Description of Baseline

The evaluator reviewed the project files and interviewed the site contact to gather information on the baseline. DNV determined the control upgrade project is a retrofit measure, and using existing conditions as the baseline is appropriate.

Evaluation Calculation Method

The evaluator created an hourly analysis model to simulate the building HVAC system consumption by first estimating the cooling and heating load from the building envelope loss, infiltration, and ventilation load and internal heat gain from lighting, plug load, and occupancy load based on the typical office building. This bottom-up approach will capture the actual building load more accurately load than the top-down approach used by tracking analysis, which uses simplied assumptions for space load based on outdoor temperature. The evaluator used ASHRAE 90.1 2004 as the code for the building envelope information and the key parameters are shown in Table 5-281. The site indicated the trend data is not readily available due to a cybersecurity breach. Therefore, DNV used metered data to determine the thermostat setpoint and fan operation. The calculation below involves several terminologies regarding the airflow as follows:

Supply airflow: The actual AHU airflow going through the supply fan.

Heating or cooling airflow: Calculated airflow required to meet the space load only. This is the calculated airflow in the intermediate step, not the actual CFM.

Ventilation airflow: The outdoor airflow that is brought in to meet ventilation requirement. The supply airflow will always be equal or larger than the ventilation airflow.

For each hour, the space load is calculated as

If the system is in heating mode

Hourly Heating load [kBtu/hr] = Envelope Loss [kBtu/hr] + Ventilation Load [kBtu/hr] + Infiltration Load (Assume only occurs if there is no mechanical ventilation) [kBtu/hr] – Internal Load [kBtu/hr]

Whereas

Envelope Loss [kBtu/hr] = U-value x Envelope Area x (Indoor Setpoint – OAT)

*Ventilation Load [kBtu/hr] = 1.08 [kBtu/cfm-F-hr] x (Indoor Setpoint – OAT) * Ventilation Rate [cfm] x Ventilation Schedule / 1000*

*Infiltration Load [kBtu/hr] = 1.08 [kBtu/cfm-F-hr] x (Indoor Setpoint – OAT) * Infiltration Rate [cfm] x (1-Ventilation Schedule) / 1000*

Internal Load [kBtu/hr] = Equipment Load at given hour [kBtu/hr] + Lighting Heat Gain at given hour [kBtu/hr] + Occupancy Heat Gain at given hour [kBtu/hr]

The heating airflow is

Heating Airflow [cfm] = Heating Load [kBtu/hr] x 1000 / [1.08 x (VAV Box Supply Air Temperature – AHU Supply Air Temperature]

If the system is in cooling mode,

Hourly Cooling load [kBtu/hr] = Envelope Loss [kBtu/hr] + Ventilation Load [kBtu/hr] + Infiltration Load [kBtu/hr] + Internal Load [kBtu/hr]

Whereas

Envelope Loss [kBtu/hr] = U-value x Envelope Area x (OAT - Indoor Setpoint)

*Ventilation Load [kBtu/hr] = 4.5 [lbs dry air/hr-cfm] x (Outdoor Air Enthalpy [Btu/lbs dry air] - Indoor Air Enthalpy [Btu/lbs dry air]) * Ventilation Rate [cfm] x Ventilation Schedule / 1000*

*Infiltration Load [kBtu/hr] = 1.08 [kBtu/cfm-F-hr] x (Outdoor Air Enthalpy [Btu/lbs dry air] - Indoor Air Enthalpy [Btu/lbs dry air]) * Infiltration Rate [cfm] x (1-Ventilation Schedule) / 1000*

Cooling airflow = Hourly Cooling load [kBtu/hr] / System Design Capacity [kBtu/hr] x System design airflow [cfm]

The hourly cooling energy is

*Hourly cooling energy [kW] = Hourly Cooling load [kBtu/hr] / 12000[Btu/Ton] * Average Chiller Efficiency [kW/ton]*

The actual AHU supply airflow is

AHU airflow [cfm]= Max (Cooling airflow [cfm], Heating airflow [cfm], Ventilation airflow [cfm], Minimum AHU airflow [cfm])

The Exhaust Fan Power is

Exhaust Fan Power [kW] = (Ventilation Airflow / Exhaust Design Airflow)$^{2.7}$ x Exhaust Full Load Power

Whereas the Exhaust full load power is the same as the applicant's calculation

The Supply Fan Power for the baseline case is

Baseline Supply Fan Power [kW] = (AHU Airflow / Supply Fan Design Airflow)$^{2.7}$ x Supply Fan Design Full Load Power

The Supply Fan Power for the post-installation case is

Post Supply Fan Power [kW] = (AHU Airflow / Supply Fan Design Airflow)$^{2.8}$ *x Supply Fan Design Full Load Power*

The slight change in the exponent is to accounts for the static pressure reset.

The interactive cooling energy savings from fan heat is

*Hourly interactive cooling savings [kW] = Min [(Baseline Supply Fan Power [kW] - Post Supply Fan Power [kW]) * 3.412, Hourly Cooling load [kBtu/hr]] / 12 x Average Chiller Efficiency [kW/ton]*

Hourly savings [kW] = Hourly interactive cooling savings [kW] + Baseline *Supply Fan Power [kW]* - Post *Supply Fan Power [kW]* + Baseline *Exhaust Fan Power [kW]* - Post *Exhaust Fan Power [kW]* + Baseline Hourly cooling energy *[kW]* - Post Hourly cooling energy *[kW]*

The annual energy savings are the sum of the hourly savings.

The savings result from the change in the scheduling of the ventilation rate, thermostat setpoint, supply air temperature reset, static pressure reset and interactive cooling energy savings from a reduction in fan heat.

Table 5-297: Key parameters for evaluator's model

Parameter	Value(s)	Source of Parameter Value	Note
Conditioned space area	23,600 ft2	TA study	
Lighting	1.04 W/ft2	ASHRAE 90.1	For the hourly schedule, please refer to the analysis spreadsheet.
Equipment	0.80 W/ft2	DNV estimate for a typical office building	
Occupants load	200 sqft/person. 420 BTUH/person.	ASHRAE 90.1	
Envelope	Wall: R-13 Roof: R-19 Window: U-0.57 Infiltration: 0.2 CFM/ft^2 exterior wall	ASHRAE 90.1 (2004) for metal building	
Thermostat setpoint	Baseline Cooling:71F Post-installation: Cooling: 71F (occupied); 76F (unoccupied)	Return air temperature measurement	
	Baseline Cooling:72F Post-installation: Heating: 70F (occupied); 66F (unoccupied)		
Ventilation schedule	Baseline: Provide minimum OA at all times. Post-installation: Provide minimum OA during 7:30 AM-6:30 AM No OA for the rest of the time except for economizer operation	TA study/Site interview	
VAV box supply air temperature in heating	95F	TA Study	
Minimum AHU airflow	3000 cfm	TA Study	

Average Chiller Efficiency	1 kW/ton	A weighted average of TA Study	Based on typical chiller efficiency manufactured before 2004. Per ASHRAE 90.1 2004.

Final Results

The evaluated savings for the lighting project were slightly greater than the applicant-reported savings primarily due to a discrepancy stemming from heating and cooling interaction. Detailed values are shown in Table 5-196. Summary of Key Parameters, comparing changes in the baseline and proposed conditions for both the application and evaluation hours of use for each area.

Table 5-85 shows the key parameters that are used in the applicant and evaluator's analysis.

Table 5-298. Summary of Key Parameters

	BASELINE		PROPOSED / INSTALLED	
Parameter	**Tracking Value(s)**	**Evaluation Value(s)**	**Tracking Value(s)**	**Evaluation Value(s)**
Ventilation scheduling	Always provide min OA regardless of building occupancy.	Always provide min OA regardless of building occupancy	Always provide min OA regardless of building occupancy	Provide minimum OA during 7:30 AM-6:30 PM Monday to Friday No OA for the rest of the time except for economizer operation
Occupied/Unoccupided setpoint	Cooling: 75F Heating: 70F Assumed 50% (occupied hours)/56% (unoccupied hours) of design cooling load at 95F outdoor air temperature (OAT) and 30% (occupied hours)/23% (unoccupied hours) design load at 55F OAT Assumed 0% heating load at 55F OAT and 100% heating load at 0F OAT for both occupied and unoccupied hours	Cooling: 75F Heating: 70F	Cooling: 71F Heating: 71F Assumed space load as 45% (occupied hours)/10% (unoccupied hours) of design cooling load at 95F outdoor air temperature (OAT) and 30% (occupied hours)/10% (unoccupied hours) design load at 55F OAT	Cooling: 72F (occupied); 76F (unoccupied) Heating: 70F (occupied); 66F (unoccupied)

Explanation of Differences

The evaluated savings are higher than the applicant's savings because the applicant's calculation did not include the savings from static pressure reset, ventilation scheduling, and associated exhaust fan energy savings and cooling energy savings. Additionally, the applicant didn't account for the fan heat interactive effect on the cooling energy savings. In addition, the metered data indicated the outdoor temperature reset does not follow the control strategy in the TA report. Therefore DNV excludes the savings from supply air temperature reset. The verified demand savings are significantly lower than the applicants because the control upgrade primarily generates savings during unoccupied hours. There are minimal savings during the on-peak period since both existing and post-installation scenarios operate near full load conditions. The applicant calculation uses the bin method, which will not capture the demand savings as accurately as the hourly analysis done by DNV. Further details regarding deviations from the tracked savings are presented in Section 3-4. Table 5-51 provides a summary of the differences between tracking and evaluated values.

Table 5-299. Summary of Deviations

Measure	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
8556355	Calculation	Scheduling of ventilation	23.5%	Savings increase because the evaluation captured the savings from ventilation scheduling and static pressure reset, reducing fan and cooling energy uses.
8556355	Calculation	Static pressure reset	1.9%	Savings increase because the evaluation captured the savings from static pressure reset, reducing fan energy use
8556355	Operation	Supply air temperature reset	-0.4%	The evaluator did not include the savings from supply temperature because the metered data did not show a clear reset strategy
8556355	Interactive Adjustment	Cooling interactive savings	1.7%	Savings increase because the reduction in fan heat also reduces the cooling energy use.
		Final RR		**126.7%**

Ancillary impacts

The project also received gas incentives for reduced heating usage for the same measure. Therefore, the gas savings is discussed in the gas application.

RICE19N064

Report Date: 5/24/2021

Application ID(s)	9505098	
Project Type	C&I Initial Purchase & End of Useful Life	
Program Year	2019	
Evaluation Firm	DNV	
Evaluation Approach	Non-Lighting: Non-Ops Only	
Evaluation Engineer	Shravan Iyer	
Senior Engineer	Chad Telarico	

Evaluated Site Summary and Results

This site is a quick-service restaurant that operates during regular business hours like other similar restaurants. The COVID-19 pandemic impacted this site, wherein it was shut down for the better part of a year due to the lockdowns imposed. The store's hours of operation were affected significantly and have changed to adhere to state-level guidelines after different states started reopening and based on corporate requirements for reduced store hours. Therefore, owing to the considerable impacts COVID-19 has had on this site, measurement data was not used to verify operational parameters (i.e., operating hours) and only non-operational parameters were assessed. The measure involves installing demand defrost controls on the fan coil units of a walk-in freezer and walk-in cooler. The controls save energy in by reducing the number and total duration of the defrost cycle, which reduces the energy use by the electric resistance defrost heater and by reducing the cooling load on the refrigeration system since the refrigeration system no longer must remove as much heat from the more frequent defrost cycles. The evaluators learned that the controls have a self-learning algorithm and customize themselves to the individual evaporator. It determines when the system requires defrosting using temperature sensors on the evaporator coil and analyzing when defrost is necessary.

The evaluation found the measure savings to be 1,405 kWh annually, which is the same as the tracking savings listed in the applicant documentation. The evaluation results are presented in Table 1 1.

Table 5-300. 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)
9511291	Demand Defrost Controls	Tracked	1,405	45%	0.16	0.16
		Evaluated - ops	1,405	45%	0.16	0.16
		Realization Rate	100%	100%	100%	100%
Totals		**Tracked**	**1,405**	**45%**	**0.16**	**0.16**
		Evaluated - ops	**1,405**	**45%**	**0.16**	**0.16**
		Realization Rate	**100%**	**100%**	**100%**	**100%**

Explanation of Deviations from Tracking

The evaluated savings, which include only the non-operational adjustments of the measure savings, are the same as the applicant-reported savings because the measure was verified to have been installed and operational.

Recommendations for Program Designers & Implementers

There are no recommendations currently.

Customer Alert

There were no customer alerts.

Evaluated Measures

The measure involves installing demand defrost controls on the fan coil units of a walk-in freezer and walk-in cooler.

Application Information and Applicant Savings Methodology

The site installed an electronically operated defrost controller to reduce the walk-in cooler and freezer energy consumption. The applicant savings calculation methodology involved estimating the kWh consumption per defrost cycle for both the freezer and the cooler. The savings estimates were based on values and alogorithms obtained from the RI Technical Reference Manual(TRM)[91]. The savings for this measure was broken down as shown in the table below:

Savings Type	Annual kWh Savings	% Savings
Defrost heater Savings	970.5	69%
Reduced Cooling Load Savings	434.8	31%
Total Savings	1,405.3	100%

Applicant Description of Baseline

The applicant baseline was described as the pre-existing system, i.e., the existing walk-in freezer and cooler operating with no defrost controls. The measure consisted of installing the new add-on controller. The calculations (based on the RI TRM) assume that the baseline operating hours are 973 (based on four defrost cycles per day, 365 days/year for 40 minutes per defrost cycle) and that the post-case defrost hours are 65% of 973 or 632 hours/year[91]. The measure was classified as a retrofit with an add-on.

The following table shows the key inputs used in the applicant savings calculation methodology:

Table 5-301. Applicant baseline key parameters

		BASELINE		
Measure	Parameter	Value(s)	Source of Parameter Value	Note
Demand Defrost Controls	Defrost Cycles/day	4 cycles/day	RI TRM	
Demand Defrost Controls	Defrost Cycle Time	40 Minutes	RI TRM	
Demand Defrost Controls	Operating Hours (Defrost Cycle)	973 hours/year	RI TRM	

Applicant Description of Installed Equipment and Operation

The applicant documentation describes the proposed defrost control as a microprocessor-driven controller with sensors that can control the system with precision and accuracy that is superior to mechanical controls. The sensors provide feedback from the system to allow the logic learn from the performance and adapt the control sequence.

Table 5-302: Application proposed key parameters

		PROPOSED		
Measure	Parameter	Value(s)	Source of Parameter Value	Note
Demand Defrost Controls	Defrost Cycles/day	4	RI TRM	
Demand Defrost Controls	Defrost Cycle Time	40 Minutes	RI TRM	
Demand Defrost Controls	Operating Hours (Defrost Cycle)	632 hours/year	RI TRM	

Applicant Energy Savings Algorithm

The applicant used the algorithms found in the RI TRM (Technical Reference Manual) to estimate savings. Those algorithms are provided below.

$$Total\ Savings = Defrost\ Heater\ Savings + Reduced\ Cooling\ Load\ Savings$$

[91] http://rieermc.ri.gov/wp-content/uploads/2019/10/py2019-ri-trm.pdf

$$Defrost\ Heater\ Savings = kW_{Defrost} \times DRF\ \times Hours$$

$$Reduced\ Cooling\ Load\ Savings = Defrost\ Heater\ Savings\ \times RefrigEff \times \frac{3{,}412\ \frac{Btu}{hr}}{kW} \times \frac{ton}{12{,}000\frac{Btu}{hr}}$$

Where,

$kW_{Defrost} = Load\ of\ electric\ defrost$: $site\ specific$: 2.8488 KW

$DRF = Defrost\ reduction\ factor - pecent\ reduction\ in\ defrosts\ requred\ per\ year$: 35%[91]

$Hours = Number\ of\ hours\ defrost\ occurs\ over\ a\ year\ without\ the\ defrost\ controls$: 973 $hours$[91]

$RefrigEff = Efficiency\ of\ typical\ refrigeration\ system\ \left(\frac{kW}{ton}\right)$: 1.6[91]

So, with the above numbers:

$$Defrost\ Heater\ Savings = 2.8488\ kW \times 35\%\ \times 973\ Hours = 970.5\ kWh$$

$$Reduced\ Cooling\ Load\ Savings = 970.5\ kWh\ \times 1.6\frac{kW}{ton} \times \frac{3{,}412\ \frac{Btu}{hr}}{kW} \times \frac{ton}{12{,}000\frac{Btu}{hr}} = 434.8\ kWh$$

$$Total\ Savings = \ 970.5\ \text{kWh}\ +\ 434.8\ \text{kWh} = 1{,}405.3\ \text{kWh}$$

Here, the 973 hours comes from assuming that the baseline defrost strategy involves 4 defrost cycles per day, 365 days/year for 40 minutes per defrost cycle

The total kWh savings for this measure was estimated to be 1,405 kWh.

Evaluation Assessment of Applicant Methodology

The applicant savings were calculated based on values provided in the RI TRM. The evaluation finds this method to be reasonable and agrees with the applicant savings methodology.

Site Inspection

A site visit was conducted on 3/25/2021 to verify the installation of the defrost controller. Since it was determined that this measure would be evaluated as non-ops only, the evaluators installed meters only to validate the operation of the defrost controllers besides the physical verification of the same. During the site visit, the evaluators talked to the store manager and confirmed that the defrost controller was installed. The following figure shows the controller as observed during the site visit:

Fig.1- Demand Defrost Controller observed onsite

To further validate the operation of the controllers, the evaluators installed HOBO energy loggers in the main electrical panel on the breakers onto which the cooler and freezer are wired. The loggers were installed for a period of 12 weeks between 2/17/2021 and 5/13/2021. The reason for installing this logger was to determine if the post-case operational data can provide any insight into the operation of the controller during the defrost cycle. Additionally, the evaluators installed state loggers on the freezer and cooler doors to record when the doors are open and closed. The state loggers come in two parts, the logger and a magnet. When the magnet and the logger are in close proximity, the logger records "closed," when the magnet is moved away, the logger records "open." The measurement can be used to see how strong or weak the correlation is between the number/duration of door openings per day and the number/duration of the defrost cycles per day. The data from the loggers were used to understand the cooler and freezer's operating profile to confirm the controller's operation. The evaluators also took photos of the controllers, asked the site contact about the hours of operation, and collected other relevant information on site.

Summary of Site Findings

The evaluators made the following observations on site:

- The defrost controls were installed as claimed in the application. There was (1) controller for the walk-in freezer and (1) controller for the walk-in cooler.
- The site was impacted by COVID -19, and the hours of operation had changed considerably.
- The following table shows the summary of the verification methods used to verify the installation of the project and the corresponding evaluation findings:

Table 5-303. Measure Verification

Measure Name	Verification Method	Verification Result
Demand Defrost Controls	Verify the installation of the demand defrost controller by physical inspection	The controller was verified to be installed
Demand Defrost Controls	Verify the operation of the demand defrost controller by installing meters and physical inspection	The controller was found to be operational

Evaluation Methods and Findings

This section describes the evaluator methods and findings.

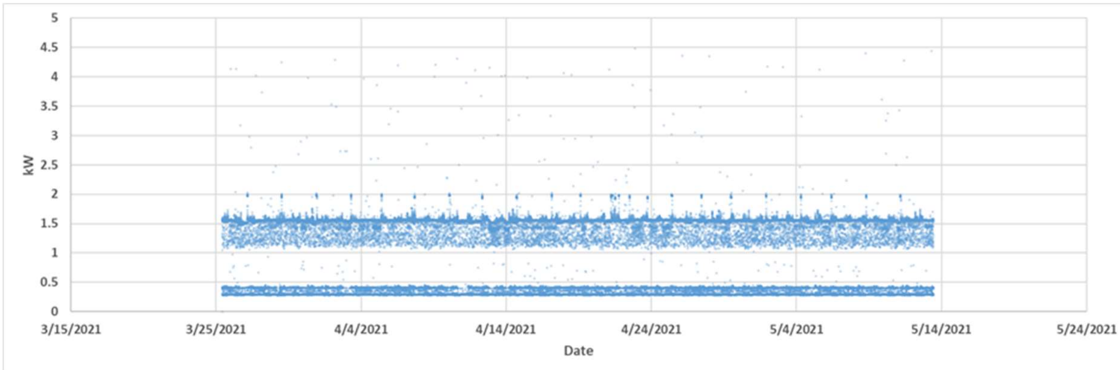
Evaluation Description of Baseline

The evaluators reviewed the project files, interviewed the site contact to gather information on the baseline for the defrost control measure. The evaluators verified that the controller was retrofitted onto the walk-in freezer and cooler at the store, and the baseline was the existing operation of the freezer and the cooler without the controller. The evaluators categorized this measure as a retrofit add-on.

