FINAL REPORT

Impact Evaluation of PY2021 Custom Electric Installations

Rhode Island Energy

Date: November 8, 2023

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List of acronyms used in this report

BMS building management system

CDA comprehensive design assistance

CHP combined heat and power

C&I commercial and industrial

EMS Energy monitoring system

EUL effective useful life

FCM forward capacity market

HVAC heating, ventilating, and air-conditioning

ISP industry standard practice

LSAF Lifetime saving adjustment factor

M&V measurement and verification

MBSS model-based statistical sampling

ML measure life

Non-Ops Non-Operational Parameters

PY program year

PYR plan year report

RR realization rate

SCADA supervisory control and data acquisition

TMY3 typical meteorological year 3

TA study technical Assistance study

MRD minimum requirements document

EERMC energy efficiency resource management council

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) 2021 Custom Electric Installations, conducted for RI Energy, carried out from September 2022 to July 2023. The DNV team includes expertise from our partner firm DMI.

The primary objective of the impact evaluation was to provide verification and re-estimation of energy and demand savings for a sample of statistically selected custom electric projects through site-specific verification, monitoring, and analysis. The results of this study, combined with those from previous years, were used to determine the gross realization rates to be used for custom electric energy efficiency projects implemented in 2024 and will be updated annually as subsequent impact evaluations are completed.

The key objectives of this evaluation were as follows:

1. **Evaluate savings impacts of PY2021 custom electric projects** to be pooled with the results of the recently completed PY2019 and PY2020 studies. This study will aim to quantify:
    - Achieved electric energy savings for custom non-lighting projects, with a targeted combined sampling precision of ±15% at 90% confidence when pooled with the results from the PY2019and PY2020 studies.
    - Summer and winter on-peak demand realization rates will also be calculated at 80% confidence for custom non-lighting when pooled with the results from the PY2019 and PY2020 studies.
2. **Evaluate lifetime savings adjustment factors (LSAF)** for PY2021 using the results for the sites included in the study and the sampling weights calculated for Objective 1 above. LSAF was not calculated until PY2020. Therefore, PY2021 (considered Year-2) cannot be applied to future programs but would require combining LSAFs from three years (rolling/staged; PY2020+PY2021+PY2022) for program planning purposes.

1.2 Organization of report

The rest of the report is organized as follows:

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

2 METHODOLOGY AND APPROACH

This study is the fifth annual C&I custom electric impact evaluation in Rhode Island using the rolling average approach. Like the 2019 and 2020 studies, the beginning of this year's study was modified to adapt to limitations associated with the COVID-19 pandemic. Like last year's study, this year's study calculated savings and realization rates for non-lighting projects only. This year, all 10 sites received on-site full M&V with loggers installed and data collected.

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

The primary objective of the Impact Evaluation of PY2021 Custom Electric Installations was to provide verification and re-estimation of energy and demand savings for a sample of statistically selected non-lighting custom electric projects through site-specific verification, monitoring, and analysis. The results of this study were used to determine the gross realization rates for custom electric energy efficiency projects implemented in 2021 and were combined with the previous two studies to provide rolling results based on the most recent three years of study.

The goals of this study were to quantify the following:

1. Achieve electric energy savings for custom non-lighting segments statewide, with a targeted combined sampling precision of ±15% at 90% confidence when pooled with the results from the PY2019 and PY2020 studies.
2. Calculate summer and winter on-peak demand realization rates at 80% confidence at ±20% relative precision for custom non-lighting when pooled with the results from the PY2019 and PY2020 studies.
3. Calculate lifetime savings adjustment factors (LSAFs) for custom electric projects statewide for PY2021.
4. Percent on-peak realization rates will also be calculated for custom non-lighting for the three-year rolling average.

2.1 Sample development

2.1.1 Tracking data review

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

The data included a total of 224 non-lighting applications at 149 unique sites. As mentioned earlier, the scope excluded lighting projects in this round of evaluation. More details of this sampling approach are provided below. PY2021 claimed 26.1 million gross annual Energy (kWh) savings, nearly 140% more than the previous year (see Table 2-1). The increased savings are primarily due to 2 large[1] sites in PY2021 with a combined total of 15.35 million kWh.