Evaluation Calculation Method

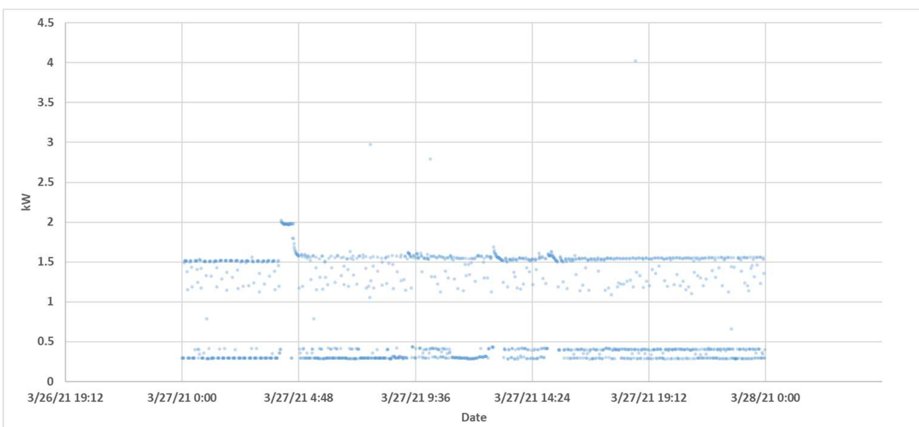
As stated above, this measure was evaluated as a non-ops only. The evaluators looked at the metered data from the energy logger installed onsite to validate the operation of the controller, which was found on site. The following figure shows the raw kW data of the walk-in cooler:

Fig.2- Raw-kW Data for Walk-in Cooler



We can observe that most of the data points are scattered between 0 and 0.5 kW and between 1.5 and 2 kW from the above figure. The evaluators believe that these data points reflect the operation of the condenser fans and the compressor, respectively. However, we can also observe certain spikes in the data just around 2 kW that occurs during certain times at irregular intervals. The evaluators believe this to be the kW draw during the defrost cycle. Based on the data from the above figure, we can conclude that the defrost controller is operational as was claimed in the project documentation and is corroborative of the same and confirmed that the controller operates less than four times per day. For additional context, the following figure shows a more granular version of the data shown in Figure 2, where we can observe clearly that the defrost cycle runs less than four times per day as it was supposed to after the installation of the controller.

Fig.3- Raw-kW Data for Walk-in Cooler (Sample Daily Data)



From the above figure, which shows the metered data for a period of one day, we can observe that the spike which is the defrost cycle that was observed earlier in Figure 2 occurs only once during the day, confirming the operation of the controller. Therefore, the evaluators used the same savings methodology and parameters outlined in the applicant documentation to estimate the savings and did not make any operational adjustments to the analysis but only verified the installation of the defrost control system. Therefore, the measure resulted in an annual energy savings of 1,405 kWh.

Final Results

The following table summarizes the key parameters that were used in the estimation of savings and compares them with the tracking and post case:

Table 5-304. Summary of Key Parameters

Parameter	BASELINE Tracking Value(s)	BASELINE Evaluation Value(s)	PROPOSED / INSTALLED Tracking Value(s)	PROPOSED / INSTALLED Evaluation Value(s)
Defrost Hours	973 hours	632 hours	973 hours	632 hours

Explanation of Differences

The evaluation found no difference in the savings because this measure was non-ops -only assessment, and there were no operational adjustments made to the tracking savings. Therefore, there are no deviations between the applicant and evaluation savings.

Ancillary impacts

There are no ancillary impacts.

RICE19N081

Report Date: 5/24/2021

Application ID(s)	9511291	
Project Type	C&I Initial Purchase & End of Useful Life	
Program Year	2019	
Evaluation Firm	DNV	
Evaluation Approach	Non-Lighting: Non-Ops Only	
Evaluation Engineer	Shravan Iyer	
Senior Engineer	Chad Telarico	

Evaluated Site Summary and Results

This site is a quick-service restaurant that operates during regular business hours like other similar restaurants. The COVID-19 pandemic impacted this site, wherein it was shut down for the better part of a year due to the lockdowns imposed. The store's hours of operation were affected significantly and have changed to adhere to state-level guidelines after different states started reopening and based on corporate requirements for reduced store hours. Therefore, owing to the considerable impacts COVID-19 has had on this site, measurement data was not used to verify operational parameters (i.e., operating hours) and only non-operational parameters were assessed. The measure involves installing demand defrost controls on the fan coil units of a walk-in freezer and walk-in cooler. The controls save energy in by reducing the number and total duration of the defrost cycle, which reduces the energy use by the electric resistance defrost heater and by reducing the cooling load on the refrigeration system since the refrigeration system no longer must remove as much heat from the more frequent defrost cycles. The evaluators learned that the controls have a self-learning algorithm and customize themselves to the individual evaporator. It determines when the system requires defrosting using temperature sensors on the evaporator coil and analyzing when defrost is necessary.

The evaluation found the measure savings to be 1,405 kWh annually, which is the same as the tracking savings listed in the applicant documentation. The evaluation results are presented in Table 1-1.

Table 5-305. 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)
9511291	Demand Defrost Controls	Tracked	1,405	45%	0.0	0.16
		Evaluated - ops	1,405	45%	0.16	0.16
		Realization Rate	100%	100%	N.A.	100%
Totals		**Tracked**	**1,405**	**45%**	**0.0**	**0.16**
		Evaluated - ops	**1,405**	**45%**	**0.16**	**0.16**
		Realization Rate	**100%**	**100%**	**N.A.**	**100%**

Explanation of Deviations from Tracking

The evaluated savings, which include only the non-operational adjustments of the measure savings, are the same as the applicant-reported savings because the measure was verified to have been installed and operational.

Recommendations for Program Designers & Implementers

There are no recommendations currently.

Customer Alert

There were no customer alerts.

Evaluated Measures

The measure involves installing demand defrost controls on the fan coil units of a walk-in freezer and walk-in cooler.

Application Information and Applicant Savings Methodology

The site installed an electronically operated defrost controller to reduce the walk-in cooler and freezer energy consumption. The applicant savings calculation methodology involved estimating the kWh consumption per defrost cycle for both the freezer and the cooler. The savings estimates were based on values and algorithms obtained from the RI Technical Reference Manual (TRM)[92]. The savings for this measure was broken down as shown in the table below:

[92] http://rieermc.ri.gov/wp-content/uploads/2019/10/py2019-ri-trm.pdf

Savings Type	Annual kWh Savings	% Savings
Defrost heater Savings	970.5	69%
Reduced Cooling Load Savings	434.8	31%
Total Savings	1,405.3	100%

Applicant Description of Baseline

The applicant baseline was described as the pre-existing system, i.e., the existing walk-in freezer and cooler operating with no defrost controls. The measure consisted of installing the new add-on controller. The calculations (based on the RI TRM) assume that the baseline operating hours are 973 (based on four defrost cycles per day, 365 days/year for 40 minutes per defrost cycle) and that the post-case defrost hours are 65% of 973 or 632 hours/year[89]. The measure was classified as a retrofit with an add-on.

The following table shows the key inputs used in the applicant savings calculation methodology:

Table 5-306. Applicant baseline key parameters

BASELINE				
Measure	**Parameter**	**Value(s)**	**Source of Parameter Value**	**Note**
Demand Defrost Controls	Defrost Cycles/day	4 cycles/day	RI TRM	
Demand Defrost Controls	Defrost Cycle Time	40 Minutes	RI TRM	
Demand Defrost Controls	Operating Hours (Defrost Cycle)	973 hours/year	RI TRM	

Applicant Description of Installed Equipment and Operation

The applicant documentation describes the proposed defrost control as a microprocessor-driven controller with sensors that can control the system with precision and accuracy that is superior to mechanical controls. The sensors provide feedback from the system to allow the logic to learn from the performance and adapt the control sequence.

Table 5-307: Application proposed key parameters

PROPOSED				
Measure	**Parameter**	**Value(s)**	**Source of Parameter Value**	**Note**
Demand Defrost Controls	Defrost Cycles/day	4	RI TRM	
Demand Defrost Controls	Defrost Cycle Time	40 Minutes	RI TRM	
Demand Defrost Controls	Operating Hours (Defrost Cycle)	632 hours/year	RI TRM	

Applicant Energy Savings Algorithm

The applicant used the algorithms found in the RI TRM (Technical Reference Manual) to estimate savings. Those algorithms are provided below.

$$Total\ Savings = Defrost\ Heater\ Savings + Reduced\ Cooling\ Load\ Savings$$

$$Defrost\ Heater\ Savings = kW_{Defrost} \times DRF\ \times Hours$$

$$Reduced\ Cooling\ Load\ Savings = Defrost\ Heater\ Savings\ \times RefrigEff \times \frac{3{,}412\,\frac{Btu}{hr}}{kW} \times \frac{ton}{12{,}000\,\frac{Btu}{hr}}$$

Where,

$kW_{Defrost} = Load\ of\ electric\ defrost: site\ specific$: 2.8488 kW

$$DRF = Defrost\ reduction\ factor - pecent\ reduction\ in\ defrosts\ requred\ per\ year : 35\%$$ [89]

$$Hours = Number\ of\ hours\ defrost\ occurs\ over\ a\ year\ without\ the\ defrost\ controls: 973\ hours$$ [89]

$$RefrigEff = Efficiency\ of\ typical\ refrigeration\ system\ \left(\frac{kW}{ton}\right): 1.6$$ [89]

So, with the above numbers:

$$Defrost\ Heater\ Savings = 2.8488\ kW \times 35\%\ \times 973\ Hours = 970.5\ kWh$$

$$Reduced\ Cooling\ Load\ Savings = 970.5\ kWh\ \times 1.6\frac{kW}{ton} \times \frac{3{,}412\ \frac{Btu}{hr}}{kW} \times \frac{ton}{12{,}000\frac{Btu}{hr}} = 434.8\ kWh$$

$$Total\ Savings = \ 970.5\ \text{kWh}\ +\ 434.8\ \text{kWh} = 1{,}405.3\ \text{kWh}$$

Here, the 973 hours comes from assuming that the baseline defrost strategy involves four defrost cycles per day, 365 days/year for 40 minutes per defrost cycle

The total kWh savings for this measure was estimated to be 1,405 kWh.

Evaluation Assessment of Applicant Methodology

The applicant savings were calculated based on values provided in the RI TRM. The evaluation finds this method to be reasonable and agrees with the applicant savings methodology.

Site Inspection

A site visit was conducted on 3/25/2021 to verify the installation of the defrost controller. Since it was determined that this measure would be evaluated as non-ops only, the evaluators installed meters only to validate the operation of the defrost controllers besides the physical verification of the same. During the site visit, the evaluators talked to the store manager and confirmed that the defrost controller was installed. The following figure shows the controller as observed during the site visit:

Fig.1- Demand Defrost Controller observed onsite

To further validate the operation of the controllers, the evaluators installed HOBO energy loggers in the main electrical panel on the breakers onto which the cooler and freezer are wired. The loggers were installed for a period of 12 weeks between 3/25/2021 and 5/13/2021. The reason for installing this logger was to determine if the post-case operational data can provide any insight into the operation of the controller during the defrost cycle. Additionally, the evaluators installed state loggers on the freezer and cooler doors to record when the doors are open and closed. The state loggers come in two parts, the logger and a magnet. When the magnet and the logger are in close proximity, the logger records "closed," when the magnet is moved away, the logger records "open." The measurement can be used to see how strong or weak the correlation is between the number/duration of door openings per day and the number/duration of the defrost cycles per day. The data from the loggers were used to understand the cooler and freezer's operating profile to confirm the controller's operation. The evaluators also took photos of the controllers, asked the site contact about the hours of operation, and collected other relevant information on site.

Summary of Site Findings

The evaluators made the following observations on site:

- The defrost controls were installed as claimed in the application. There was (1) controller for the walk-in freezer and (1) controller for the walk-in cooler.
- The site was impacted by COVID -19, and the hours of operation had changed considerably.

The following table shows the summary of the verification methods used to verify the installation of the project and the corresponding evaluation findings:

Table 5-308. Measure Verification

Measure Name	Verification Method	Verification Result
Demand Defrost Controls	Verify the installation of the demand defrost controller by physical inspection	The controller was verified to be installed
Demand Defrost Controls	Verify the operation of the demand defrost controller by installing meters and physical inspection	The controller was found to be operational

Evaluation Methods and Findings

This section describes the evaluator methods and findings.

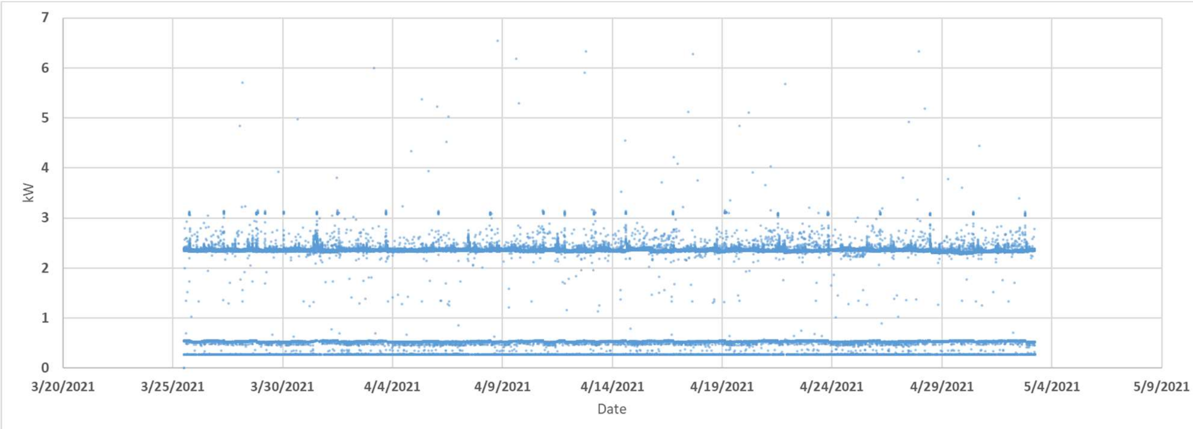
Evaluation Description of Baseline

The evaluators reviewed the project files, interviewed the site contact to gather information on the baseline for the defrost control measure. The evaluators verified that the controller was retrofitted onto the walk-in freezer and cooler at the store, and the baseline was the existing operation of the freezer and the cooler without the controller. The evaluators categorized this measure as a retrofit add-on.

Evaluation Calculation Method

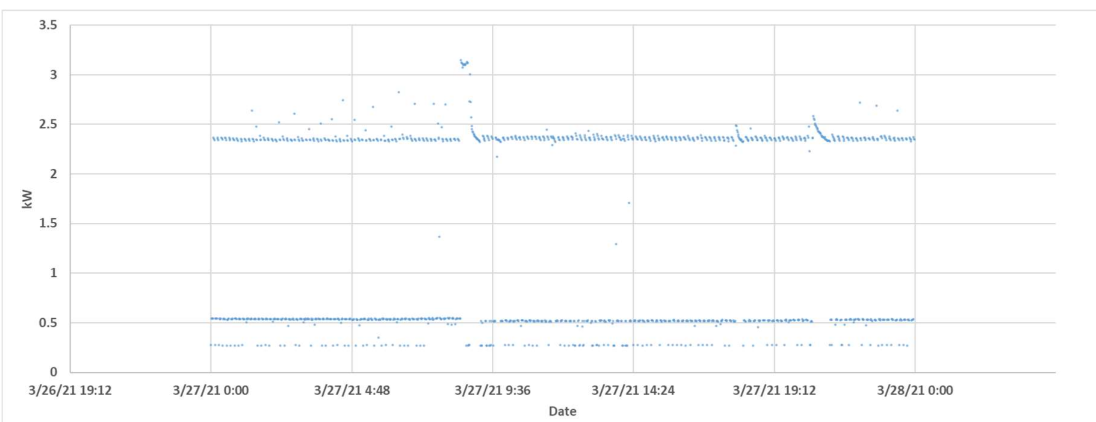
As stated above, this measure was evaluated as a non-ops only. The evaluators looked at the metered data from the energy logger installed onsite to validate the operation of the controller, which was found on site. The following figure shows the raw kW data of the walk-in cooler:

Fig.2- Raw-kW Data for Walk-in Cooler



From the above figure, we can observe that most data points are scattered between 0 and 1 kW and between 2 and 3 kW. The evaluators believe that these data points reflect the operation of the condenser fans and the compressor, respectively. However, we can also observe certain spikes in the data just over 3 kW that occurs during certain times at irregular intervals. The evaluators believe this to be the kW draw during the defrost cycle. Based on the data from the above figure, we can conclude that the defrost controller is operational as was claimed in the project documentation and is corroborative of the same and confirmed that the controller operates less than four times per day. For additional context, the following figure shows a more granular version of the data shown in Figure 2, where we can observe clearly that the defrost cycle runs less than four times per day as it was supposed to after the installation of the controller.

Fig.3- Raw-kW Data for Walk-in Cooler (Sample Daily Data)



From the above figure, which shows the metered data for a period of one day, we can observe that the spike which is the defrost cycle that was observed earlier in Figure 2 occurs only once during the day, confirming the operation of the controller. Therefore, the evaluators used the same savings methodology outlined in the applicant documentation to estimate the savings and did not make any operational adjustments to the analysis but only verified the installation of the defrost control system. Therefore, the measure resulted in an annual energy savings of 1,405 kWh.

Final Results

The following table summarizes the key parameters that were used in the estimation of savings and compares them with the tracking and post case:

Table 5-309. Summary of Key Parameters

	BASELINE		PROPOSED / INSTALLED	
Parameter	Tracking Value(s)	Evaluation Value(s)	Tracking Value(s)	Evaluation Value(s)
Defrost Hours	973 hours	632 hours	973 hours	632 hours

Explanation of Differences

The evaluation found no difference in the savings because this measure was non-ops-only assessment, and there were no operational adjustments made to the tracking savings. Therefore, there are no deviations between the applicant and evaluation savings.

Ancillary impacts

There are no ancillary impacts.

RICE19N083

Report Date: 5/12/2021

Application ID(s)	8677820 (Child), 5388014 (Parent)	
Project Type	New Construction	
Program Year	2019	
Evaluation Firm	DMI	DMI
Evaluation Engineer	Bennett Rose	
Senior Engineer	Mickey Bush	

Evaluated Site Summary and Results

The site is an industrial manufacturer of metal powders. The project that is being evaluated is the construction of a new wastewater treatment system to serve three process waste streams; steam A – silisphere process waste-water which contains alcohol, steam B – batch process and dirty wash water, stream C – clean wash water.

The customer has had numerous sewer permit violations in the past for excessive biological oxygen demand (BOD), chemical oxygen demand (COD), total nitrogen, ammonia and metals in the wastewater discharged to the City. The first step taken by the site to address the wastewater permit violations was to install one microfilter per waste stream (3 total) to remove suspended metals and precipitated silver. In addition to this, the site agreed with the City to install a treatment system to reduce or eliminate total BOD, COD, nitrogen, and ammonia to avoid additional surcharge pay-outs.

The installed wastewater treatment system is a distillation process. The specific distillation system installed at the site is a Buflovak system. Because waste streams B and C have all the necessary contaminants removed via microfilters and the proposed case system does not require specific chemistry to operate, the installed system only serves waste stream A (compared to baseline, which must treat all three streams – see applicant baseline section). By separating the alcohol and water, the site can recycle the alcohol for their process and reuse the water after treatment.

This is a new construction application with a standard efficiency biological wastewater treatment system serving as the baseline.

The project results in electric energy savings due to lower pumping/blower power and run hours for the proposed case system compared to the baseline system. There is a gas penalty associated with the steam required to run the distillation process in the proposed case system. Due to this fuel penalty, the non-energy benefit of water savings is a critical factor in the measure passing screening.

The tracking annual electric savings for this measure are 1,458,522 kWh. The annual gas penalty associated with the measure is 221,533 therms. The annual water savings is 9,100,000 gallons.

The evaluated savings are 145,852 kWh or 10% of the applicant savings based on the evaluation finding that the installed wastewater system was shut down after a year and a half of operation due to a change in production priorities at the site unrelated to COVID. The site was comfortable with the evaluator conducting an onsite inspection, so this site was selected for an operational M&V evaluation.

The evaluation results are presented in Table 5-2.

Table 5-310. 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)
8677820 (Child), 5388014 (Parent)	Waste Water Treatment System	Tracked	1,458,522	61%	120	120
		Evaluated	145,852	61%	12	12
		Realization Rate	10%	100%	10%	10%
Totals		**Tracked**	**1,458,522**	**61%**	**120**	**120**
		Evaluated	**145,852**	**61%**	**12**	**12**
		Realization Rate	**10%**	**100%**	**10%**	**10%**

Explanation of Deviations from Tracking

The evaluator found that the proposed case wastewater treatment system is installed, but not currently operating. The site is not running the process that produces waste stream A, which is what the installed system is designed for and the process will not run for the foreseeable future. The system ran for approximately one and a half years before it was shutdown. The method for handling this finding is to consider the first-year savings to be equal to the average annual savings over the course of the 15 year measure life. This approach results in a 10% realization rate for the project.

Recommendations for Program Designers & Implementers

There are no recommendations currently.

Customer Alert

There are no customer alerts.

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 information available.

The project consisted of the installation of a distillation water treatment system to serve a specific process waste stream. The alternative to the installed system is a biological system that would require the treatment of three waste streams because it requires specific chemistry to operate properly.

Application Information and Applicant Savings Methodology

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

Applicant Description of Baseline

This section describes the baseline equipment, system, assumptions, and/or control sequence as described by the applicant. This project is classified as a new construction project and considers a new construction baseline.

The applicant baseline is a new biological wastewater treatment system, which uses microorganisms to break down the waste components into sludge which can be separated from the water and shipped off site. After treatment, the water contaminant levels are suitable for discharge to the city. The applicant documents include verification from the customer that a biological system would be able to meet the City's discharge requirements.

The base case system would treat all of the wastewater (waste streams A, B, and C) in order to achieve the required chemistry for the bioprocess to work as desired.

The system would need to operate continuously because its treatment is based on a biological process as compared to a distillation process, which operates on demand based on the wastewater flow. Annual operating hours for the baseline system are estimated to be 8,760 hours/year.

Biological treatment does not produce water that can be recycled by the site and does not capture alcohol from waste stream A for reuse.