Table 2-1. PY2021 Gross annual energy and peak demand savings

Total Unique Accounts (Sampling Unit)	Total Energy Savings (kWh)	Total Peak Summer Savings (kW)	Total Peak Winter Savings (kW)
149	26,073,183	3,685.1	3,099.3

[1] RICE21N069 has a tracking savings value of 11,129,352 kWh and RICE21N087 saved 4,221,939 kWh in PY2021, per the Custom Detail file provided by RI Energy.

2.1.2 Sampling plan

Model-based statistical sampling (MBSS) techniques were used to develop the sample design. The sample design's general principle is that each year's results would need to achieve ±26% precision at the 90% confidence interval to maintain a three-year pooled result of ±15% precision at 90% confidence for non-lighting gross energy realization rates. The error ratios[2] (ER) for PY2021 presented below in Table 2-2, were calculated using the actual ER from PY2019 and PY2020.

Table 2-2. Sampling targets

Annual Sampling Target	3-Year Pooled Sampling Target	Error Ratio
±26% on Non-Lighting Energy (kWh) at the 90% confidence interval	±15% on Non-Lighting Energy (kWh) at the 90% confidence interval	PY2021 = 0.45

Table 2-3 presents the sample design for PY2021 and samples for previous evaluations of PY2019 and PY2020. The combined RI sample for the first three years in the staged evaluation resulted in very reasonable projected relative precision (RP) estimates of ±11.6 % RP @ 90% for non-lighting; well within the goal of ±15 % RP.

Table 2-3. 2021 project sample design and estimated relative precisions

End-use	Program year	Energy Savings (kWh)	Sample Size	RP
				@90% CI
Non-Lighting	2019	12,804,067	15	±18.4% (actual)
	2020	10,676,671	10	±28.2% (actual)
	2021	26,073,183	10	±15.8% (design)
Non-Lighting (3-year rolling)	**2019+2020+2021**	**49,553,921**	**35**	**±11.6%**

PY2021 Site weight calculation

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

Table 2-4. Stratification and weighting

Strata#	Population (N)	Sample (n)	Weight
1	127	4	31.75
2	20	4	5.0
3	2	2	1.0

For the PY2021 annual evaluation, each site has a single case weight based on the stratum they were assigned to.

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

2.2 Description of methodology

Due to the continued restrictions of the COVID-19 pandemic at the beginning of this evaluation potentially limiting site work, this study's methodology was modified from typical years, which is consistent with last year's study. However, all 10 sites selected for evaluation received full[3] M&V with no customer operation disrupted by COVID.

The team has updated the realization rates yearly as part of this custom electric evaluation framework. The evaluation also generated lifetime savings adjustment factors (LSAFs) in this round. See Appendix D for more information on LSAF.

2.3 Customer outreach

Project engineers reached out to customer site contacts using an RI Energy-approved communication protocol and the information provided in the project files. During this initial outreach, the engineers discussed the purpose of the outreach, facility operation and usage, the scope of measures installed, the availability of onsite trend/SCADA/production data, any other applicable parameters relevant to the evaluation and confirmed the site's ability and willingness to participate in the evaluation. Efforts were made to minimize pre-recruitment evaluation activities until the customer site contact indicated they would accommodate the evaluation process. A backup site was selected if the site contact was unresponsive or refused to participate in the evaluation. All 10 primary sites agreed to a visit. No backups were selected in this round of the evaluation.