The key baseline parameters are summarized in Table 2-1.

Table 5-311. Applicant baseline key parameters

		BASELINE		
Measure	**Parameter**	**Value(s)**	**Source of Parameter Value**	**Note**
EEM #1	Sum of process motor nominal HP	732 HP	Budgetary Price Proposal	
	Average motor load (for all motors)	60%	TA study	
	Average week-day process motor load	223.9 kW	TA Study	
	Average weekend process motor load	111.5 kW	TA Study	
	Weekday operating hours	6,264 hours	TA Study	
	Weekend Operating Hours	2,496 hours	TA Study	

Applicant Description of Installed Equipment and Operation

This section describes the proposed condition assumed in the application analysis. It only discusses the assumptions made in the original analysis, not any information gained through this evaluation. The proposed case system is a Buflovak distillation wastewater treatment system to serve waste stream A specifically. Unlike the other two waste streams, waste stream A contains alcohol. Waste stream B and C can be adequately processed via microfilters. The distillation process will remove the alcohol from waste stream A and the water will be recycled for use at the site.

The applicant's key proposed case parameters are presented in Table 2-2.

Table 5-312: Application proposed key parameters

	PROPOSED			
Measure	Parameter	Value(s)	Source of Parameter Value	Note
EEM #1	Buflovak Process Motor BHP	38.8 bhp	Vendor Specifications	
	Total Fan and Pump Nominal HP	90 HP	Vendor Specifications	
	Average total motor load	71 kW	TA Study	
	Annual Operating Hours	3,000 hours	TA Study	

Applicant Energy Savings Algorithm

The applicant assumes an average operating demand for all system components and annual operating hours for each system to forecast the annual energy usage. The baseline calculations are summarized in table 2-3 below:

Table 5-3: Application baseline key parameters

Process / Equipment		Motor			Weekday		Weekend	
	Description	hp (bhp)	Eff	kW	Hours	kWh	Hours	kWh
EQ Tank Module	Jet Mixing Pump-circ pump	12	93.0%	5.8	6,264	36,178	2,496	14,416
	Transfer pump	2	86.5%	1.0	6,264	6,483	2,496	2,583
	Transfer pump[1]	2	86.5%	1.0	0	0	0	0
Anoxic Module	Jet Mixing Pump-circ pump	12	93.0%	5.8	6,264	36,178	2,496	14,416
	Jet Mixing Pump-circ pump[1]	12	93.0%	5.8	0	0	0	0
	Positive Displace Blower	75	95.0%	35.3	0	0	2,496	88,201
	Membrane Feed Pump	20	93.0%	9.6	6,264	60,296	0	0
	Membrane Feed Pump[1]	20	93.0%	9.6	0	0	0	0
Chemical Module	Sodium hydroxide pump	1	85.5%	0.5	6,264	3,279	0	0
	Sulfuric acid pump	1	85.5%	0.5	6,264	3,279	0	0
	Sulfuric acid pump	1	85.5%	0.5	6,264	3,279	0	0
	Sulfuric acid pump[1]	1	85.5%	0.5	0	0	0	0
	Carbon dosing pump	1	85.5%	0.5	6,264	3,279	0	0
	Carbon dosing pump[1]	1	85.5%	0.5	0	0	0	0
	Phosphorus dosing pump	1	85.5%	0.5	6,264	3,279	0	0
	Phosphorus dosing pump[1]	1	85.5%	0.5	0	0	0	0
bioFLOW skids	Circulation pump	125	95.4%	58.6	6,264	367,370	0	0
	Circulation pump	125	95.4%	58.6	6,264	367,370	0	0
	Circulation pump	125	95.4%	58.6	6,264	367,370	2,496	146,385
	Circulation pump[1]	125	95.4%	58.6	0	0	0	0
CIP Module	Electric heater			5.0	4,380	21,900	0	0
	Mixing pump	2	86.5%	1.0	6,264	6,483	0	0
	CIP feed pump	20	93.0%	9.6	6,264	60,296	0	0
	CIP feed pump[1]	20	93.0%	9.6	0	0	0	0
	NaOH feed pump	1	85.5%	0.5	6,264	3,279	0	0
	NaOCL feed pump	1	85.5%	0.5	6,264	3,279	0	0
	HCL feed pump	1	85.5%	0.5	6,264	3,279	0	0
Permeate/ Recycle	Permeate Recycle Pumps	2	86.5%	1.0	6,264	6,483	0	0
	Permeate Recycle Pumps[1]	2	86.5%	1.0	0	0	0	0
Sludge Tank	PD Blowers	10	91.7%	4.9	6,264	30,575	2,496	12,183
	PD Blowers[1]	10	91.7%	4.9	0	0	0	0

Total	732	351.5	1,393,214	278,183
[1]*All equipment associated in the baseline system is included in Table 2-3, including equipment installed for redundancy*				

The number of each type of equipment operating in the base case is expected to vary. It is assumed that the average number of pumps running will be one unit less than the number installed, i.e., one EQ tank module transfer pump is supplied for redundancy.

The weekday/weekend run hours are calculated assuming 8,760 total system run hours and broken out as follows

(8760 total hours - [52 weeks X 2 days/weekend x 24 hrs/day = 2,496 hrs {weekend hours}] = 6,264 hrs/yr {weekly hours})

The average motor demand is calculated for every base case motor assuming an average load factor of 60%.

It is assumed that only one unit of each piece of equipment will be in operation during weekend hours (2,496 hrs/yr). This assumption is based on the expectation that treatment will happen during the hours of product production and be idled to maintain the biological system on weekends. The applicant assumes that the Chemical module, CIP module, and Permeate/Recycle module do not run during the weekend.

The same general approach is used to forecast the annual energy use of the proposed case system. The proposed system summary table is presented below:

Table 5-4: Application proposed key parameters

Proposed Equipment	Motor		VFD	Demand	Annual	kWh
	hp	eff	Eff	kW	Hours	
Buflovak Process	38.8	89.0%	N/A	32.5	3,000	97,567
Cooling Tower Fans	15	91.0%	97.0%	8.3	3,000	24,808
Cooling Tower Pump	25	93.6%	N/A	15.9	3,000	47,821
Process Water Pump	40	94.1%	97.0%	9.8	3,000	29,507
Boiler Combustion Fan	5	89.5%	97.0%	1.5	3,000	4,421
Boiler Feed Pump	5	89.5%	N/A	2.9	3,000	8,752
Total	128.8			71.0	3,000	212,876

Note the HP listed for the Buflovak Process item is actually the sum of the rated brake-horsepower for the process motors associated with the system, not the nominal HP of the motors.

The cooling tower fan average kW is calculated using a bin model and manufacturer selection software data to calculate the average fan power over a year.

The average cooling tower pump power is calculated assuming an average load of 80%.

The average process water pump power is calculated assuming that the average process flow will be 64% of design flow and using the affinity law with an exponent of 2.5.

The boiler fan power is calculated using the affinity law (exponent of 3) and assuming an average fan speed of 70%.

The boiler feed pump average demand is calculated assuming a load of 70%.

The operating hours are calculated assuming 60 hrs/week based on production projections from the site contact and 50 weeks per year resulting in 3,000 annual operating hours.

The annual savings are calculated using the following equation.

$$Annual\ Savings\ kWh = Baseline\ Weekday\ kWh + Baseline\ Weekend\ kWh - Proposed\ Case\ kWh$$

Evaluation Assessment of Applicant Methodology

This section summarizes the evaluator's assessment of the application's savings methodology. The applicant developed a reasonable approach for forecasting the baseline and proposed case annual energy consumption. The connected power associated with each system is based on the inventory of process motors associated with each system and is based on specifications provided by system vendors. Run hours are assumed for each system based on feedback from the site. No errors were identified with the applicant's methodology.

Onsite Inspection

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

Summary of Onsite Findings

The evaluator visited the site on 4/8/21 and met with the systems engineer. The site visit included an interview and a tour of the wastewater treatment equipment installed at the facility.

- The waste stream treated by the installed equipment came from a production process that the site is no longer running and that the site does not anticipate restarting in the future. All of the waste that is produced by the site can be filtered with the micro-screen filtration system to meet the requirements to be sent to the sewer and the installed treatment system does not need to operate.
- The shut-down of the installed waste water treatment system is completely unrelated to COVID.
- The site did not have any issues with the installed system during the 1.5 years it was operating.
- All of the process motor nominal capacities (with the exception of the cooling tower fans) were confirmed onsite. Cooling tower fan motor capacity could not be verified due to accessibility.

Table 5-5. Measure Verification

Measure Name	Verification Method	Verification Result
Buflovak Waste Water Treatment System	Visual inspection of motor nameplates	All the motor nameplate horsepower values were confirmed onsite with the exception of the cooling tower fans due to accessibility.

Evaluation Methods and Findings

This section describes the evaluator methods and findings.

Evaluation Description of Baseline

The evaluator agrees with the new construction classification of this project because it is an entirely new water treatment system that was installed to eliminate sewer permit violations. The site contact stated during the site visit that the contaminants in the waste stream could be processed with a biological process to meet the city's effluent requirements. Based on this information the evaluator agrees with the baseline defined by the applicant.

The site listed multiple reasons for why they decided to install the distillation system instead of a biological system. The reasons include:

- The footprint required for the biological system is much greater than the footprint of the distillation process.
- The amount of connected power associated with the biological process is costly to operate (energy savings).
- Handling the large quantity of sludge produced by the biological system is a drawback to the biological system.
- The ability to recycle water and alcohol is a major advantage of the distillation system.

Evaluation Calculation Method

As described above the installed system is not currently operating and the site does not have plans to operate the system in the future. This finding was relayed to the evaluation team and the PAs to determine how to proceed. The system ran for approximately one and a half years (end of 2017 through early 2019). It was determined that the method for handling system shutdowns is to consider the first-year savings to be equal to the average annual savings over the course of the measure life. The measure life for new construction process measures is 15 years. This approach results in a 10% adjustment factor which is applied to both demand and energy savings. The evaluated first year savings are calculated using the formula below.

$$Evaluated\ Savings = Applicant\ Savings * \frac{1.5\ Years\ Operating}{15\ Year\ Measure\ Life}$$

The equipment does not run, so metering the installed equipment is not an option. The evaluator was able to confirm the quantity and nominal horsepower of all the installed process motors. For these reasons the applicant's first year savings are not adjusted by the evaluator and the only operational adjustment made to the savings is the finding that the system was shut-down after one and a half years of operation.

A review of the non-operational discrepancies is below.

Baseline: The evaluator confirmed that the baseline biological process was a viable option. The evaluator also agrees with the measure classification of the project as new construction. Because of this, there are no evaluated changes to the baseline for this project.

Applicant Calculation Methodology: The applicant developed a reasonable approach for forecasting the baseline and proposed case annual energy consumption. The connected power associated with each system is based on the inventory of process motors associated with each system and is based on specifications provided by system vendors. Run hours are assumed for each system based on feedback from the site. No errors were identified with the applicant's methodology so there are no evaluated changes made to the analysis methodology.

Tracking and administrative: The applicant savings match the tracking savings for the project. There are no tracking and administrative discrepancies.

Technology: The installed distillation wastewater treatment system was observed onsite. With the exception of the cooling tower fan motor, the motor capacity of all the process motors included in the installed water treatment system was verified onsite. The cooling tower fan motor sizes could not be confirmed or denied onsite because the cooling tower is on a platform that cannot be accessed without a ladder and a ladder was not available at the time of the site visit. The cooling tower nameplate was not visible from the ground.

Quantity: The installed motor quantity was confirmed onsite.

Final Results

This section summarizes the evaluation results determined in the analysis above. This section includes a summary table of savings by major end use and application.

Table 5-313. Summary of Key Parameters

	BASELINE		PROPOSED / INSTALLED	
Parameter	Tracking Value(s)	Evaluation Value(s)	Tracking Value(s)	Evaluation Value(s)
Average Process Power	Weekday: 223.9 kW Weekend: 111.5 kW	Weekday: 223.9 kW Weekend: 111.5 kW	71.0 kW	71.0 kW
Annual Operating Hours	Weekday: 6264 hours Weekend: 2,496 hours	Weekday: 6264 hours Weekend: 2,496 hours	3,000 hours	3,000 hours
Years Operating/ Measure Life	15 years/15 years	1.5 years/15 years	15 years/15 years	1.5 years/15 years

Explanation of Differences

The evaluation found that the site stopped running the installed system after a year and a half of operation and is not expected to run in the future. The adjustment made to the savings to reflect this finding is to consider the average annual savings over the course of the measure life. This adjustment results in evaluated savings that are 10% of the tracking/applicant savings.

3.2 Ancillary impacts

Alcohol and water were recovered and both were reused by the plant when the treatment system was operating. In addition to the water and alcohol, the process concentrated the salt in the waste stream and the site shipped the salt to a fertilizer company. Because the system is not operating this is not happening anymore. The fuel penalty and water savings would be reduced by 90% based on the operational adjustment.

RICE19N115

Report Date: 5/10/2021

Application ID(s)	9955597, 10471027	
Project Type	C&I Initial Purchase & End of Useful Life	
Program Year	2019	
Evaluation Firm	DNV	
Evaluation Approach	Non-Lighting: Full M&V	
Evaluation Engineer	Shravan Iyer	
Senior Engineer	Stephen Carlson	

Evaluated Site Summary and Results

The site is an industrial facility that manufactures vinyls, thermoplastic elastomers (TPEs), engineering thermoplastics (ETPs) etc., for various end-use applications. The facility operates three shifts per day, and the production schedules are: The first shift begins at 7 a.m. and lasts until 3 p.m., the second shift between 3 p.m. and 11 p.m., and the third shift between 11 p.m. to 7 a.m. The facility operates 24 hours per day, six days per week and operates on Sundays depending on production requirements, with a two-day annual shutdown for preventive maintenance around the 4th of July. The facility has an internal preventive maintenance policy to conduct compressed air leak audits and other similar preventive maintenance measures annually. This site was categorized as an essential service and was therefore allowed to operate as usual during the COVID-19 pandemic in 2020. The production staff worked onsite, but the corporate, administrative, and other support staff had transitioned to remote work. Therefore, the evaluation approach used for this site involved a full M&V evaluation because the operation and manufacturing oriented efficiency measures was not impacted by the COVID-19 pandemic. The energy-efficiency measures installed at this site include:

EEM-1: Fixing air leaks in the compressed air system- The measure involves fixing air leaks in the facility's compressed air system. A total of (155) air leaks were tagged, and all of them were fixed, reducing the leak load from 232 cfm to 34 cfm.

EEM-2: Dust Collector Interlocking- The measure involves interlocking the individual dust collectors to each of the blenders that are used in the blending/mixing of different grades of polymers, using PLCs, so that dust collection is turned on only when necessary, such as when the blenders are being filled or emptied and during the mixing process.

A brief note on how each non-lighting measure saves energy is described below:

EEM-1: Fixing air leaks in 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 compressor doesn't have to draw as much power to maintain the required cfm and pressure levels by fixing the air leaks because the line losses would be minimal.

EEM-2: Dust Collector Interlocking- The energy savings for this measure come from the reduced run hours of the dust collectors, i.e., by operating them only when needed.

The evaluation found the total measure savings to be 225,334 kWh annually, which is lower than the tracking savings listed in the applicant documentation. The evaluation results are presented in Table 1-1:

Table 5-314. 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)
9955597	Fixing Compressed Air Leaks	Tracked	250,183	50%	31.3	31.3
		Evaluated - ops	213,034	48%	24.08	24.45
		Realization Rate	85%	104%	77%	73%
10471027	Dust Collector Interlocking	Tracked	74,110	56%	10.4	10.4
		Evaluated - ops	12,300	30%	1.44	1.55
		Realization Rate	17%	54%	14%	15%
Totals		**Tracked**	**324,293**	**51%**	**41.67**	**41.67**
		Evaluated - ops	**225,334**	**39%**	**25.5**	**26.0**
		Realization Rate	**69%**	**76%**	**61%**	**62%**

Explanation of Deviations from Tracking

The evaluated savings are lower than the applicant-reported savings primarily due to the operating profiles of the compressors in the post case, i.e., the 250HP compressors are operating in the post case in a way in which resulted in the efficiencies going higher up on the curve which resulted in lower compressed air savings. The other factor is the higher post-case operating hours of one of the dust collectors compared to the tracking estimate and the non-operation of the interlocking controls on the other dust collector. Additionally, the discrepancy between the tracking documentation and the onsite finding regarding the project's scope, i.e., the ID of the dust collectors interlocked and claimed in the application, resulted in reduced savings. Further details regarding deviations from the tracked savings are presented in Section 3-4.

Recommendations for Program Designers & Implementers

It is recommended that the project's scope is documented accurately to mirror what was installed onsite.

Customer Alert

There were no customer alerts.

Evaluated Measures

The measures installed at this site include:

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

EEM-2: Dust Collector Interlocking- The measure consisted of interlocking dust collectors with the associated blenders so that the dust collectors run only when required, thereby reducing the dust collectors' run-hours.

Application Information and Applicant Savings Methodology

EEM-1: Fixing air leaks in the compressed air system- The facility conducted a compressed air leak audit to identify air leaks in the compressed air system throughout the facility. A total of (155) air leaks were tagged and fixed, reducing the leak load from 232 cfm to 34 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 would generate the demand, energy, and peak savings for the project based on the user-provided inputs.

EEM-2: Dust Collector Interlocking- The applicant savings calculation methodology used metered data to estimate both pre-and post-interlock motor kW draw for four weeks. The difference between the pre and post-kWh consumption was the savings. Further details on the applicant savings methodology are described in the subsequent sections.

The following section provides additional description of the affected systems, i.e., the compressed air system and the blender/dust collector system:

Description of Affected Systems

Compressed Air System

The facility's compressed air system consists of (2) 250HP centrifugal compressors operating on a primary/backup configuration. The primary compressor is served by a 400 Gallon storage tank and a cycling dryer. The facility also has multiple satellite storage tanks at different production areas for localized pressure and flow requirements. Additionally, the facility also installed a 100HP two-stage, twin-screw variable speed compressor integrated with a cycling dryer for an isolated section of the plant and is integrated with a 1,060 Gallon storage tank.

Blender/Dust Collector System

The facility's blender system consists of (5) blenders used to mix different grades of polymers, and each blender is equipped with a dust collector. The dust collectors are of various sizes with motor capacities ranging from 20 to 25HP motors and collect the dust that emanates from the blenders during the mixing/blending process. The dust collectors run

24 hours per day though the blenders themselves run for only about 6-8 hours per day. The table below shows the inventory of the dust collectors and their sizes:

Table 5-315. Applicant baseline key parameters

Sl. No	Dust Collector ID	Motor Size (HP)
1	DC #5	20
2	DC #6	25
3	DC #7	20
4	DC #8	20
5	DC #9	25

The applicant documentation states that dust collectors DC #7 and DC #9 were interlocked with the Blenders and therefore claimed savings for the above, but the evaluators observed a discrepancy during the site visit, which will be discussed further in the subsequent sections.

The evaluators found the applicant savings calculations reasonable after reviewing the applicant documentation and the savings calculation methodologies used to estimate the tracking savings.

Applicant Description of Baseline

EEM-1: Fixing air leaks in the compressed air system- The applicant documentation describes the facility's compressed air system consisting of (2) 250HP centrifugal air compressors that run on a primary/backup configuration and (1) a 100HP compressor that serves an isolated section of the plant. The applicant hours of operation were estimated to be 8,000 hours/year. The measure was categorized as a retrofit measure.

EEM-2: Dust Collector Interlocking- The applicant baseline consists of (2) dust collectors that have motors that are 20HP and 25HP that each serve a blender. The blenders run for about 6-8 hours per day, but the dust collectors run 24 hours per day. The measure was categorized as a retrofit measure.

The following table (Table 2-2) lists the key baseline parameters used to estimate the baseline consumption by the applicant:

Table 5-2. Applicant baseline key parameters

		BASELINE		
Measure	**Parameter**	**Value(s)**	**Source of Parameter Value**	**Note**
Fixing Compressed Air Leaks	Compressor System Efficiency	6.32 cfm/kW	Applicant Documentation	
Fixing Compressed Air Leaks	Hours of Operation	8,000 Hours	Applicant Documentation	
Fixing Compressed Air Leaks	Number of Leaks Fixed	155	Applicant Documentation	
Fixing Compressed Air Leaks	Centrifugal Compressor HP	250 HP	Applicant Documentation	
Fixing Compressed Air Leaks	Centrifugal Compressor HP	250 HP	Applicant Documentation	
Fixing Compressed Air Leaks	Screw Compressor HP	100 HP	Applicant Documentation	
Fixing Compressed Air Leaks	Pre-Case Compressed air leaks (CFM)	232 cfm	Applicant Documentation	
Dust Collector Interlocking	DC #7 Motor HP	20 HP	Applicant Documentation	

Dust Collector Interlocking	DC #9 Motor HP	25 HP	Applicant Documentation	
Dust Collector Interlocking	Pre-Case Operating Hours	7,083 Hours	Applicant Documentation	
Dust Collector Interlocking	DC #7 Percent Run Time	84.3%	Applicant Documentation	
Dust Collector Interlocking	DC #9 Percent Run Time	85.6%	Applicant Documentation	

Applicant Description of Installed Equipment and Operation

The post-case/installed case equipment for each of the measures described in the application documentation is described below:

EEM-1: Fixing air leaks in the compressed air system- The facility proposed fixing the compressed air leaks observed throughout the facility. The facility 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 compressed air. The facility was able to identify and tag (155) air leaks which were fixed as part of the project. This reduced the leak load from 232 cfm prior to fixing the air leaks to 34 cfm after fixing the air leaks.

EEM-2: Dust Collector Interlocking- In the post case, the applicant documentation states that dust collectors DC #7 and DC #9 were interlocked with the Blenders using PLCs. By integrating the dust collectors with the blenders using PLCs, the dust collectors' run hours were reduced.

The following table (Table 2-3) lists the key post-case parameters used to estimate the post-case consumption by the applicant:

Table 5-3: Application proposed key parameters

PROPOSED				
Measure	**Parameter**	**Value(s)**	**Source of Parameter Value**	**Note**
Fixing Compressed Air Leaks	Compressor System Efficiency	6.32 cfm/kW	Applicant Documentation	
Fixing Compressed Air Leaks	Hours of Operation	8,000 Hours	Applicant Documentation	
Fixing Compressed Air Leaks	Number of Leaks Fixed	155	Applicant Documentation	
Fixing Compressed Air Leaks	Centrifugal Compressor HP	250 HP	Applicant Documentation	
Fixing Compressed Air Leaks	Centrifugal Compressor HP	250 HP	Applicant Documentation	
Fixing Compressed Air Leaks	Screw Compressor HP	100 HP	Applicant Documentation	
Fixing Compressed Air Leaks	Post-Case Compressed air leaks (CFM)	34 cfm	Applicant Documentation	
Dust Collector Interlocking	DC #7 Motor HP	20 HP	Applicant Documentation	
Dust Collector Interlocking	DC #9 Motor HP	25 HP	Applicant Documentation	
Dust Collector Interlocking	Post-Case Operating Hours	1,680 Hours	Applicant Documentation	
Dust Collector Interlocking	DC #7 Percent Run Time	20%	Applicant Documentation	

Dust Collector Interlocking	DC #9 Percent Run Time	20%		Applicant Documentation

Applicant Energy Savings Algorithm

Some general facility-related information along with the energy savings calculation methodology found in the applicant document for each measure is described below:

Hours/Day= 24 Hours

Days/Week= 7 Days

Annual Production Weeks= 50 Weeks

Annual Production Hours= 8,400 Hours

EEM-1: Fixing air leaks in the compressed air system- 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 below:

Compressor Capacities:
Compressor #1= 250HP
Compressor #2= 250HP
Compressor #3= 100HP

Compressor Efficiencies:
Compressor #1 Efficiency (cfm/kW) = 6.73
Compressor #2 Efficiency (cfm/kW) = 6.73
Compressor #3 Efficiency (cfm/kW) = 5.20

Average flow from pre-repair metering[93] *= 232 cfm*
Average flow from post-repair metering[94]*= 34 cfm*
Weighted Average System Efficiency[95] *(cfm/kW) = 6.32*
Annual operating hours= 8,000 hours

Average flow saved= pre-repair cfm – post-repair cfm
Average flow saved= 232 cfm – 34 cfm
Average flow saved= 198 cfm

Average Power saved= Average Flow saved/System Efficiency
Average Power saved= 198 cfm/6.32 cfm/kW
Average Power saved= 31.273 kW

Annual Energy Savings= 31.273 kW x 8,000 hours
Annual Energy Savings= 250,183 kWh

Therefore, the tracking savings for this measure was found to be 250,183 kWh and the summer and winter seasonal demand was found to be 31.273[96] kW.

EEM-2: Dust Collector Interlocking- The savings for this measure was estimated using metered data. Data loggers (Amp loggers) were installed on (5) Dust collectors for a period of 4 weeks to estimate the kW draw of the motors and model their operating profiles to estimate annual run hours. The annual pre-case utilization rate of the dust collectors was estimated using the metered data (which was found to be 84%), and the annual operating hours (8,400 hours) were

[93] From project files
[94] From project files
[95]Tracking calculations use weighted average efficiency of the three compressors to calculate savings. Weighting was determined by the tool.
[96] 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

de-rated using the estimated utilization rate to calculate actual operating hours. The average kW draw was multiplied by the actual operating hours to estimate the pre-case kWh consumption for DC #7 and DC #9.

For the post-case kWh consumption, the facility had initially (before submitting the application) completed the interlocking of the dust collector with the blender on DC #7 and therefore had pre and post-case metered data for this dust collector. Upon comparing the pre and post-case metered data for DC #7, a 7.1% increase in the post case kW draw of the 20HP motor (serving DC #7) was observed while there was a significant reduction in the operating hours as expected. The post case percent run time was estimated to be 20% which takes into account both the post case utilization rate[97] of 13% (obtained from post case metered data) and any variation in the production schedules caused by the time that the plant was not supposed to operate, such as on Sundays. The post case percent run time (20%) was multiplied by the pre-case annual operating hours (8,400 hours) to calculate the post case actual operating hours (for both DC #7 and DC #9). The post case kW draw was multiplied by the post case actual operating hours to calculate total post case kWh consumption. The difference between the pre and post case consumption is the total kWh savings

Annual kWh Savings= Pre-Case kWh Consumption - Post Case kWh Consumption
Annual kWh Savings= 99,036 kWh- 24,926 kWh
Annual kWh Savings= 74,110 kWh

Total Energy Savings= EEM-1 kWh Savings + EEM-2 kWh Savings
Total Energy Savings= 250,183 kWh + 74,110 kWh

Total Energy Savings= 324,293 kWh

The total kWh savings shown in the savings calculation spreadsheets found in the project documentation matches the tracking savings value.

Evaluation Assessment of Applicant Methodology

EEM-1: Fixing air leaks in the compressed air system- The evaluators agree with the applicant savings methodology. The evaluators agree with the methodology used to identify the compressed air leaks in the facility using an ultrasonic leak detector to determine the pre-repair cfm consumed in the facility. The post-repair cfm was measured similarly, and the pre-and post-repair cfm values were used as inputs in the savings calculator spreadsheet. The evaluator finds this methodology reasonable.

EEM-2: Dust Collector Interlocking- The evaluators agree with the applicant baseline and find the savings calculation methodology reasonable. However, the evaluators observed a difference in the project's scope, wherein the applicant claimed savings on a different dust collector compared to what was documented in the application. This discrepancy is further discussed in Section 2.4 of the report.

Site Inspection

A site visit was performed on 2/23/2021 to verify the compressed air leaks fixed as part of the project, verify the dust collectors that were interlocked with the blenders, and install ElitePRO power loggers to capture trend data (voltage, amperage, and power factor) on the (2) compressors and the dust collectors in the facility. The evaluators had initial discussions with the Electrical Maintenance Supervisor, who was the site contact for the facility and learned that it was Dust Collectors DC #7 and DC #8 that were interlocked with the blenders at the time of submitting the incentive application and not DC #9 as stated in the project documentation. The site contact confirmed that all (5) dust collectors inventoried in the application had been interlocked with the blenders but were done one after the other in phases. The only dust collectors for which an incentive had been claimed were DC #7 and DC #8. The site contact further added that DC #6 and DC #9 had been partially complete when the application was submitted and completed later (after the new year) after completing DC #7 and #8. The line running DC #5 was scheduled to be decommissioned. The site contact also confirmed that all the blenders that were integrated with the dust collectors were running different product mixes at the time of the site visit compared to the product that was run on the lines at the time of installing the project. The evaluators learned that the dust collectors that have been interlocked to the blenders using PLC controls are run using a

[97]Refers to the percentage of time for which the dust collector is operational during the metering period. Estimated from metered data. The 13% utilization rate was annualized by factoring in down-times and non-operational times which came up to 20%.

timer, and a starter and the dust collectors run only during specific times during certain operations such as when filling the blender, cycling and during opening/closing of the blender lids. During the visit, the evaluators found that the PLC control logic for DC #9 was overridden at the site visit. After discussions with the site contact, it was confirmed that DC #9 would be run without the control logic and would therefore run as it did before it was interlocked with the blender.

The evaluators then verified the (2) 250 HP centrifugal compressors. The compressors are controlled manually wherein they have operated alternately, i.e., one 250HP compressor runs for a week, and the other 250HP compressor runs for the following week. The evaluators observed two main compressed air lines that run throughout the plant that serve the plant's compressed air requirements. At any time, there is only one compressor that is operating to maintain plant pressure requirements. The major compressed air loads in the plant are the automated conveyors, pneumatically controlled production equipment and the air guns used in the machining area. The operating pressures of the 250HP compressors are 105 psig which is the required operating pressure in the plant, and the compressors are rated at 125 psig. The 250HP compressors serve most of the plant except in certain areas. The evaluators also inspected the other 100HP two-stage twin-screw variable speed compressor. This compressor was installed to reduce the load on the (2) 250HP compressors. This compressor serves an isolated section of the plant, i.e., the lab area. The pre-case operating pressure was found to be 115 psig (before fixing the air leaks), and the operating pressures found in the plant now are 105 psig.
The compressor also uses a cycling air dryer and is integrated with a 1,060 Gallon storage tank. Other tanks in the facility serve localized pressure and flow requirements in different areas of the plant. It was learned that the facility conducts a compressed air leak audit every year. Another air leak audit was completed after the audit was performed as part of this project. But the process was slowed down, and the incentive application process was delayed due to COVID-19. Therefore, the tagged leaks as part of this project were not tagged at the time of the visit. But the evaluators were able to verify a sample of leaks in certain areas to confirm if they had been fixed as part of the project described in this application.

The evaluators also verified the production schedules of the facility and confirmed that the site operates three shifts per day. The evaluators installed ElitePRO kW loggers to record volts, amps and power factor on the equipment claimed as part of the projects and therefore installed one ElitePRO logger (SP1212145) on DC #7, one logger on DC #8 (XC1307124), the two dust collectors that were initially completed. For the compressed air system, the evaluators installed an ElitePRO logger on one 250 HP compressor (XC1805074) and another on the 100HP compressor (SP1212073). The loggers were installed for a period of five weeks. The loggers were installed to help the evaluators gain insight into the post-case operating profile of the compressors and dust collectors, respectively. The following section summarizes the principal findings made by the evaluators onsite:

Summary of Virtual/On-Site Findings

The evaluators made the following observations on site:

- Based on the Electrical Maintenance Supervisor conversations, the evaluators confirmed that the compressed air leak repair project was completed as claimed in the applicant documentation.
- The evaluators also learned that dust collectors #7 and #8 had been interlocked and not #9 as stated in the applicant documentation.
- The evaluators confirmed the presence of (3) air compressors, i.e. (2) 250 HP and (1) 100HP 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 105 psig.
- The compressors are controlled manually and are run weekly. The 100HP compressor runs all the time. The compressors work together to maintain the required plant operating pressure.

- The evaluators verified a sample of the spaces in which the air leaks were fixed as part of the project in 2019 because the leaks found onsite were that of the next cycle of air leaks that were fixed in 2020 and those labeled for the 2019 project were no longer labeled.

The following table lists the parameters verified by the evaluators during the site visit:

Table 5-4. Measure Verification

Measure Name	Verification Method	Verification Result
Fixing Compressed Air Leaks	Verify the compressors' nameplate matches the project description via. physical inspection	The nameplates matched the project description.
Fixing Compressed Air Leaks	Verify the compressed air leaks that were fixed as part of the project via. physical inspection	The compressed air leaks that were fixed were verified during the facility walk-through and confirmed by the site contact
Fixing Compressed Air Leaks	Verify control types on each compressor via. physical inspection	The 250 HP compressors modulate using a mechanical control valve, and a VFD controls the 100HP compressor
Dust Collector Interlocking	Verify the motor nameplate data on the 20HP motor on DC #7	Verified onsite
Dust Collector Interlocking	Verify the motor nameplate data on the 20HP motor on DC #8	Verified onsite
Dust Collector Interlocking	Verify the number of Dust collectors interlocked that were claimed in the project	Verified. Found to be DC #7 and #8

Evaluation Methods and Findings

This section describes the evaluator methods and findings.

Evaluation Description of Baseline

The evaluator reviewed the project files and interviewed the site contact to gather information on the baseline for both measures installed at the site. For the compressed air measure, the evaluators confirmed that the compressed air leak audit had been conducted and the leaks identified during the audit were fixed. For the dust collector interlocking measure, the evaluators confirmed that the dust collectors were interlocked and identified the discrepancy between the applicant documentation and the findings onsite. The evaluators have adjusted this accordingly in the analysis. The evaluator determined these measures to be retrofit with a single baseline, and the baseline is the pre-existing condition.

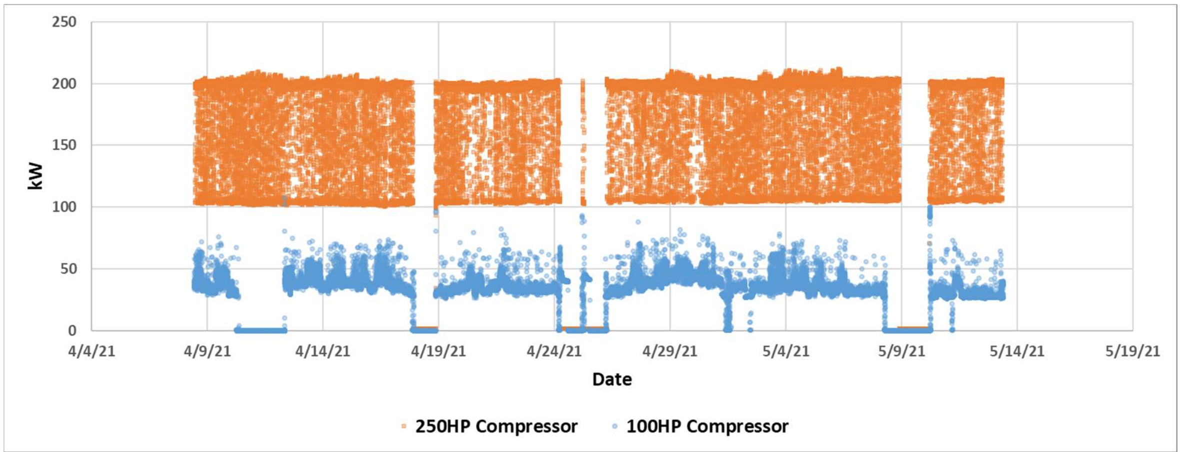
Evaluation Calculation Method

The evaluator savings calculation methodologies for each of the measures are described in detail below:

EEM-1: Fixing air leaks in the compressed air system

The evaluators used metered data obtained from the ElitePRO power loggers to understand the operating profile of the 250HP and 100HP compressors. The loggers were installed between April 8th and May 13th, 2021, for five weeks. During this period, the operating profile of the loggers from the metered data was observed to be as shown below:

Fig.1- Metered Data for 250HP and 100HP compressors



The above figure shows that the two compressors have nearly similar operating profiles wherein they are shut off simultaneously during the metering period. The 250HP centrifugal compressors act as the primary compressed air system that serves the facility's compressed air requirements. The 100HP modulates as required and serves the remainder of the pressure and cfm requirements. It should be noted that though the site has two 250HP compressors that are manually set to run alternatively weekly, the site contact agreed to run the 250HP compressor that was metered for the duration of the metering period. The metered data shown above reflects this operating profile. The evaluators modelled 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 both compressors where the average hourly kW draw was modelled over a typical week during the metering period as shown below:

Fig.2- Average Hourly kW draw of 250 HP Compressor (from metered data)

250HP Compressor- Average Hourly kW Draw							
Hour/Day	Sun	Mon	Tue	Wed	Thu	Fri	Sat
0	61.66	97.80	180.15	179.44	184.48	170.39	168.24
1	64.79	99.10	175.81	171.41	178.99	170.87	171.86
2	62.76	104.18	182.83	174.81	172.41	169.39	166.84
3	64.64	98.35	181.85	171.68	171.05	175.24	167.34
4	60.08	97.61	179.70	170.60	174.28	169.21	159.51
5	61.64	103.12	180.80	169.89	170.56	173.48	159.57
6	84.05	120.77	183.82	174.02	174.25	168.70	138.80
7	68.17	164.21	181.18	170.22	169.85	169.33	125.83
8	58.80	179.09	181.01	173.13	176.45	178.18	129.32
9	58.27	176.57	184.84	176.00	173.77	179.24	128.27
10	58.85	172.61	185.30	182.48	179.86	172.89	123.28
11	59.52	173.93	189.75	163.85	176.46	172.78	122.83
12	59.00	170.56	187.28	175.60	179.07	175.74	125.61
13	58.30	176.07	177.37	172.83	181.30	175.86	118.00
14	59.16	172.70	183.07	175.29	169.80	175.41	126.98
15	58.32	176.56	178.75	171.24	176.59	171.14	119.51
16	60.18	172.80	182.65	178.94	173.89	169.46	119.10
17	57.93	175.94	173.75	177.95	172.63	168.24	118.02
18	58.82	172.48	183.61	178.53	169.59	167.53	121.24
19	60.15	175.15	183.69	180.43	170.57	172.45	117.10
20	68.79	180.22	178.07	187.32	177.13	169.01	115.02
21	87.95	178.07	175.44	171.96	168.67	171.20	111.31
22	86.49	170.52	164.94	177.73	175.38	172.08	86.29
23	89.28	175.36	173.30	174.41	163.92	161.31	63.44

Fig.3- Average Hourly kW draw of 100 HP Compressor (from metered data)

100HP Compressor- Average hourly kW Draw							
Hour/Day	Sun	Mon	Tue	Wed	Thu	Fri	Sat
0	7.29	13.12	33.57	32.79	35.11	35.21	34.46
1	7.41	13.10	34.17	32.98	35.17	35.12	34.69
2	7.34	13.43	33.54	33.10	35.15	34.68	34.91
3	7.39	12.98	35.09	33.53	35.36	35.14	33.89
4	7.46	12.85	33.71	33.72	35.31	35.13	32.25
5	10.71	27.62	33.33	33.33	36.20	35.06	31.52
6	8.64	19.90	34.03	34.53	35.03	35.08	34.85
7	11.58	24.13	41.43	36.04	37.86	36.40	25.15
8	14.34	28.40	43.85	36.96	38.89	37.50	22.25
9	14.32	34.57	44.06	36.07	40.75	38.72	20.28
10	13.95	35.73	43.60	37.72	44.04	41.06	19.83
11	13.78	35.46	42.19	38.38	41.68	40.00	19.19
12	14.19	34.74	41.43	38.97	40.81	38.82	18.80
13	7.38	34.89	40.11	38.89	39.47	39.35	18.80
14	6.22	33.11	36.75	37.60	38.60	38.42	17.68
15	7.17	36.45	39.01	38.32	39.30	39.48	12.94
16	7.24	36.45	39.70	39.92	39.52	38.21	13.45
17	7.40	35.19	39.69	39.43	39.57	38.09	13.28
18	7.17	35.68	38.40	38.27	38.88	37.53	13.13
19	7.21	34.48	38.34	39.03	38.74	37.70	13.05
20	6.73	35.37	38.67	38.61	38.07	39.14	12.72
21	13.21	35.75	37.94	38.05	37.58	38.75	11.77
22	12.75	35.32	33.47	36.06	35.52	35.40	9.49
23	12.93	33.67	32.63	35.50	36.09	34.27	7.13

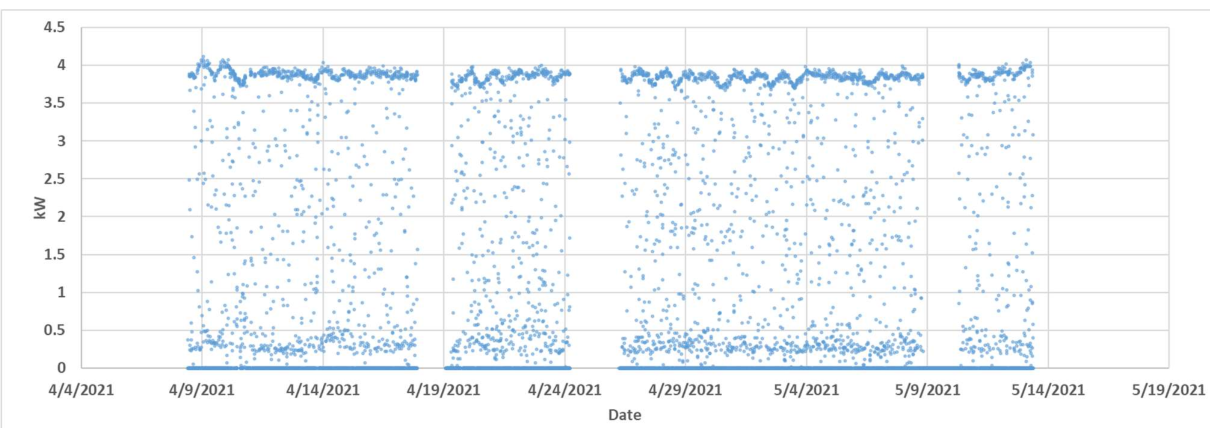
From the heatmaps, we can infer that the two compressors have very similar operating profiles. From Fig.2, We observe that the compressor is shut off for much of the weekend while exhibiting a near-constant kW-draw for the rest of the metering period. From Fig.3**,** we observe that the compressor modulates as required and supplements the operation of the 250HP compressor, i.e., it operates based on the pressure and cfm requirements of the plant. 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 week profiles as shown in the above heat maps, averaged by the hour of the day and weekday to represent the typical kW demand of the air compressor. From Fig.2 we can observe that the 250HP compressor serves the primary compressed air requirements of the site and the cfm reduction would occur in this compressed air system. Therefore, this data was extrapolated to a year (using an 8,760-hourly spreadsheet) to model the post-case annual kWh consumption of the compressors. The baseline compressor kW was modeled using metered data obtained from the loggers, which was converted to cfm using compressor CAGI sheet data. The leak load was added to the post-case cfm to estimate the base-case cfm, which was again converted to kW to estimate the baseline kWh consumption of the 250 HP compressor. The difference between this calculated baseline kWh and the estimated kWh from metered data in the 8,760 sheet is the annual kWh energy savings. The annual kWh savings for this measure was estimated to be 213,034 kWh. The reason for the lower savings is because the leak load was distributed proportionately between the two compressed air systems consisting of three compressors in the tracking, whereas in the post case, the operating profiles of the 250HP compressors show that they account for the overwhelming majority of the compressed air requirements and therefore resulted in reduced savings.