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

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

2.3.1 Onsite M&V

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

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

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

A unique savings analysis was created for each sampled project. When required, a typical meteorological year (TMY3 for Providence, RI) dataset of ambient temperatures was used for temperature-sensitive calculations. Energy savings were

[3] A full M&V site will include evaluation discrepancies calculated from both operational and non-operational parameters. More details are provided in section 4.

either calculated by the hour in an 8,760-hour spreadsheet or allocated to each hour in the year to estimate on-peak kW and kWh savings impacts. Each analysis provided estimates for annual kWh savings, on-peak kWh savings, and on-peak demand (kW) savings at the times of the winter and summer peaks, as defined by the ISO New England Forward Capacity Market (FCM). All coincident summer and winter peak reductions were calculated using the following FCM definitions:

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

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

Engineers submitted draft site reports to RI Energy upon completion of each site evaluation. The DNV team responded to the comments received and submitted revised reports for comment. A sample of reports was also submitted to the EERMC Team for review. The final site reports are included in APPENDIX E. 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:

- PY2021 tracking data provided by RI Energy
- PY2019 and PY2020 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.
- Customer or vendor-supplied operational data that metered or trended data

4 ANALYSIS AND RESULTS

4.1 Introduction

A total of 10 sites were evaluated within the PY2021 population for an onsite visit with full M&V. Full M&V is considered a traditional measurement and verification (M&V) that involves onsite measurements using power, time-of-use meters or validated trend data and measure verification. A summary of sampled projects is listed in APPENDIX A.

Table 4-1 presents the adjustment factors used in the evaluation.

Table 4-1. Adjustment factors for site evaluation

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

The results from this study involved the following steps:

- The evaluated non-operational adjustments and operational adjustments for PY2021 were multiplied together to arrive at an overall realization rate (RR) for PY2021.
- The realization rate for PY2021 was combined with the overall RRs from PY2020 and PY2019 in proportion to their respective first year savings relative to the total savings for the three program years to provide an estimate of the overall three-year RR.

4.2 PY2021 results

4.2.1.1 Combined Program Level Results

This section presents rolled-up/program-level realization rates by combining PY2019, PY2020 and PY2021 evaluated sample results.

The site-level evaluation results were aggregated using the final case weights for each respective year. The realization rates for each year were calculated by taking a product of Operational and Non-Operational Adjustment factors and then applied to total tracking savings to determine their total evaluated savings for that year. As discussed above, these one-year RRs were then used to calculate the three-year rolling RR.

Table 4-2 presents the non-lighting realization rates for each year and the combined prospective realization rate for the custom electric program in RI to be used to calculate 2024 savings. The combined RR for non-lighting meets the targeted relative precision (RP) of ±15% at a 90% confidence interval (CI) with a value of ±11.6% with a three-year rolling RR of 89.1%. Five out of 10 sites reported savings below 100% of ex-ante estimates, with major discrepancies in Operational changes. Additional reasons for discrepancies at site-level are discussed in individual site reports in APPENDIX E.

Table 4-2. Combined non-lighting realization rates (kWh)

Non-Lighting	RI			Combined Results
	PY2019	PY 2020	PY 2021	PY2019+ PY2020+PY2021
Tracking Energy Savings (kWh)	12,804,067	10,676,671	26,073,183.00	49,553,921
Sample Size (n)	15	10	10	35
RR	104.1%	68.6%	88.4%	88.2%
Relative precision @ 90% CI	±18.4%	±28.2%	±15.8%	±11.6%
Operational Results	97.4%	75.4%	86.8%	
Non-operational Results[4]	106.8%	91.0%	101.8%	

Table 4-3 and Table 4-4 present prospective realization rates for Summer and Winter peak demand (kW) savings, and Table 4-5 presents prospective realization rates for %On-peak energy savings. Both Summer and Winter peak demand (kW) savings RR s increased from the previous two rounds along with improved relative precisions for each. The three-year rolling/combined results for both Summer and Winter peak demands met the target precision of ±20% at 80% CI.

Table 4-3. Prospective realization rates from Evaluated Summer Peak Demand (kW) Savings for Non-Lighting Measures

Non-Lighting	RI			Combined Results
	PY2019	PY2020	PY2021	PY2019+ PY2020+PY2021
Tracking Summer Demand (kW)	1,754	1,441	3,099	6,294
Sample Size (n)	15	10	10	35
RR	72.4%	52.7%	83.3%	73.3%
Relative precision@ 80% CI	±24.5%	±32.9%	±15.6%	±13.1%
Operational Results	64.6%	56.4%	80.2%	
Non-operational Results	112.1%	93.5%	103.9%	

[4]Starting in 2020, the non-operational results (non-ops) ratio is calculated using 2 factors. Non-ops 1 and non-ops 2; non-ops 1 includes discrepancies from Baseline, Methodology and Administrative adjustment factors while non-ops 2 includes Technology and Quantity adjustment factors.