EEM-2: Dust Collector Interlocking

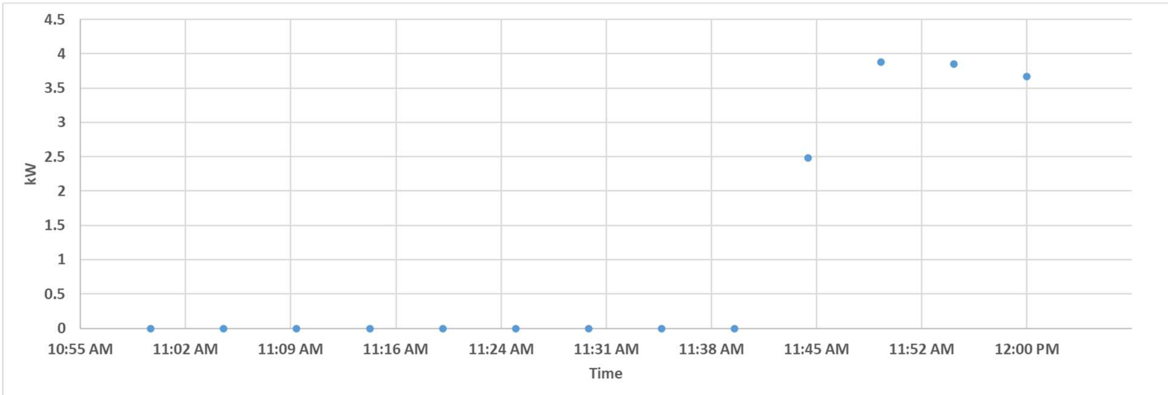
The evaluators used metered data obtained from the ElitePRO power loggers to gain insight into the operating profile of the dust collectors. 20HP motors power the two dust collectors in question, DC #7 and #8. It should be noted that based on the discussion in the above sections, the evaluators confirmed onsite that the interlocking of dust collectors #7 and #8 were the ones that were complete at the time the application was submitted. Therefore, the evaluators estimate savings for DC #7 and #8 and not #9 as was erroneously claimed in the application. The following figure shows the metered kW data for DC #7:

Fig.4- Metered Data for 20HP Motor for DC #7



From the above figure, we can observe that the dust collector, while operating at part-load, is shut off for a considerable amount of time. In this case, the evaluators observed that the interlocking mechanism of the dust collector and the blender was working as was claimed in the applicant documentation, which was visible in the metered data. The following figure shows a more granular representation of the metered data over the period of one hour, wherein the dust collector remains shut-off for the better part of an hour and turns on only as required. This is illustrated in the figure below:

Fig.5- Metered Data for 20HP Motor for DC #7 (Sample Hourly data)



As we can observe from the above figure, the dust collector interlocking mechanism appears to be working as claimed. The metered data was used to model the typical weekly operating profile of the dust collector for a typical week during the metering period, as shown in the heat map below:

Fig.6- Average Hourly kW draw of DC #7 (from metered data)

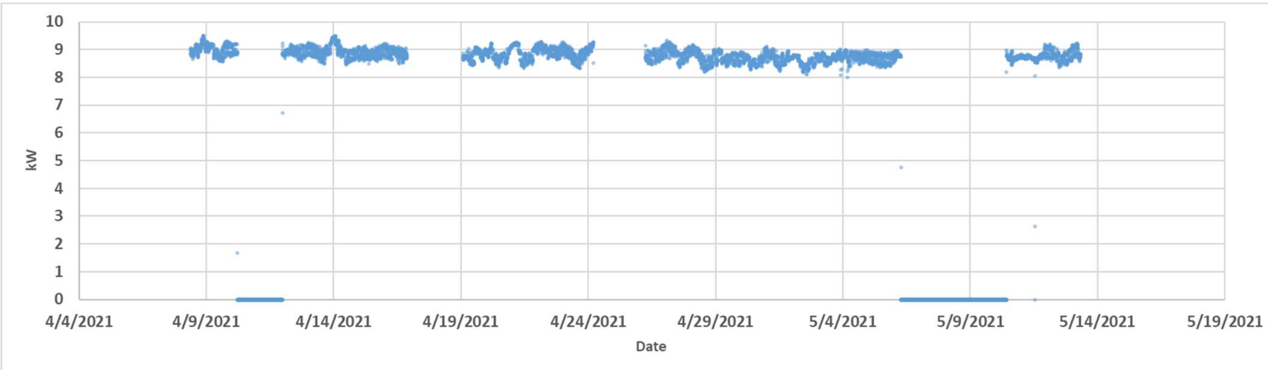
Operating Profile of DC #7							
HOUR/DAY	Sun	Mon	Tue	Wed	Thu	Fri	Sat
0:00	0.57	0.67	0.92	0.97	1.05	0.67	1.01
1:00	1.28	0.56	1.19	0.88	1.23	1.06	1.22
2:00	0.46	0.61	1.34	1.34	1.47	0.81	0.53
3:00	0.62	0.69	1.75	1.24	0.90	1.15	1.49
4:00	0.75	0.73	0.98	0.40	1.62	0.83	1.42
5:00	0.92	0.65	1.35	1.34	0.91	1.56	0.89
6:00	0.43	0.26	1.43	1.26	0.90	0.92	1.16
7:00	0.34	0.90	1.44	0.59	0.86	1.28	1.50
8:00	0.54	1.39	1.05	1.26	1.32	0.79	1.29
9:00	0.55	1.05	0.75	1.56	1.02	0.86	1.36
10:00	0.77	0.88	0.87	0.94	0.79	1.13	1.05
11:00	0.84	0.83	1.01	0.82	0.81	0.48	1.35
12:00	0.70	0.90	1.39	0.31	1.06	0.84	1.91
13:00	0.68	1.07	0.69	1.06	1.30	1.12	1.30
14:00	0.53	1.12	0.85	0.99	0.45	0.56	0.70
15:00	1.07	0.71	0.96	0.62	1.22	0.99	0.88
16:00	0.73	0.78	0.92	0.75	1.02	1.02	1.12
17:00	0.21	1.34	1.22	0.99	1.09	0.91	1.13
18:00	0.59	1.60	1.09	0.65	0.43	0.30	1.24
19:00	0.67	0.53	1.74	0.84	1.16	1.02	1.65
20:00	0.40	0.79	1.11	1.50	1.04	1.08	0.98
21:00	0.62	1.08	0.82	1.21	0.93	1.36	0.75
22:00	0.87	0.84	0.60	0.97	0.87	0.73	0.62
23:00	0.87	0.94	1.31	1.31	0.83	1.33	0.42

From the heat map, we can observe that the motor is operating at part load throughout the metering period. Therefore, the post case metered kW data were annualized using an 8,760 spreadsheet to determine the total post case kWh consumption. For the base case, the motor load factor was estimated to be 16%, and the base case kW drawn was estimated to be 2.4 kW[98] which was annualized using the 8,760 custom spreadsheet. The difference between the base case and post case resulted in savings.

[98] From metered data

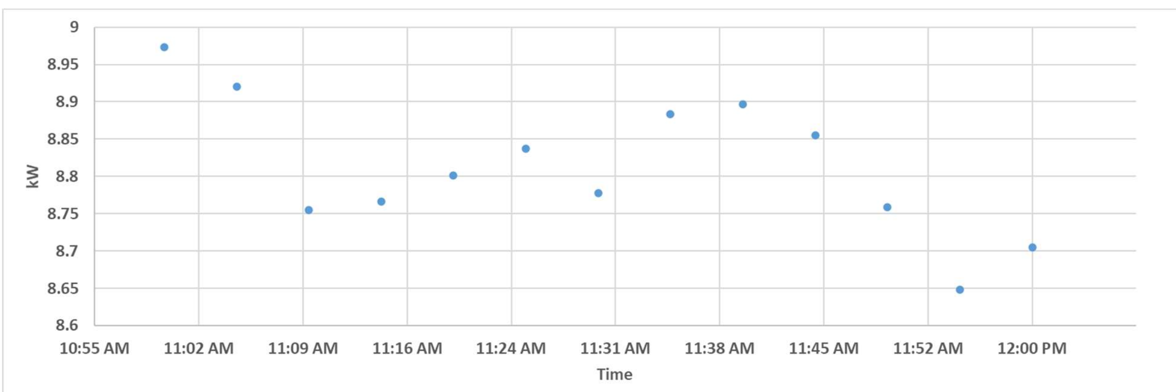
The evaluators used the same approach to determine the savings for DC #8. The following figure shows the metered kW data for DC #8:

Fig.7- Metered Data for 20HP Motor for DC #8



From the above figure, we can observe that the dust collector is operating at a higher part-load than DC #7 and is not shutting off the way the interlocking mechanism is supposed to work compared to DC #7. On further examination of hourly profiles of the metered data, it was observed that the dust collector runs at a near-constant load with no shutdowns. The following figure shows a more granular representation of the metered data over the period of one hour wherein the dust collector does not shut off at all, as shown below:

Fig.8- Metered Data for 20HP Motor for DC #8 (Sample Hourly data)



To further illustrate the above point, the metered data were aggregated over a typical week to observe the operating profile of the dust collectors to gain insight into its operating profile as shown in the heat map below:

Fig.9- Average Hourly kW draw of DC #8 (from metered data)

Operating Profile of DC #8							
Hour/Day	Sun	Mon	Tue	Wed	Thu	Fri	Sat
0	2.90	5.58	8.95	9.04	8.82	7.18	6.73
1	2.91	5.84	8.86	9.02	8.82	7.25	6.68
2	2.92	6.55	8.95	9.07	8.85	7.19	6.72
3	2.92	6.58	8.95	9.04	8.96	7.09	6.69
4	2.92	6.59	8.86	8.91	8.98	7.15	6.74
5	2.92	6.63	8.93	8.99	8.91	7.18	5.69
6	2.89	6.93	8.80	8.95	8.86	7.10	2.97
7	2.88	6.99	8.82	8.83	7.27	7.08	2.93
8	2.82	7.00	8.84	8.82	7.06	7.08	2.86
9	2.84	6.97	8.82	8.75	6.76	6.97	2.85
10	2.79	7.30	8.79	8.71	7.03	7.03	2.90
11	2.77	8.72	8.76	8.66	7.05	7.00	2.84
12	2.80	8.64	8.72	8.65	7.05	6.95	2.80
13	2.80	8.80	8.45	8.62	7.08	6.97	2.80
14	2.78	8.87	8.65	8.56	7.09	6.88	2.89
15	2.76	8.79	8.71	8.67	7.11	6.88	2.92
16	2.81	8.79	8.76	8.61	7.09	7.00	2.83
17	2.84	8.78	8.79	8.62	7.10	7.04	2.84
18	2.86	8.76	8.72	8.69	7.05	7.03	2.87
19	2.89	8.79	8.76	8.69	7.09	7.13	2.92
20	2.82	8.75	8.82	8.66	7.19	7.04	2.96
21	2.82	8.82	8.87	8.72	7.18	7.06	2.90
22	2.86	8.79	8.97	8.88	7.17	6.74	2.89
23	2.92	8.87	9.09	8.92	7.12	6.72	2.90

From the heat map and the hourly operating profile data, we can observe that the motor operates at part load throughout the metering period but never shuts off, indicating that the dust collector's interlocking mechanism with the blender does not seem to work. The dust collector appears to be running the same way as before installing the interlocking mechanism, and the evaluators have no reason to believe otherwise, and the site contact confirmed the controls were not in use. Therefore, after observing the above data, the evaluators conclude that this dust collector does not generate any savings.

From the metered data shown above, we can infer that the post-case operating hours of DC #7 are higher than what was claimed in the applicant documentation, which has resulted in lower savings. DC #8 does not generate any savings. The total savings for this measure was estimated to be 12,300 kWh.

Therefore, the total evaluated savings for the project is:

Total Energy Savings= EEM-1 kWh Savings + EEM-2 kWh Savings
Total Energy Savings= 213,034 kWh + 12,300 kWh

Total Energy Savings= 225,334 kWh

Final Results

The following table summarizes the key parameters used by the evaluators in estimating savings and compares them with the tracking and post case. The dust collector #8 did not appear to be controlled as much in the post case, therefore, resulting in lower savings

Table 5-316. Summary of Key Parameters

	BASELINE		PROPOSED / INSTALLED	
Parameter	Tracking Value(s)	Evaluation Value(s)	Tracking Value(s)	Evaluation Value(s)
Average kW of DC #7- Base Case	3.86 kW	2.4 kW	3.86 kW	2.4 kW

Operating Hours of DC #7	7,083 Hours	8,760 Hours	1,680 Hours	8,760 Hours
Compressed Air leaks (cfm)	232 cfm	34 cfm	232 cfm	34 cfm
Operating Pressure (psig)	115	105	115	105
Specific Power (kW/100acfm)	15.8	17.9	15.8	17.9

Explanation of Differences

This section describes the key drivers behind the difference in the application and evaluation estimates. The major parameters that have caused the savings are the technology, i.e. the reduced HP of the motors compared with the tracking and evaluation from 25HP to 20HP. For both measures, the post-case hours of operation were higher than claimed in the tracking documentation. Table 3-2 provides a summary of the differences between tracking and evaluated values.

Table 5-317. Summary of Deviations

Measure	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
Fixing Compressed Air Leaks	Operation	Operating power	-12%	Decreased savings – 37,149 kWh
Dust Collector Interlocking	Operation	Post Case Hours of Operation and lack of interlocking	-19%	Decreased savings – 61,810 kWh
		Final RR		69%

Ancillary impacts

This section will explain the ancillary impacts associated with each fuel based on the model output.

RICE19N172

Report Date: April 13. 2021

Program Administrator	National Grid	
Application ID(s)	10026201, 10806043, 8923824, 8038934, 8923825, 8124545	
Project Type	Retrofit	
Program Year	2019	
Evaluation Firm	DNV GL	
Evaluation Approach	Non-Ops only without Qty and Tech.	
Evaluation Engineer	Ryan Brown	
Senior Engineer	Stephen Carlson	

1.8 Evaluated Site Summary and Results

The evaluated project was implemented at an industrial manufacturing facility and consists of three different measures within one application:

(1) reduction of CO_2 flow for the hot extraction process by increasing temperature of the CO_2 through the installation of a heat exchanger,

(2) reduction in flow for the chilled water (CW) system through the installation of a throttling valve to convert to a variable primary flow system, and

(3) dewpoint demand control for desiccant dryers.

Hot extraction: The facility utilizes supercritical CO_2 (a phase that is a mixture of liquid and gas phases) in an ethanol extraction process to make their product. This measure included the installation of heat exchangers to the process loop to increase process temperature. By increasing the temperature of the CO_2 in the extractor, the process of ethanol removal during the treatment phase is accelerated, thereby reducing the total treatment time and total volume of the supercritical CO_2 required in the process. Since the CO_2 requires compressing, heating, and cooling as it flows through the process loop, reducing the total volume of CO_2 used in preparation for the process saves both electricity and gas for cooling and heating. The evaluation is only focused on the electric portion of project savings. The gas portion was reported as part of the RI Custom Gas PY2018 project (site ID: 2018RIG55).

The project was split into three phases totaling 31 extractors. The same chilled water plant services phase 1 and 2, while phase 3 has a separate chiller. Phase 1 and 2 include 24 extractors, while phase 3 includes 7.

The evaluator agrees with the tracking program classification of the project as a retrofit baseline. The project's cost includes the installation of a second loop of heat exchangers to maintain the process temperature for the extractors. Electric savings result from the change in the enthalpy based on process temperature and pressure and the reduction in process cycle time.

CW system: The chilled water plant that supplies CW to the process plant consists of two chillers, (1) 999 ton and (1) 700 ton. The chilled water pumping system is arranged in a Primary/Variable Secondary configuration where each chiller has a fixed speed pump with a bypass line to move water through each chiller and one variable flow pump to supply CW to the plant. The site installed a throttling valve in the bypass line of the 999 ton chiller and throttled the flow to ~10% to reduce the overall pumping power of the current system by converting to a variable flow system through the chiller. As a result, the overall demand for the two variable speed pumps supplying chilled water to the plant floor has been reduced.

The evaluator agrees with the tracking program classification of the project as a retrofit baseline. The project's cost includes installing a throttling valve to the bypass of the 999-ton chiller to reduce the overall pumping power of the current system. Electric savings result from the reduction in demand for the chilled water pumps due to the variable flow.

Dewpoint control: There are two Zeks 500 cfm externally heated desiccant dryers used to supply -40 °F dew point compressed air to bag houses and dust collectors located outdoors. The ultralow dewpoint air prevents water from condensing in the cooler months and freezing in the lines. It also prevents water mist from being sprayed onto filter media during pulse down. The pre-existing system was set up to run on a timed purge and purged regardless of moisture load. The purging consumed roughly 80 cfm and also needed to be heated from 80 to 350 °F using the internal electric heat on each dryer to remove moisture from the desiccant beds. The project consisted of installing dew point controllers to each dryer to reduce the purge air and hours.

The evaluator agrees with the tracking program classification of the project as a retrofit baseline. The project's cost includes the installation of dew point controls to reduce the purge air cfm and time purging for each dryer.

Based on a desk review and facility walk-through (completed for the gas portion of the project), the evaluated savings are equal to the tracking reported savings. Though the evaluation could not further adjust for operational discrepancies due to the impact of the COVID-19 pandemic on the ability to capture data in a timely manner, this report will document the findings and evaluation efforts from a non-operational evaluation with no M&V. The evaluation results are presented in Table 5-2.

Table 5-318. 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)
8923824, 8038934,	Heat exchangers for extraction process (Ph 1 & 2)	Tracked	800,695	48%	85.87	85.87
		Evaluated	800,695	48%	85.87	85.87
		Realization Rate	100%	100%	100%	100%
8923825, 8124545	Heat exchangers for extraction process (Ph 3)	Tracked	200,174	48%	21.47	21.47
		Evaluated	200,174	48%	21.47	21.47
		Realization Rate	100%	100%	100%	100%
10806043	Throttling valve on the CW system	Tracked	169,825	48%	18.21	18.21
		Evaluated	169,825	48%	18.21	18.21
		Realization Rate	100%	100%	100%	100%
10026201	Dew point controls for the desiccant air dryer	Tracked	144,766	63%	15.6	15.6
		Evaluated	144,766	63%	15.6	15.6
		Realization Rate	100%	100%	100%	100%
Totals		**Tracked**	**1,315,460**	**50%**	**141.08**	**141.08**
		Evaluated	**1,315,460**	**50%**	**141.08**	**141.08**
		Realization Rate	**100%**	**100%**	**100%**	**100%**

1.8.1 Explanation of Deviations from Tracking

There are no reported discrepancies at this point in the evaluation. Due to the impacts of the COVID-19 pandemic, the evaluator could not gather the required data from the site contact to complete the evaluation but did conduct a site visit to verify the measures were installed and operational. The evaluator performed a desk review to review application documents and analysis and did not find discrepancies regarding baseline, methodology, or tracking. Further details regarding the project are presented in the following Sections.

1.8.2 Recommendations for Program Designers & Implementers

Consider providing clear documentation and or project as-builts and clearly define delta savings between tracking and the application if applicable.

1.8.3 Customer Alert

The customer requested to redact site-sensitive information in the site report.

1.9 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 heat exchangers to the industrial process to allow for the increase in CO_2 enthalpy, the installation of a throttling valve to reduce the flow and demand on the CW pumps, and dewpoint controls to reduce the amount of purge cfm and time purging for each desiccant dryer.

1.9.1 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.

1.9.2 Applicant Description of Baseline

The applicant classified both the hot extraction and CW system measures as a retrofit baseline. Baseline energy use was modeled under existing conditions where cycle time was developed based on the pounds of existing CO_2 and the known mass flow rate of the $CO_{2,}$ which is a constant per the process formula and are variables that are used to develop the baseline enthalpy model. The CW system was modeled using baseline metered data from the customer's BMS, which monitors drive % speed, which was converted to kW using performance curves developed by taking kW readings at various Hz levels. The desiccant dryers were modeled under baseline conditions where each dryer was on a timed purge and purged regardless of moisture level. The four sub-sampled sites in this project are classified as a lighting retrofit project in the application. The majority (95.0%) of the baseline fixtures/lamps are categorized as T8 fluorescents (81.4%) and CFLs (13.6%). The remaining baseline fixtures/lamps are categorized as halogens, high-pressure sodium, incandescent, LEDs, metal halides, T5s, and T12s. The site documentation reported that the baseline consisted of 4,400 fixtures that operated varying watts from 12 to 455 watts. Application baseline usage hours ranged from 760 to 8,760 annual hours. The key applicant baseline parameters are summarized in Table 5-3.

Table 5-3 presents the main parameters of the baseline as defined by the applicant.