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

Non-Lighting	RI			Combined Results
	PY2019	PY2020	PY2021	PY2019+ PY2020+PY2021
Tracking Winter Demand (kW)	1,713	1,168	3,685	6,566
Sample Size (n)	15	10	10	35
RR	98.4%	70.5%	120.6%	105.9%
Relative precision@ 80% CI	±44.3%	±26.8%	±23.7%	±18.4%
Operational Results	101.9%	72.3%	115.5%	
Non-operational Results	96.6%	97.5%	104.4%	

Table 4-5. Prospective realization rates from Evaluated %On-Peak Energy Savings for Non-Lighting Measures

Non-Lighting	RI			Combined Results
	PY2019	PY 2020	PY 2021	PY2019+PY2020+PY2021
%On Peak Energy	12,804,067	10,676,671	26,073,183	49,553,921
Sample Size (n)	15	10	10	35
RR	68.4%	91.1%	74.7%	76.6%
Relative precision@ 80% CI	±40.4%	±8.7%	±7.1%	±10.3%
Operational Results	52.9%	92.5%	70.7%	
Non-operational Results	129.4%	98.5%	105.6%	

4.2.2 Lifetime savings adjustment factors (LSAFs)

Lifetime savings adjustment factors were developed for the second time in this study using the weighted tracking and evaluated lifetime savings. The LSAFs for non-lighting are provided in Table 4-6. As shown below, the lifetime savings realization rate (LSRR) for PY2021 is 93% and the LSAF is 105%. All sites except for site ID RICE21N120 had the same tracking and evaluated measure life (ML). The methodology for these calculations can be found in APPENDIX D.

Table 4-6. Custom non-lighting LSAFs

LSAF	Statewide
PY2021 LSRR	93%
PY2021 LSAF	105%
Three-year pooled RR	To be calculated after PY2022 evaluations are completed.

Although only one site had a different evaluated ML compared to tracking, LSAFs are not based solely on a change in measure life. LSRR may be higher if those measures with longer measure lives also happened to have higher evaluated first-year RRs as compared to those measures with shorter measure lives.

In PY2021 there was one site with a 25-year ML and several others with 15-year ML that had RRs greater than 100%. Comparatively, sites with 10- and 6-year ML had RRs less than 100%. The result is affected by the relative savings of each project and their sample weight. In this case, the LSRR worked out to be 93% as compared to the first-year RR of 88%, giving an LSAF of 105%.

4.2.3 PY2021 Site-level discrepancies and RR

This section provides an overview of the top five discrepancies from PY2021 that had the biggest difference in site-level tracking and evaluated results. For each of the 10 sites in the PY2021 study, the site engineers identified factors that led to differences between the program reported tracking savings and the evaluated savings. The factors are classified into seven categories: baseline, methodology, tracking/administrative, technology, quantity, HVAC interaction, and operational. A more discrete breakdown of possible differences and how they are categorized is presented below in Table 4-7. More details on each site can be found in the individual site writeups in APPENDIX E.

Table 4-7. Discrepancy factors and their mapping to major categories

Major Discrepancy Category	Discrepancy Definition or Examples
Baseline	Change in the baseline of the post-retrofit condition
Methodology	Accuracy/appropriateness of Analysis Methodology Calculation changes Non-metered data input updates
Tracking/Admin	Accuracy of Tracking Savings Errors during claimed savings input Savings changed but not changed in tracking savings
Technology	Differences in proposed vs. installed technology or measure type
Quantity	Quantity of installed equipment is different
Operational	Boiler combustion efficiency Difference in equipment hours of operation Different equipment load profile Inaccurate pre-project characterization Steam operating pressure difference System optimization or programming not implemented Faulty or improperly installed equipment Operating temperature differences
HVAC Interaction	Interactive effects