Table 5-319. Applicant Baseline Summary

Operation Description	Value
Chiller efficiency	0.355 kW/ton
Average cycle time	4.7 hours
CO_2 Extraction temperature	150°F
Total cycles per year	26,180[99]
Avg Hz (PU-9119)	49.4
Avg Hz (PU-9117)	54.3
Avg kW Demand (PU-9119)	37.4
Avg kW Demand (PU-9117)	67.7
Dryer purge hours	8,204
Dryer avg purge cfm	87.4
Compressor efficiency	0.19 kW/cfm
Air temp in	80 °F
Air temp out	350 °F

Applicant Description of Installed Equipment and Operation

The hot extraction measure includes the installation of heat exchangers to allow for the change in CO_2 enthalpy. The load was calculated for both the extractors and the high-pressure separators, as both phases in the process are considered under the extraction cycle. The CW system measure includes installing a throttling valve to the bypass line of the 999-ton chiller to convert the process to variable flow. The installation of the dewpoint controls reduces the amount of purge cfm and purging time for both desiccant dryers. Table 5-320. Applicant Proposed Summary presents the main parameters of the proposal as defined by the applicant.

Table 5-320. Applicant Proposed Summary

Operation Description	Value
Chiller efficiency	0.355 kW/ton
Average cycle time	3.7 hours
CO_2 Extraction temperature	180°F
Total cycles per year	26,180
Avg Hz (PU-9119)	45.3
Avg Hz (PU-9117)	49.0
Avg kW Demand (PU-9119)	27.1
Avg kW Demand (PU-9117)	51.6
Dryer purge hours	6,235
Dryer avg purge cfm	30.7
Compressor efficiency	0.19 kW/cfm
Air temp in	80 °F
Air temp out	350 °F

Applicant Energy Savings Algorithm

The applicant calculated the savings using a custom spreadsheet for all measures. Cooling load requirements for the hot extraction measure were calculated based on an enthalpy model under existing and proposed conditions of operating temperature, pressure, and mass flow rate. The load was calculated both for the condensing ($Load_{Cond}$) and the subcooling ($Load_{Subcool}$) portions as both phases in the process are considered under the extraction cycle. Applicant savings calculations use the following formulas for the hot extraction measure. Savings are calculated for both pre and post conditions using the same formulas:

[99] Cycles per year are based on a total of 31 extractors being able to run a 4.7- hour cycle each so one extractor is operating on average about 4,000 hour per year.

$$Total\ Savings = \ \Delta Annual\ kWh$$

$$Annual\ kWh_{Pre\ and\ post} = Demand\ kW * Quantity_{Extractors} * Avg\ Annual\ Operating\ Hours_{Extractor}$$

$$Demand\ kW = (\Delta Load_{Chill\quad per\ extractor} + \Delta Load_{Pump\ per\ extractor}) * Average\ extractors\ running\ per\ hour$$

$$Load_{Chiller} = (Load_{Chiller\ CO\quad Cond} + \ Load_{Chil\quad CO\quad Subcool}) * Conversion * Chiller\ kW/ton$$

$$Load_{Chill\quad CO\quad Cond} = \Delta((H_{Cond\ out} - H_{Cond\ in}) * \dot{m} * 60\frac{min}{hr})$$

$$Load_{Chiller\ CO\quad Subcool} = \Delta((H_{Subcool\ out} - H_{CO\quad Subcool\ in}) * \dot{m} * 60\frac{min}{hr})$$

$Load_{pump}$ uses excel in trending the average kW per extractor, number of extractors running, and # extractions per pump to determine the kW per extraction for the pump

$$Avg\ Annual\ Operating\ Hours_{Extractor} = \frac{Annual\ Extraction\ Cycles * \frac{Hours}{Cycle}}{Quantity_{Extractors}}$$

$Conversion$ = 1 ton = 12,000 Btu/hr

$\dot{m}$ = 130 (lbs/min)

H = enthalpy (btu/lb)

$Chiller\ kW/ton$ = .355

The CW system measure was also calculated using a custom spreadsheet, where pre and post-metering data were used to characterize the system. Algorithms are below:

$$Total\ Savings = \ \Delta Demand\ kW * Annual\ Operating\ hours$$

$$Demand\ kW_{Pre} = \sum Pump\ kW_{Pre}$$

$$Demand\ kW_{Post} = New\ Demand\ kW - Chiller\ Demand\ kW$$

$$New\ Demand\ kW = \sum Pump\ kW_{Post} * (1 + Adjustment\ Factor)$$

$$Chiller\ Demand\ kW = Chilled\ Water\ Load\ Savings_{ton} * Chiller\ \eta$$

$$Chiller\ Water\ Load\ Savings_{ton} = (Demand\ kW_{Pre} - New\ Demand\ kW) * \frac{3412}{12000} * .95$$

$Hours$ = 24 hrs * 7 days * 50 weeks = 8,400 hours

H = enthalpy (btu/lb)

$Chiller\ \eta$ = 0.355 kW/ton

$Adjustment\ Factor$ = 10%

An adjustment factor was applied to address the potential for the downstream chiller recirculating pump to see an increase in kW demand from installing the bypass valve. Since this pump is not monitored, this value is unknown. 10% was applied so that savings were not overstated.

Reducing pumping power also reduces the amount of heat load transferred from the pump to the water, which heats the water. The chiller then cools this load. Chiller load reductions were calculated to account for the savings from the reduced chiller load.

The dewpoint control measure was also calculated using a custom spreadsheet. Pre and post-metering data were used to characterize the dryer and capture purge cfm and time spent purging. Algorithms are below:

$$Total\ Savings = \ \sum\Delta Demand\ kW * Annual\ purge\ hours$$

$$Demand\ kW = Demand\ kW_{Compressor} + Demand\ kW_{Heater}$$

$$Demand\ kW_{Compressor} = Avg\ purge\ cfm * Compressor\ \eta$$

$$Avg\ purge\ cfm = Inlet\ cfm - Outlet\ cfm$$

Where inlet and outlet cfm are metered:

$$Demand\ kW_{Heater} = \frac{(Air\ temp_{out} - Air\ temp_{in}) * 1.08 * Avg\ purge\ cfm}{3412}$$

$$Annual\ purge\ hours = Hours * \%time\ purging$$

Where % time purging is based on metered data and represents all points where avg purge cfm >10 cfm.

$Hours$ = 24 hrs * 7 days * 51 weeks = 8,568 hours

$Compressor$ = 0.19 kW/cfm

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

Evaluation Assessment of Applicant Methodology

The applicant's overall method for calculating the savings is appropriate and of sufficient rigor for both measures. The evaluator reviewed the application files with respect to baseline, methodology, and administrative errors. There was initial concern with the approach used to calculate annual operating hours for the hot extraction measure. Considering the process contains a given number of extractors that are not all operating simultaneously or at the same point in the cycle, the algorithm for annual hours was developed to use cycle time as a way to determine runtime hours. The evaluators did not agree with this initial approach as the units in the equations did not cancel out to yield hours appropriately. Instead, the evaluator worked with the vendor to recreate the equation in a more appropriate way, which is what is displayed in the equations in section 2.2.2. This method estimates the sum of the operating hours the extractors will run each year based on a function of annual extraction cycles and cycle time. This approach is clearer algorithmically and yields the same result as the initial approach. The CW system and dewpoint control measures were calculated using metered data for the chillers and pumps and the dryers both pre and post. The evaluator deemed this methodology reasonable.

1.9.3 On-Site Inspection and Metering

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

Summary of On-site Findings

The evaluators conducted a site visit on February 18, 2020 (to complete the PY2018 RI Custom Gas project). During the site visit, the evaluators interviewed the facility manager and verified that the heat exchangers were installed on the extraction process through visual inspection. The evaluators took a walk through the plant with the site contact and a representative from National Grid to understand the process phases and observe the in-house site meters installed to observe and maintain temperature, process, and flow. Most of the on-site visit was spent discussing the project and the measures setpoints as part of the EMS platform. The site has extensive metering in place to capture and control data for temperature, pressure, and mass flow at each of the phases of the industrial process. Considering these setpoints are integral to the formulation of the product, they are tightly observed and managed. However, the site did not provide the evaluators with any trend or metered data.

The site runs its process 24/7 360 days of the year. The five days of shut down are not for specific holidays and mostly for inventory or downtime. It was confirmed the extractors and the extraction process as a whole have not been adjusted since the retrofit was implemented. Considering the extensive set of data collected on the EMS, DNV and the National Grid representative thought it would be acceptable to use the site data rather than install metering equipment.

Phase 1 and 2 of the projects have one chilled water plant, while Phase 3 has a different plant. It was confirmed that all of this equipment is used for the industrial process and not for supplemental space cooling. A summary of the on-site verification is provided in DNV interviewed the facility staff and verified the equipment installed onsite. DNV completed an initial site visit on 4/8/21 to visually verify and collect data on select measures.

Table 5-34 shows the verification method and result for each of the ten measures evaluated within this report.

Table 5-34.

Table 5-321. Measure Verification

Measure Name	Verification Method	Verification Result
Heat exchangers for extraction process	Visual confirmation of heat exchangers, industrial process, and EMS database. Interview with site staff.	The heat exchangers were installed as proposed. The enthalpy model is operating as proposed according to the EMS platform.

Measured and Logged Data

During the site visit, the evaluator worked with the site contact to develop setpoints and trend data to calculate program savings. Unfortunately, after the site visit, the site contact became very unresponsive, so EMS data was never sent. Due to the impact of COVID-19, the evaluator could not return to the site to deploy energy loggers to capture data. Therefore, site data was never fully captured. DNV was unable to contact the site for the current evaluation, so further data was not obtained for the electric portion of the hot extraction process, the CW system, nor the desiccant dryers. DNV hopes to collect the data in the near future from the customer.

1.9.4 Evaluation Methods and Findings

This section describes the evaluator methods and findings.

Evaluation Description of Baseline

The evaluator reviewed the project files and interviewed the site contact to gather information on the baseline. The evaluator classified these measures as single retrofit baselines, where the baseline operation is according to the enthalpy model, the CW system, and the desiccant dryer operation as proposed by the applicant in Table 5-220.Applicant Baseline Summary.

Evaluation Calculation Method

The evaluator was not able to obtain metered data nor EMS trend data from the site contact. However, while at the site, the evaluator did note the EMS platform was trending data points as set by the enthalpy model proposed by the applicant and the CW system as proposed by the applicant. Without data, the evaluators were not able to verify the savings for any of the measures.

1.10 Final Results

The project consisted of installing heat exchangers to the industrial extraction equipment to operate the process at higher temperatures and a lower cycle time, as well as installing a throttling valve to allow for variable flow on the CW system, as well as installing dewpoint controls to limit the purging air and time purging for both desiccant dryers. The evaluated savings are equivalent with the applicant reported savings estimates. The parameters impacting the analysis are summarized in The evaluated savings for the lighting project were slightly greater than the applicant-reported savings primarily due to a discrepancy stemming from heating and cooling interaction. Detailed values are shown in Table 5-196. Summary of Key Parameters, comparing changes in the baseline and proposed conditions for both the application and evaluation hours of use for each area.

Table 5-85.

Table 5-322. Summary of Key Parameters

Parameter	Applicant	Evaluator
Chiller efficiency kW/ton	3.55	3.55
Average baseline cycle time	4.7	4.7
Average proposed cycle time	3.7	3.7
Baseline CO_2 extraction temperature	150°F	150°F
Proposed CO_2 extraction temperature	180°F	180°F
Total cycles per year	26,180	26,180
Avg Hz (PU-9119) baseline	49.4	49.4
Avg Hz (PU-9117) baseline	54.3	54.3
Avg kW Demand (PU-9119) baseline	37.4	37.4
Avg kW Demand (PU-9117) baseline	67.7	67.7
Avg Hz (PU-9119) proposed	45.3	45.3
Avg Hz (PU-9117) proposed	49.0	49.0
Avg kW Demand (PU-9119) proposed	27.1	27.1
Avg kW Demand (PU-9117) proposed	51.6	51.6
Dryer purge hours baseline	8,204	8,204
Dryer purge hours proposed	6,235	6,235
Dryer avg purge cfm baseline	87.4	87.4
Dryer avg purge cfm proposed	30.7	30.7
Compressor efficiency	0.19 kW/cfm	0.19 kW/cfm
Air temp in	80 °F	80 °F
Air temp out	350 °F	350 °F
Annual electric savings (kWh)	1,315,460	1,315,460
Electric realization rate	100%	

1.10.1 Explanation of Differences

The evaluation is equivalent with the tracking reported savings. The evaluator did not make operational adjustments considering site EMS data could not be obtained due to COVID-19 restrictions. Table 5-205. Summary of Deviations provides a summary of the primary differences between tracking and evaluated values.

Table 5-323. Summary of Deviations

End-use	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
-	-	-	-	There are no reported discrepancies.

Ancillary impacts

There are no ancillary impacts associated with this measure.

RICE19N086

Report Date: 15 November 2022

Application ID(s)	9209203/677949, 9310038, 9808916	
Project Type	C&I Initial Purchase & End of Useful Life	
Program Year	2019	
Evaluation Firm	DMI	
Evaluation Engineer	Dan McKinley	
Senior Engineer	Jay Robbins	

Evaluated Site Summary and Results

This site is an approximately 250,000 ft^2 light industrial facility specializing in the manufacture of textiles. The site uses compressed air for production 24 hr/day, 5 days/week, with occasional Saturday production. There are small compressed air loads during non-production hours. The energy savings measures installed were as follows:

9209203 (child app of 677949) – Installation of two new variable speed oil flooded air compressors, one cycling refrigerated air dryer, one 400 gal air receiver, low pressure-drop filters, piping improvements, and two zero-loss condensate drains. Piping improvements and the low pressure-drop filters allowed for operating pressure reduction to 105 psig from 125 psig. The applicant classified this measure as new construction.

9310038 – Compressed air leak survey and repair. The applicant classified this measure as a retrofit.

9808916 – Compressed air pressure reduction from 105 psig to 95 psig. This measure was implemented by trial-and-error testing to determine the lowest pressure that the site's production equipment could operate at. It appears to have been enabled by the piping improvements installed as part of app 9209203 which were reportedly installed to increase airflow at the end of the facility far from the compressor. The applicant provided no classification for this measure.

The measures were installed sequentially as shown in Table 1-1.

Table 5-324. Measure and metering timeline

Event	START DATE	END DATE
Distributed compressor metering	10.02.2018	10.08.2018
App 9209203 (new VFD comp.) post-inspection	12.21.2018	
Pre-leak repair metering	01.09.2019	01.23.2019
App 9310038 (leak repair) post-inspection	03.20.2019	
Post-leak repair metering 1	03.19.2019	03.26.2019
Post-leak repair metering 2	04.08.2019	05.01.2019
App 9808916 (pressure reduction)	05.21.2019	

Energy savings for all measures (combined) come from three sources:

Table 5-325. 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)
9209203 (child app of 677949)	New VFD Compressors	Tracked	445,455	48%	52.3	52.7
		Evaluated - ops	545,437	51%	68.8	66.3
		Realization Rate	122%	107%	132%	126%
9310038	Compressed Air Leak Repair	Tracked	86,486	45%	12.6	12.6
		Evaluated - ops	95,387	40%	8.5	8.6
		Realization Rate	110%	90%	67%	68%
9808916	Compressed Air Pressure Reduction	Tracked	34,016	48%	4.0	4.0
		Evaluated - ops	28,072	50%	3.8	3.9
		Realization Rate	83%	104%	95%	98%
Totals		**Tracked**	**565,957**	**48%**	**68.94**	**69.35**

	Evaluated - ops	**668,896**	**50%**	**68.8**	**66.3**
	Realization Rate	**118%**	**104%**	**100%**	**96%**

Installing new variable speed compressors which will provide a better part-load efficiency than the baseline case. Improved part-load efficiency allows for the new compressors to consume less energy per unit of compressed air produced.

Reducing compressed air flow by repairing leaks (9310038) and lowering operating pressure (9209203 and 9808916), which reduces the airflow load associated with any remaining leaks.

Reducing compressed air pressure drop by installing new piping, which improves compressor performance (kW/cfm).

The operation at this site was not impacted by COVID. The evaluation conducted a full metering and verification approach because the operation of the installed equipment was not impacted by COVID and the site was comfortable with the evaluator conducting an in-person site visit and metering. The evaluation results are presented in Table 1-2.

Explanation of Deviations from Tracking

The applicant did not use consistent operating hours between the three applications nor do any of these operating hours correspond to the evaluator observed hours, which were greater than the values used by the applicant, which increases savings for all measures. Additionally, the following measure-specific deviations were present:

9209203 (two new VFD compressors)

1. The applicant calculated savings for the proposed compressors at the baseline operating pressure, and then adjusted the savings using the compressor datasheet to estimate 0.8% power reduction per 2 psi of pressure reduction. The evaluator deviated from this methodology and instead followed the standard rule of 1% power reduction per 2 psi of pressure reduction.
2. The evaluator corrected a minor error in the applicant's baseline compressor performance curve takeoffs, which also increased savings.
3. The applicant determined bin average airflow values by visual inspection. By instead using the average airflow per bin (obtained by averaging all relevant metered airflow trends within the bin bounds to produce a weighted average), a different flow profile is present, decreasing savings.

9310038 (leak repair) – The applicant estimated measure savings by assuming that 80% of the pre-measure leak load was repaired, while the evaluator directly compared pre and post airflow data to determine the actual leak reduction. This deviation decreased savings because the evaluator found a smaller leak reduction airflow (cfm savings) than estimated by the applicant. The applicant also estimated savings using compressor performance data at 125 psi, however the system was operating at 105 psi. Adjusting the compressor performance for the lower operating pressure increased compressor efficiency and decreased savings. Including the operating hours deviation however, this measure has a net savings increase.

9808916 (pressure reduction)

1. The evaluator observed the compressors to be operating at a lower pressure (93 psi) than the proposed case reported by the applicant (95 psi). This deviation increased savings.
2. The evaluator used the load profile from metered power data rather than the assumed % load profile used by the applicant, which decreased savings.
3. The evaluator used the CAGI datasheet adjusted for operating pressure rather than the % savings per psi of pressure reduction formula by (Kissock, 2005) used by the applicant. The evaluator's approach decreased savings.

Further details regarding deviations from the tracked savings are presented in Section 3-4.

Recommendations for Program Designers & Implementers

Interval data was requested for this site but not received at the time of report writing. It would be valuable to have interval data for this and similar sites to provide additional confidence to annual compressor runtime values derived from evaluator metering and applicant airflow trends.

Customer Alert

The customer requested a copy of the site report.

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 new VFD compressors, a cycling air dryer, low pressure drop filters, zero-loss condensate drains, one 400 gal receiver, and new compressed air piping (App 9209203, child of 677949), compressed air leak repair (App 9310038), and compressed air operating pressure reduction (App 9808916).

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.

Applicant Description of Baseline

9209203 (two new VFD compressors) – The applicant classified this measure as new construction. The baseline consists of 1 x 200 hp fixed speed, single stage compressor (Quincy QSI 925) operating load/no-load at 125 psig and 1 x 1,250 cfm non-cycling refrigerated dryer (Gardner Denver RNC1250). The total compressor power does not appear to align with the proposed case of 2 x 125 hp variable speed compressors, however the selected baseline compressor appears to be capable of meeting the facility's compressed air loads. Existing compressors were assumed to remain in place but only serve as backup. The applicant does not address existing dryers. The baseline does not include the pipework improvements or low pressure-drop filters, so the operating pressure is 125 psig. No savings are calculated by the applicant for the zero-loss condensate drains, so the applicant does not identify a baseline condensate drain. The applicant used a CAGI datasheet for the baseline compressor performance and a manufacturer's cutsheet for the baseline air dryer performance.

9310038 (leak repair) – The applicant classified this measure as a retrofit. The baseline is therefore the existing leak conditions at time of survey (post app 9209203). The applicant used a CAGI datasheet for the Gardner Denver L90RS variable speed compressor operating at 125 psi.

9808916 (pressure reduction) – The applicant provided no classification for this measure but implicitly has classified it as a retrofit. The baseline is the compressed air system operating at 105 psig with the existing (post apps 9209203 and 9310038) compressor, pipe configuration, and air filters. The applicant used the CAGI datasheet for compressor performance from the proposed case (installed) compressor in 9209203.

Table 5-326. Applicant baseline key parameters

		BASELINE		
Measure	**Parameter**	**Value(s)**	**Source of Parameter Value**	**Note**
New VFD Compressors	compressor operating hours	7,488 hr/yr	Applicant Calculations	
	compressed air system operating pressure	125 psig	Applicant Calculations	
	compressed air storage capacity	2 gal/cfm	Applicant Calculations	

	compressor performance curve	load/unload 2 gal/cfm curve	Compressed Air Challenge	per applicant calculations
	compressor rated capacity	925 cfm	QSI 925 CAGI Datasheet	per applicant calculations
	compressor package input power at rated capacity	176.1 kW	QSI 925 CAGI Datasheet	per applicant calculations
	compressor package input power at zero flow	52.8 kW	QSI 925 CAGI Datasheet	per applicant calculations
	air dryer rated capacity	1,250 cfm	Gardner Denver RNC 1250 Specs	per applicant calculations
	air dryer input power at rated capacity	7.29 kW	Gardner Denver RNC 1250 Specs	per applicant calculations
	air dryer input power at zero flow	70%	Gardner Denver Energy Savings Chart	per applicant calculations
Compressed Air Leak Repair	compressor operating hours	6,864 hr/yr	Applicant Report	
	compressor operating pressure	125 psig	Applicant Report	
	average pre-repair airflow	386 cfm	Applicant Report	
	compressor performance curve	per datasheet	Gardner Denver L90RS CAGI datasheet at 125psi	per applicant report
Compressed Air Pressure Reduction	compressor operating hours	6,400 hr/yr	Applicant Calculations	
	compressor operating pressure	105 psi	Applicant Calculations	
	compressor performance curve	rotary screw, single stage, VFD	MassSave Pay for Performance Compressed Air Leaks and Pressure Reduction Tool	applicant calculations
	compressor rated capacity	583 cfm	Gardner Denver L90RS CAGI datasheet at 125psi	

Applicant Description of Installed Equipment and Operation

9209203 (two new VFD compressors) – 2 x 125 hp variable speed compressors (Gardner Denver L90RS), 1 x cycling refrigerated air dryer (Gardner Denver RSD 1250), piping improvements, two zero-loss condensate drains, one 400 gal air receiver and low pressure drop filters. The applicant used a CAGI datasheet for the compressor performance and a manufacturer's cutsheet for air dryer performance. The applicant assumes the compressors will operate in a lead/lag configuration, with simultaneous operation only required at high compressed air loads.

9310038 (leak repair) – The applicant assumes that 80% 93 cfm leak load identified in the pre-measure metering are repaired. The applicant used the CAGI datasheet for compressor performance from the proposed case (installed) compressor in 9209203.

9808916 (pressure reduction) – The compressed air system operating at 95 psig with the existing (post apps 9209203 and 9310038) compressor, pipe configuration, and air filters. The applicant used the CAGI datasheet for compressor performance from the proposed case (installed) compressor in 9209203.

Table 5-327: Application proposed key parameters

		PROPOSED		
Measure	**Parameter**	**Value(s)**	**Source of Parameter Value**	**Note**
New VFD Compressors	compressor operating hours	7,488 hr/yr	Applicant Calculations	
	compressed air system operating pressure	105 psig	Applicant Calculations	

	compressed air storage capacity	2 gal/cfm	Applicant Calculations	
	compressor performance curve	per CAGI datasheet at 125 psi	Gardner Denver L90RS CAGI datasheet at 125psi	per applicant calculations
	compressor rated capacity	583.1 cfm	Gardner Denver L90RS CAGI datasheet at 125psi	per applicant calculations
	compressor package input power at rated capacity	113.7 kW	Gardner Denver L90RS CAGI datasheet at 125psi	per applicant calculations
	compressor package input power at zero flow	12.0 kW	Gardner Denver L90RS CAGI datasheet at 125psi	per applicant calculations
	air dryer rated capacity	1,250 cfm	Gardner Denver RSD1250 Specs	per applicant calculations
	air dryer input power at rated capacity	6.34 kW	Gardner Denver RSD1250 Specs	per applicant calculations
	air dryer input power at zero flow	10%	Gardner-Denver Energy Savings Chart	per applicant calculations
Compressed Air Leak Repair	compressor operating hours	6,864 hr/yr	Applicant Report	
	compressor operating pressure	125 psig	Applicant Report	
	average airflow reduction from repairing 80% of leaks	74 cfm	Applicant Report	
	compressor performance curve	per datasheet	Gardner Denver L90RS CAGI datasheet at 125psi	per applicant report
Compressed Air Pressure Reduction	compressor operating hours	6,400 hr/yr	Applicant Calculations	
	compressor operating pressure	95 psi	Applicant Calculations	
	compressor performance curve	rotary screw, single stage, VFD	MassSave Pay for Performance Compressed Air Leaks and Pressure Reduction Tool	applicant calculations
	compressor rated capacity	583 cfm	Gardner Denver L90RS CAGI datasheet at 125psi	

Applicant Energy Savings Algorithm

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

9209203 (two new VFD compressors) – The applicant calculated annual savings by developing a flow profile from 1 week of metered airflow data which aggregates four site flow meters. The flow profile was created using flow points of 0,35,103,334,503, and 680 cfm, where the applicant binned average hourly airflow between the flow points. Note that aggregated flow meter data does not correspond to the applicant's baseline of 1 x 200 hp fixed-speed compressor, rather it corresponds to the pre-existing site conditions of 6 smaller compressors distributed throughout the facility. Nonetheless, this appears to be a reasonable method to develop the expected compressed air load. The flow profile was scaled from 1 week to 1 year to create bins of compressor performance accounting for operation 7,488 hr/year. Although not explicitly described by the applicant, the annual operation appears to have been calculated according to:

$$24 \text{ hr/day} * 7 \text{ days/wk} * 50 \text{ wk/year} = 7{,}488 \text{ hr/year}$$

% flow for each bin was calculated by dividing bin max airflow by compressor max airflow per the 125 psi CAGI datasheet. For example, the 35 cfm airflow bin, which encompasses airflow greater than 0 cfm and less than or equal to 35 cfm, uses 35 cfm in the % flow calculation.

The base case compressor power was found by using a Compressed Air Challenge curve for 2 gal/cfm storage capacity to calculate % full load power vs % flow. This appears to have been done by visual inspection of the curve. Compressor power multiplied by bin hours yields compressor energy consumption per bin, which are summed to provide the baseline compressor kWh/yr.

The base case refrigerated air dryer power consumption was calculated using the manufacturer's datasheet for the baseline installed air dryer, which provides full-load flow and power values only. The applicant calculated dryer power for each bin average airflow according to:

$$P_{d,n} = 0.75 * P_{d,f} + (\% \text{ load} * 0.25 * P_{d,f})$$

where:

$P_{d,n}$ = dryer power for any given bin *n*

$P_{d,f}$ = full-load dryer power

Dryer power multiplied by bin hours yields dryer energy consumption per bin, which are summed to provide the baseline dryer energy. Total baseline annual energy consumption is found by adding the compressor and dryer energy.

The proposed case installs two new compressors and replaces the air dryer. The existing compressors remain installed for backup only. The applicant assumes that a single compressor will serve the compressed air load until the load increases above the capacity of one compressor, at which point the second compressor will energize and serve the remaining load. The same average flow bins used in the baseline case are used in this calculation, however the bin with an average flow greater than one compressor's capacity is separated into two bins with equal bin hours to account for this operating condition. The proposed case compressor annual energy consumption is calculated using a CAGI datasheet for the proposed case compressor at 125 psig by multiplying the bin specific power (kW/100acfm) by the bin max airflow and the annual bin hours of operation.

The proposed case refrigerated air dryer power consumption for each bin average airflow was calculated according to:

$$P_{d,n} = 0.1 * P_{d,f} + (\% \text{ load} * 0.9 * P_{d,f})$$

where:

$P_{d,n}$ = dryer power for any given bin *n*

$P_{d,f}$ = full-load dryer power

Dryer power multiplied by bin hours yields dryer energy consumption per bin, which are summed to provide the proposed dryer kWh/yr.

The applicant calculates energy savings from the reduction in operating pressure associated with piping improvements (which reduce the operating pressure from 125 to 105 psi) by comparing the full-load specific power values from the CAGI datasheets for the proposed compressor at 125 psig and 100 psig. The applicant states that the specific power at max airflow decreases from 19.5 to 17.6 kW/100acfm between 125 and 100 psi, equating to 0.8% specific power reduction per 2 psi of pressure reduction. The applicant therefore concludes that a 20 psi reduction in operating pressure will result in an 8% reduction in power, and adjusts the annual savings for the compressor down by 8%. The applicant calculates the proposed kWh/year as:

$$E_a = (1-0.08) * E_c + E_d$$

where:

E_a = annual energy consumption of the proposed case at 105 psig, kWh/yr

E_c = annual energy consumption of the compressor at 125 psig, kWh/yr

E_d = annual energy consumption of the dryer, kWh/yr

Measure energy savings are calculated by subtracting the baseline annual energy consumption from the proposed annual energy consumption. Measure demand savings are calculated by subtracting the annual energy consumption of the base and proposed case and dividing this value by 8,760 hr/year. This average demand reduction is applied to the summer and winter peak periods.

9310038 (leak repair) – The applicant calculated energy savings for this measure by identifying the leak load in pre-measure airflow trends from 11/21/2018 – 11/28/2018 as 93 cfm, and then assuming that 80% of these leaks were repaired for an airflow savings of 74 cfm. The applicant has averaged compressed air demand during what appears to be non-production hours to determine the leak load. The applicant used the pre-measure average airflow metered on 01/09/2019 – 01/23/2019 (386 cfm) as the base case and this same average airflow, less the 74 cfm of airflow savings, for the proposed case. The applicant uses a CAGI datasheet for the Gardner Denver L90RS compressor at 125 psi to determine that a 386 cfm load corresponds to a compressor power of 76.51 kW and a 312 cfm load corresponds to a compressor power of 63.91 kW. The applicant does not provide detail on this calculation but appears to have linearly interpolated between performance points listed in the CAGI datasheet to obtain compressor power at 386 cfm and 312 cfm.

Savings are found according to:

$$E_s = (76.51 \text{ kW} - 63.91 \text{ kW}) * 6{,}864 \text{ hr/y} = 86{,}486 \text{ kWh/yr}$$

where the operating hours were calculated as:

$$24 \text{ hr/day} * 5.5 \text{ days/wk} * 52 \text{ wk/yr} = 6{,}864 \text{ hr/yr}$$

It is unclear why the annual hours of operation do not correspond with those used in application 9209203. The demand savings are the difference of the two power values.

9808916 (pressure reduction) – The applicant calculated savings using the Mass Save Pay for Performance compressed air tool. This tool accepts user inputs on compressed air system base/proposed operating pressure, compressor types, and compressor capacities and calculates savings based on an applicant entered weekly loading profile. The weekly loading profile for each compressor is used to calculate an average loading for each compressor; the applicant values used generate 55% average load for one compressor and 25% for another for 8,400 hours per year. It is unclear why these annual hours of operation differ from those used in applications 9209203 and 9310038 but appear to have been calculated from:

$$24 \text{ hr/day} * 7 \text{ days/wk} * 50 \text{ wk/yr} = 8{,}400 \text{ hr/yr}$$

The fractional savings for each compressor based on the pressure setpoint reductions are calculated according to:

$$\% \, savings = \frac{\left(\frac{p_b + p_a}{p_a}\right)^{0.286} - \left(\frac{p_p + p_a}{p_a}\right)^{0.286}}{\left(\frac{p_b + p_a}{p_a}\right)^{0.286} - 1}$$

where:

p_a = atmospheric pressure at sea level, 14.7 psi

p_b = baseline compressed air operating pressure, 105 psi

p_p = proposed compressed air operating pressure, 95 psi

This equation is cited in the compressed air tool as ‘K. Kissock, “Modeling and simulation of air compressor energy use,” in ACEEE Summer Study on Energy Efficiency in Industry, vol. 1, no. 13, 2005, pp. 131– 142.’

Demand savings are calculated by:

$$P_d = (hp * average\ loading * \%\ savings) / 0.7457\ hp/kW$$

where:

P_d = demand savings, kW

hp = compressor nameplate power, hp

The demand savings of both compressors, multiplied by the annual operating hours, yields annual energy savings for this measure.

Evaluation Assessment of Applicant Methodology

The applicant uses different compressor operating hours between each measure, which does not appear to be reasonable because all measures were implemented within a few months of each other and the site contact has not identified any large changes in production. One common set of operating hours should be used for all measures.

9209203 (two new VFD compressors) – The applicant calculated savings for the new compressors at the baseline operating pressure, and then adjusted the savings using the compressor datasheet to estimate 0.8% power reduction per 2 psi of pressure reduction, although this is conservative, 1% power reduction per 2 psi of pressure reduction is a more standard value to use Additionally, the applicant found base case compressor % power from % flow from the 2 gal/cfm Compressed Air Challenge curve using visual inspection, however it would be more accurate to use a curve fit. The evaluator determined that 2 gal/cfm was a reasonable value for this site. The applicant also determined bin average airflows through visual inspection, rather than calculating the weighted average per bin, which decreased the accuracy of the calculation. Finally, the applicant assumes average peak and summer/winter demand reductions, but it would be more accurate to calculate demand reductions and peak savings using separate bins. The applicant does not calculate savings explicitly for the added air storage or low pressure drop filters, which is reasonable because these measures enable the pressure reduction but otherwise do not impact savings. The applicant does not calculate savings for zero-loss condensate drains.

9310038 (leak repair) –The applicant’s estimate of energy savings for this measure does not appear to utilize post-install data, which is the most direct method of calculating compressed air savings for this measure.

9808916 (pressure reduction) – The applicant calculated savings using the Mass Save Pay for Performance compressed air tool which uses generic compressor performance curves. This tool allows for % compressed air loads to be entered for each compressor, and the applicant has not used values which correspond to the profile in app 9209203. The applicant also used a full load airflow which corresponds to the 125 psi CAGI datasheet, not a value from the 100 psi CAGI datasheet which more closely corresponds to the base and proposed airflow of 105 and 95 psi respectively.

Site Visit

The evaluator visited the site on March 30, 2021 to interview the site contact and meter site equipment. The evaluator returned to the site on May 12, 2021 (~6 weeks from the first visit) to retrieve installed meters.

The evaluator installed power meters with 3-phase power factor correction on both variable speed compressors installed as part of application 9209203. The site was not able to facilitate safe meter installation on the refrigerated air dryer without disrupting production, so the evaluator attached a temperature sensor to the condenser exhaust to gauge run-time. Condenser exhaust is significantly warmer when the cycling dryer is on and this temperature data was sufficient for verifying runtime; dryer power will be estimated based on equipment specifications.

While onsite, the evaluator determined that compressed airflow trending capability was available and the site contact agreed to set up logging of airflow trends during the metering period. Historic airflow trends prior to the site visit are not available (with the exception of those collected by the applicant) because the airflow meter was not set to record data. Due to meter trending limits, the evaluator collected ~22 days of airflow data during the metering period. The evaluator recorded lifetime run hours on the control panels of both compressors at meter install and did so again at meter removal.

The evaluator installed motor runtime loggers on two of four facility backup compressors to verify that they do not operate. Of the two backup compressors that motor loggers were not installed on, one was completely disconnected and the other had power but appeared to have its controls disabled.

The evaluator conducted an inventory of compressed air equipment (including backup compressors) and noted that both compressors were modulating to a setpoint of 93 psig. An inventory of storage tanks was recorded, in which several tanks are located throughout the facility. The main air distribution pipe running the length of the facility was replaced with a larger 4” diameter pipe to improve airflow to equipment at the far ends of the facility.

The evaluator was not able to verify that low pressure drop filters have been installed due to difficulties accessing these filters during production. The evaluator did not attempt to verify leak repairs because the measure life has expired and the evaluator judged it would not provide valuable data for modifying savings calculations. Pre/post airflow data metered by the applicant was received via email from the applicant.

Summary of Site Visit Findings

The evaluator interviewed both the Director of Engineering, Quality, and Excellence as well as the site’s Electric Maintenance Technician during the site visit. The technician provided the site walk through and installed the evaluator’s power meters.

9209203 (two new VFD compressors):

- The site contacts stated that prior to measure implementation, the site was equipped with distributed, independent air compressors about half of which did not have air dryers. These compressors failed frequently and caused significant production downtime. Additionally, undesirable levels of oil were entering the compressed air system which endangered production equipment.
- Quantity & technology confirmation – the evaluator confirmed the quantity and technology of the installed compressors (2 x single stage, air-cooled, oil-injected, variable speed rotary screw compressors) and installed air

dryer (1 x cycling refrigerated air dryer). The evaluator confirmed that the compressed air distribution trunk pipe appeared to be new, and that 1 x 400 gal compressed air receiver had been installed as part of this measure. The evaluator was unable to confirm that low pressure drop filters were installed.

- Controls – the evaluator confirmed that the compressors operate lead/lag by observing compressor operation. This control is consistent with the site contact's statements.

9310038 (leak repair):

- The site contact stated that the compressed air leak repair took place after the installation of app 9209203.
- Quantity & technology confirmation – the evaluator did not attempt to verify repaired air leaks because the 2 year measure life had already passed at the time of the site visit.

9808916 (pressure reduction):

- The site contact was unsure of the compressed air operating pressure prior to measure implementation and speculated that it could have been 110-112 psi.
- Quantity & technology confirmation – the evaluator found that both compressors were modulating to maintain a compressed air setpoint of 93 psi.

Table 5-328. Measure Verification

Measure Name	Verification Method	Verification Result
New VFD Compressors	Inventoried compressed air storage capacity in order to verify 2 gal/cfm air compressor curved used by applicant.	The evaluator inventoried compressed air storage and confirmed that 2 gal/cfm is reasonable.
	Observed nameplate of installed compressors.	Installed compressors match proposed case.
	Observed air-dryer nameplate	Air-dryer matches proposed case.
	Meter backup compressors with to verify that they do not regularly operate.	Metering showed backup compressors no longer operate.
Compressed Air Leak Repair	Reviewed pre- and post- measure airflow data collected by the applicant to determine if the reported airflow savings are accurate.	The evaluator analyzed pre- and post- measure airflow trends in order to evaluate energy savings and confirmed a reduction in average airflow due to leak repair.
Compressed Air Pressure Reduction	Observe compressed air operating pressure.	The evaluator observed the compressed air operating pressure to be 93 psig at both site visits.

Evaluation Methods and Findings

This section describes the evaluator methods and findings.

Evaluation Description of Baseline

9209203 (two new VFD compressors) – The evaluator agrees with the applicant's classification that this is a new construction (end of useful life replacement) measure, based on the condition and functional issues with the pre-existing site compressors. The applicant selected a site specific baseline of 1 x 200 hp fixed-speed compressor as the baseline compressor which appears to be reasonable for the installed case of 2 x 125 hp VFD compressors. Neither the CAIR ISP memo nor the baseline repository offer guidance on the number of compressors that should be used in new construction baselines.

9310038 (leak repair) – The evaluator agrees with the applicant's, with the exception of the operating pressure, which the evaluator states is 105 psi. This measure is a retrofit.

9808916 (pressure reduction) – The evaluator classifies this measure as a retrofit, so the baseline is the pre-existing conditions at the time of measure implementation, which the evaluator believes to be the proposed conditions of application 9310038. This agrees with the applicant's baseline.

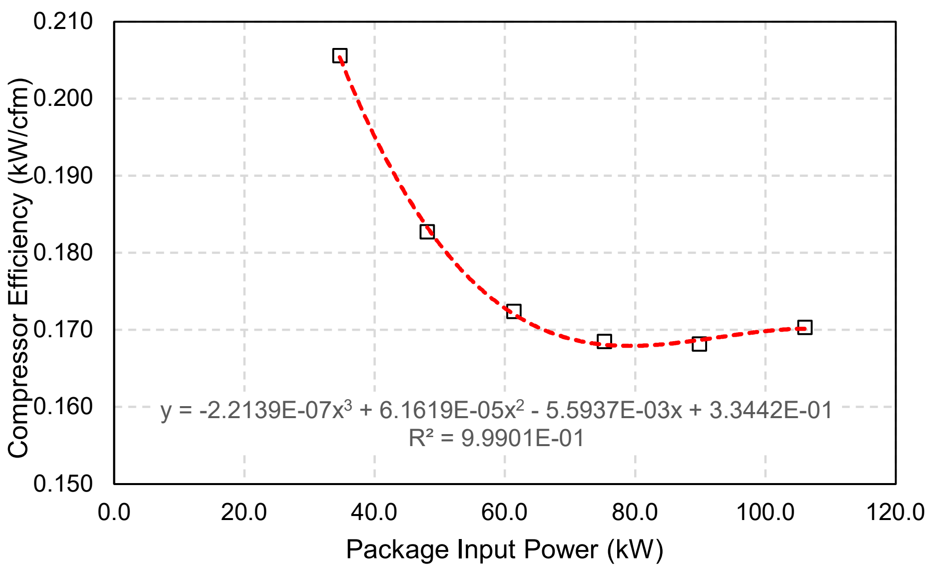
Evaluation Calculation Method

The evaluator reviewed the metered power data and using a 3rd order polynomial fit to the performance values on the 100 psi CAGI datasheet for the installed VFD compressors modified for the site conditions of 93 psi, calculated airflow data throughout the metering period according to:

$$\text{airflow} = P / \eta$$

where P is the metered power in kW and η is the compressor efficiency in kW/cfm. CAGI datasheet performance values were adjusted for site operating pressures by using the 0.5% power per 1 psi of pressure difference rule. The fit used is visualized in Figure 2-1.

Figure 2-1. 3rd order polynomial fit to CAGI compressor data at 93 psig



The metered power data was used in preference to the airflow data collected by the site contact because:

1. The power meters have a greater accuracy than the airflow meter.
2. An air receiver is located between the compressor and the airflow meter.
3. Power data was collected for the full metering period of 42 days, while the applicant was only able to collect 22 days of airflow data.

The airflow meter data would have been sufficient to complete the analysis had power metering not been available, but given both datasets the evaluator judges the power data to be of higher accuracy. The evaluator used the calculated airflow to generate an airflow profile by binning the airflow into the same 6 airflow bins used by the applicant. Each bin shows the number of hours where, on average, the airflow was less than the max and greater than or equal to the min value of the bin. Assuming that the metering period is representative of typical operation, which is likely based on feedback from the site contact, the metered hours were scaled to correspond to 1 year of operation using 8,328 hr/year. The site contact indicated that the site has two annual one week shutdowns, one in December and one in July. Accounting for these shutdowns and federal holidays (two of which take place within these shutdowns), yields 8,328 hours during which production can take place, and 432 hr/year of shutdown/holiday time. The metered power data was also binned to directly provide compressor power values in the proposed case of app 9808916, as shown in Table 2-4.

Table 5-329. Airflow Binning Summary

airflow range		avg. airflow	metered	annual	comp. P
low (cfm)	high (cfm)	(cfm)	(hrs)	(hrs)	(kW)
0	35	0	14	116	11.3
35	103	85	241	1,954	18.8
103	334	246	294	2,379	45.1
334	503	425	123	998	73.4
503	800	586	356	2,881	99.5

Based on the airflow data derived from the power metering and conversations with the site contact, the site has 24/7 compressed air demands even during non-production periods and these demands would likely still be present during shutdowns. Therefore, the evaluator assumes that the average non-production airflow demand is a reasonable value to use during holidays and shutdowns, which account for 432 hr/year.

The evaluator used the same airflow profile shown in Table 2-4 for applications 9209203 (new compressors) and 9808916 (pressure reduction). The evaluator did not use this airflow profile for app 9310038 (leak repair) because the metering used to develop this profile took place after the measure life had expired. Instead, the applicant used pre and post metered airflow data to analyze this measure. The same annual hours of operation (8,328 hr/year possible production, 432 hr/year holiday/shutdown) are used for all three applications. The airflow data was also used to develop a 24 x 7 heatmap to show compressed air usage trends and allow for precise calculation of peak demand savings.

Similar to the applicant, the evaluator did not calculate savings for the zero-loss condensate drains. A 5.5 cfm intermittent airflow savings (expected airflow for a ½" pipe for a system designed to the 2 psi/1000ft rule of thumb) per zero-loss condensate drain is negligible in comparison to the overall measure savings so the evaluator did not believe further analysis of this component of the measure was justified.

9209203 (two new VFD compressors) – The evaluator calculated annual savings by applying the airflow profile developed from metered power data (as previously discussed) to a bin model which calculated baseline and proposed operation for each airflow bin. Annual energy savings are calculated as:

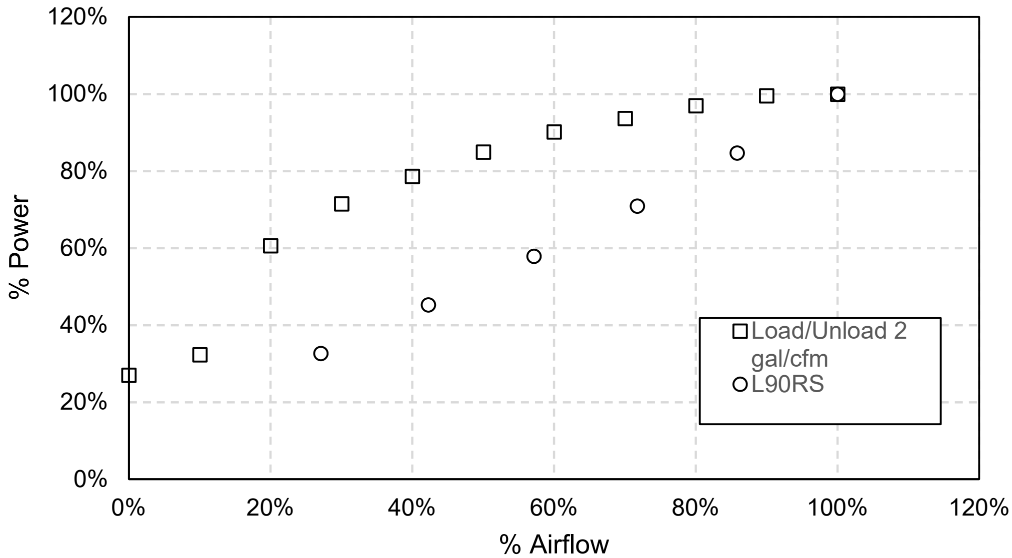
$$E_S = (E_{B,c} + E_{B,d}) - (E_{P,c} + E_{P,d})$$

where B denotes baseline equipment, P denotes proposed equipment, and c and d denote compressor and dryer respectively. For each airflow bin, these values are calculated as follows:

$E_{B,c}$ – Baseline compressor energy usage was found by calculating % airflow by dividing the bin average airflow by the CAGI rated capacity for the baseline compressor selected by the applicant, the QSI 925 (200 hp, 925 cfm, at 125 psig). Note that this is a site-specific baseline selected by the applicant which appears to be reasonable. % power was calculated using a 3rd order polynomial fit to the load/unload 2 gal/cfm compressed air challenge performance curve, which gives a R^2 of 0.98. This is a generic performance curve which the evaluator judges to be suitable for estimating load/unload compressor performance, and is shown, along with the proposed compressor curve, in Figure 2-2. Bin compressor power was calculated as % power *

CAGI package input power at rated capacity, unless the airflow was 0, in which case the compressor power was set equal to the minimum package power. Baseline compressor annual energy, $E_{B,c}$ was calculated as bin hours * bin power.

Figure 2-2. % Power vs % Airflow for the base and proposed compressors

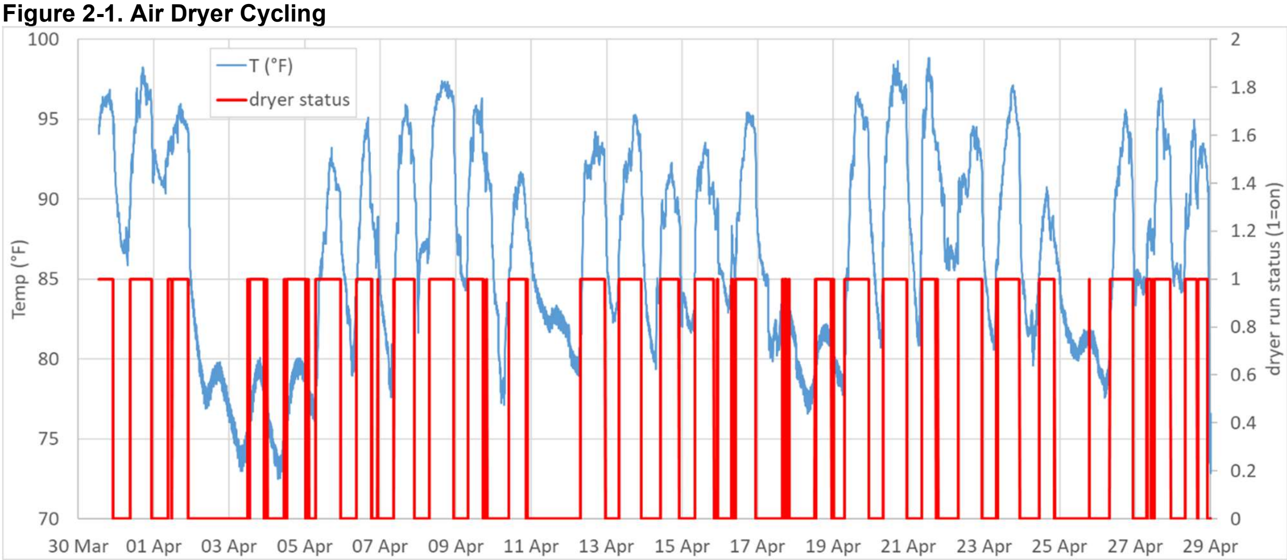


$E_{P,c}$ – Proposed compressor energy usage was found by first calculating the bin average compressor efficiency as a function of bin average airflow according to the 3rd order polynomial curve fit to the 100 psi CAGI datasheet for the installed compressor, the Gardner Denver L90RS, adjusted for operation at 105 psi. Compressor power is the product of the compressor efficiency and bin average airflow, and $E_{P,c}$ was calculated as the sum of bin power * bin hours for all bins.

$E_{B,d}$ – Baseline air-dryer energy usage was found by calculating the % airflow for each bin as the bin airflow divided by the baseline air dryer full load airflow. The % airflow was used to calculate dryer % power using a linear fit to an applicant provided air-dryer performance curve showing 75% power at 0% airflow and 100% power at 90% airflow. % power * dryer rated power yields bin power, and $E_{B,d}$ was calculated as bin hours * bin power.

$E_{P,d}$ – Proposed air-dryer energy usage was calculated by analyzing temperature trend data collected during the metering period by placing a temperature/RH logger on the dryer condenser. Because hot exhaust air blows off of the condenser when the air dyer cycles on, the temperature logger showed dryer operation. In order to determine a % runtime capacity factor from the trends, exponential smoothing was applied to the temperature value to remove noise. The derivative with respect to time of the temperature trends was used to find when the temperature changed slope (when dT/dt = 0), which approximates when the dryer cycles on and off. This analysis yielded a % runtime of 47%, and therefore $E_{P,d}$ was calculated as 47% * dryer rated power * bin hours. This analysis is shown in Figure 2-1. Had this temperature not been collected the applicant's methodology could have instead been used to calculate this value, however the evaluator wanted to utilize the most direct measurement possible to verify this value.

Figure 2-1. Air Dryer Cycling



On-peak savings were found in a separate bin of the same model previously discussed, where the bin airflow corresponds to the average M-F compressed air demand between 07:00 – 23:00 found from the 24 x 7 heatmap and bin hours correspond to the same time period, 3,980 hr/yr.

Summer and winter demand savings were also calculated using separate bins in the model, using average airflow from 13:00 – 17:00 and 17:00 – 19:00 respectively.

9310038 (leak repair) – The evaluator calculated annual savings by comparing pre and post measure implementation airflow data to assess the repaired leaks and associated savings. Notably, the analysis methodology has a large impact on the savings for this measure largely because the site appeared to be producing products on Saturday in the pre-measure airflow data, but not during the post-measure airflow data. The pre and post data was separated into production and non-production periods in order to eliminate the possibility that Saturday operation in the pre-measure data would impact the savings.

Therefore, the production period was defined as 07:00 Monday – 07:00 Sunday (in pre-measure data) and 07:00 Monday – 07:00 Sunday (in post-measure data).

These production periods align with the site contact's description of the work schedule as 5x24, 3 shift production, as well as the 24/7 heatmaps for the pre and post measure data, shown in Figure 2-2. This is not unexpected given the site contact's description of normal operating practice: Saturday production is used as needed to meet demand.

Figure 2-2. Leak Repair Pre/Post Airflow

average pre-measure airflow (cfm)							
	Day of Week (1= Monday)						
Hour	1	2	3	4	5	6	7
0	103	213	364	423	414	375	311
1	101	253	385	421	416	376	330
2	101	253	379	420	412	378	349
3	104	225	354	384	414	375	349
4	103	211	340	367	415	383	346
5	104	208	341	354	405	378	344
6	109	221	347	374	415	370	231
7	187	387	468	448	405	460	118
8	285	486	494	543	438	505	112
9	285	505	523	570	527	533	118
10	301	544	548	547	527	537	112
11	301	566	555	572	524	528	108
12	303	510	572	509	467	521	101
13	312	475	576	468	413	519	100
14	315	531	504	509	491	504	99
15	310	515	447	471	431	432	103
16	315	496	542	449	472	431	101
17	320	515	538	478	485	421	101
18	316	516	558	491	521	390	100
19	316	512	543	473	537	381	101
20	312	513	547	463	537	398	101
21	311	516	553	492	526	395	102
22	308	507	514	465	501	379	95
23	245	419	414	369	380	305	94

average post-measure airflow (cfm)							
	Day of Week (1= Monday)						
Hour	1	2	3	4	5	6	7
0	78	309	316	293	234	225	43
1	87	319	317	299	223	226	45
2	86	323	318	299	226	225	45
3	90	320	318	306	235	229	43
4	92	315	328	301	234	225	44
5	95	296	313	305	234	222	44
6	97	309	293	308	235	154	36
7	222	417	365	367	274	47	29
8	344	459	452	424	351	52	29
9	395	470	447	423	357	48	29
10	438	468	432	454	361	54	29
11	410	471	437	457	358	50	27
12	398	455	397	463	350	47	29
13	413	458	402	454	356	44	28
14	405	454	374	429	350	44	28
15	354	405	404	367	353	43	28
16	421	421	456	410	354	42	29
17	445	422	459	432	358	45	28
18	435	435	460	442	360	43	28
19	435	436	455	443	348	44	28
20	451	429	460	421	345	44	28
21	449	416	446	444	301	42	29
22	419	395	409	368	294	43	28
23	311	307	304	242	220	43	53

Additionally, the applicant provided the evaluator with three sets of data, one pre-measure dataset and two post-measure datasets (as shown in Table 2-4). In order to capture the largest range of operating conditions, the two post-measure datasets were combined. The potential airflow savings under varying methods of analyzing this data are shown in Table 2-4, with the evaluator's selected method shown highlighted.

Table 2-4 – Analysis options for average leak reduction

Airflow analysis option	airflow (cfm) pre-measure	airflow (cfm) post-measure	airflow (cfm) delta	hrs	comment
straight average pre*-post1**	379	293	86	8,760	Post1 only has 7 days of data, low Tuesday afternoon load.
straight average pre-post2***	379	265	114	8,760	pre includes Saturday production, post does not. Post2 has low Friday load.
straight average pre - post average	379	273	107	8,760	expands post data by averaging post1 and post2, however pre still includes Saturday production and post does not.
average occ (7 M - 7 Sat)	428	363	64	6,257	Splits data into occupied and unoccupied periods as shown, however pre still includes Saturday production and post does not. variations in production occur between pre and post
average non-occ (7 Sat - 7 M)	258	46	212	2,503	
average production (7 M - 7 Sun pre, 7 M - 7 Sat post)	425	363	**62**	5,825	Splits data into production and non-production periods as shown; shutdowns and holidays are included as non-production because the compressed air system is expected to be left operational. Some production variation between pre and post still likely, however by not separating night and day production potentially the magnitude of these differences will be reduced. Non-Saturday production from post data (indicated by the site contact to be typical) is used to develop hours.
average non-production	104	46	**58**	2,935	
avg day production (7-23)	463	407	56	3,883	Splits data into day production, night production, and non-production periods as shown. If night production varies significantly between base and proposed, may amplify savings.
avg night production (23-7)	373	275	98	1,942	
avg non-production	104	46	58	2,935	

*pre-measure airflow was metered starting 01.09.2019 and lasted ~15 days

**post-measure airflow 1 was metered starting 03.08.2019 and lasted ~7 days

***post-measure airflow 2 was metered starting 04.08.209 and lasted ~23 days

The measure savings were calculated in a bin model for the production and non-production hours by:

1. Using a 3rd order polynomial curve fit to the 100 psi CAGI datasheet adjusted for 105 psi operation to determine compressor efficiency (kW/cfm) at each operating airflow. The average airflow values are non-zero and below a single compressor's max airflow, so no further adjustment is needed.

2. Calculate the compressor electrical power consumption according to P = A / η where A is the average airflow and η is the corresponding compressor performance in cfm/kW.

3. Calculate the energy savings according to E = (P_{pre} – P_{post}) * t where P_{pre} and P_{post} are the pre and post compressor operating power and t is the operating hours for either the production or non-production state. Operating hours are the same for all measures and are as previously described.

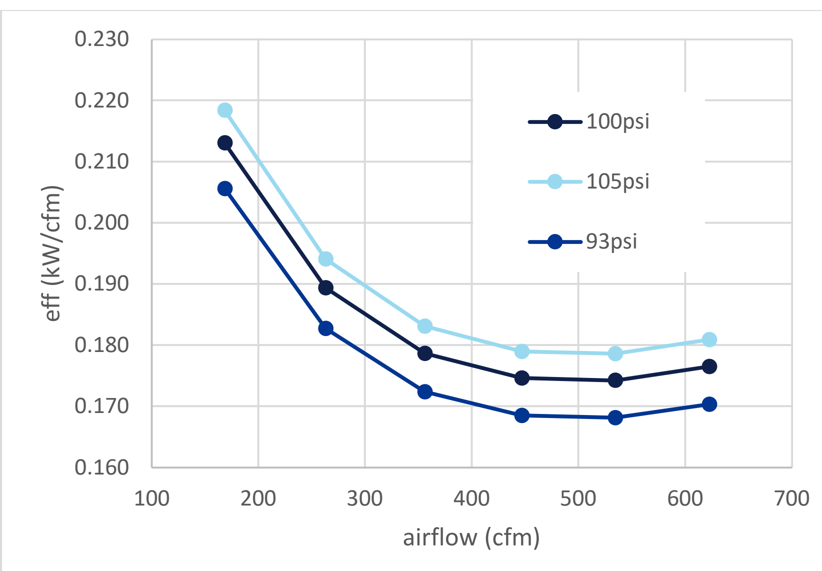
4. On-peak, summer peak, and winter peak savings were found in separate bins, using the same approach discussed in the previous measure. A summary of this analysis is shown in Table 2-5.

Table 2-5 – Analysis summary for leak reduction

		pre-measure			post-measure				savings					
case	period	airflow (cfm)	eff. (kW/cfm)	P (kW)	airflow (cfm)	eff. (kW/cfm)	P (kW)	annual hours	P (kW)	E (kWh)	airflow (cfm)	% on peak	summer (kW)	winter (kW)
evaluated	production	425	0.179	76.2	363	0.182	66.2	5,825	10.0	58,286	61.9			
	non-production	104	0.218	22.7	46	0.218	10.0	2,935	12.6	37,101	57.9			
	total							8,760		95,387				
	on-peak	464	0.179	82.9	407	0.180	73.2	3,980	9.7	38,580	57.0	40%		
	sum. demand	452	0.179	80.8	402	0.180	72.3		8.5				8.5	
	wint. demand	474	0.179	84.6	424	0.179	76.0		8.6					8.6

9808916 (pressure reduction) – The evaluator calculated annual savings for this measure using the same bin model methodology used in the first measure, 9209203 (two new VFD compressors). The baseline case is the installed compressor operating at 105 psi, and the proposed case is the installed compressor operating at 93 psi. Compressor efficiency was calculated at the baseline operating points using the same curve fits previously described as well as the same methodology to adjust performance from the 100 psi datasheet to the relevant values. Proposed case energy consumption was calculated directly from bin average power * bin hours, and savings were calculated as the difference between the base and proposed case.

Figure 2-3 – Compressor efficiency vs airflow at varying pressure.



Final Results

This section summarizes the evaluation results determined in the analysis above. This section will include a summary table of savings by major end-use and application.

Table 5-330. Summary of Key Parameters

		BASELINE		PROPOSED / INSTALLED	
Measure Name	**Parameter**	**Tracking Value(s)**	**Evaluation Value(s)**	**Tracking Value(s)**	**Evaluation Value(s)**
New VFD Compressors	compressor operating pressure	125 psig	125 psig	105 psig	105 psig
	compressor operating hours	7,488 hr/yr	production: 8,328 hr/yr non-production: 432 hr/yr	7,488 hr/yr	production: 8,328 hr/yr non-production: 432 hr/yr
	average compressor efficiency	0.504 kW/cfm	0.386 kW/cfm	0.206 kW/cfm	0.196 kW/cfm
	average airflow	401 cfm	344 cfm	401 cfm	344 cfm
	average air-dryer power	6 kW	6 kW	2.16 kW	2.98 kW
Compressed Air Leak Repair	compressor operating pressure	125 psig	105 psig	125 psig	105 psig
	compressor operating hours	6,864 hr/yr	production: 8,328 hr/yr non-production: 432 hr/yr	6,864 hr/yr	production: 8,328 hr/yr non-production: 432 hr/yr
	average compressed air demand	386 cfm	production: 425 cfm non-production: 104 cfm	312 cfm	production: 363 cfm non-production: 46 cfm
Compressed Air Pressure Reduction	compressor operating pressure	105 psig	105 psig	95 psig	93 psig
	compressor operating hours	6,400 hr/yr	production: 8,328 hr/yr non-production: 432 hr/yr	6,400 hr/yr	production: 8,328 hr/yr non-production: 432 hr/yr
	average compressor efficiency	NA	0.196 kW/cfm	NA	0.188 kW/cfm

Explanation of Differences

This section describes the key drivers behind any difference in the application and evaluation estimates, annual kWh savings, percent on-peak kWh saving, and demand savings. Table 3-2 provides a summary of the differences between tracking and evaluated values.

Table 5-331. Summary of Deviations

a	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
New VFD Compressors - App. 9209203 (child app of 677949)	Methodology	Efficiency	0.8%	Increased savings by using the 0.5% compressor power reduction per 1 psi of pressure reduction rule, rather than the applicant's 0.4% per 1 psi.
	Operational	Hours	19.2%	Increased savings by accounting for additional operating hours

	Methodology	Compressor Curve	2.6%	Increased savings by correcting baseline compressor rated capacity and visual inspection of compressor curve.
	Methodology	Bin Airflow	-4.9%	Decreased savings by changing the bin average airflow values to reflect the calculated values rather than those obtained by visual inspection.
Compressed Air Leak Repair - App. 9310038	Methodology	Compressor Curve	-1.9%	Decreased savings by using baseline compressor performance at 105 psi instead of 125 psi. Performance at lower pressure is better, reducing savings.
	Operational	Hours	4.2%	Increased savings by accounting for additional operating hours
	Methodology	Leak Repair Airflow	-0.7%	Decreased savings by reducing the airflow savings through numerical analysis of applicant metered pre/post data instead of using visual inspection and an assuming ~80% of leaks repaired.
Compressed Air Pressure Reduction - App. 9808916	Technology	Operating Pressure	1.3%	Increased savings by accounting for a greater pressure reduction
	Operational	Hours	0.3%	Increased savings by accounting for additional operating hours
	Operational	Load Profile	-1.3%	Decreased savings by using load profile from metered data rather than assumed profile
	Methodology	Pressure reduction savings formula	-1.4%	Decreased savings by using actual compressor performance rather than assumed % savings per pressure reduction formula.
	Final RR			**118%**