Operational adjustment results were used from the PY2019, PY2020 and PY2021 samples. The total number of operational adjusted sites from each program year is included, along with the total number of sites the program year contained. PY2019 used 10 out of 15 sampled sites, PY2020 used 7 out of 10 sampled sites and 10 out of 10 have been used from PY2021 as shown below. PY2021 did not use imputed historical operation adjustment because all sites were full M&V. Individual site RR are shown in APPENDIX B.

The following sites had the biggest discrepancies with respect to savings. All but one discrepancy is due to an operational adjustment:

RICE21N037: Operational – the installed system did not achieve a sufficient increase in production efficiency to achieve energy savings and resulted in a penalty. The site had an evaluated energy realization rate of -65.1%.

RICE21N043: Operational – the in-service factor of 50% applied to the installed measures not found and possibly moved to other stores. Removed equipment reduced savings. The site had an evaluated energy realization rate of 47%

RICE21N094: Quantity – the measure was not installed due to programming issues with system firewall. The site had an evaluated energy realization rate of 0%.

RICE21N120: Operational – the evaluator found the operating power to be less than estimated in tracking. This decreased the difference between baseline and installed operating power. The site had an evaluated energy realization rate of 16%.

RICE21N149: Operational & Methodology – the applicant modelled cooling setpoint was found to be different between tracking and onsite. The applicant modelled savings using eQUEST where the evaluator modelled savings using 8,760. The site had an evaluated energy realization rate of 264%.

4.2.4 PY2021 RR & Combined Program RR calculation methodology

This section discusses the methodology to calculate Combined program level and the PY2021 realization rates.

Calculation of Combined Program RR:

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

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

Where,

1- represents PY2019, 2 is PY2020, 3 is PY2021 and T is total (2019+2020+2021)

S_y - Population tracked savings of PY-y

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

q_T- percentage of three-year population tracked savings represented by each program year

RR_3 = Realization rate calculated for this program year

RR_1 and RR_2 were calculated in previous studies and have not been readjusted as part of this study. Additional details regarding prior year RRs which required imputation of operational adjustments, along with their associated standard error calculations, are provided in APPENDIX C.

Calculation of RR_3:
RR_3 is calculated using a similar, but simplified, methodology as compared to RR_1 and RR_2. Since the full sample of sites this year received an operational evaluation, no imputation to operational adjustments were needed.

Both the non-operational and operational realization rates (RR_{N3} and RR_{O3}) are calculated from the full sample using the full sample weights and the non-operational and operational adjusted savings respectively for the sample via the usual formulas.

The Overall RR is the product of the operational and non-operational RR
$RR_3 = RR_{o3}\ RR_{N3}$

Table 4-8. Non-lighting prospective realization rates PY2021

Statewide Results (n=10)	Annual	Summer On-Peak	Winter On-Peak	%On-Peak Energy
	MWh	kW	kW	MWh
Total Tracking Savings	26,073	3,099	3,685	26,073
Total Evaluated Savings	23,041	2,583	4,445	19,475
Realization Rate	**88.4%**	**83.3%**	**120.6%**	**74.7%**
Confidence Interval	90%	80%	80%	80%
Relative Precision	±15.8%	±15.6%	±23.7%	±7.1%
Operational Results	87%	80%	116%	71%
Non-operational Results	102%	104%	104%	105%

5 CONCLUSIONS, RECOMMENDATIONS, AND CONSIDERATIONS

5.1 Conclusions

This study's scope and approach were similar to the last round of evaluations (PY2019 and PY2020) in handling operational factors, with the exception that in PY2021 all sites received full M&V. Thus, there were no historical adjustments made for PY2021.

For custom non-lighting, the gross annual energy savings RRs saw a net increase in RR from PY2020 to PY2021 from 68.6% to 88.4%, but the RR was less than PY2019 RR of 104.1%. Overall, the combined three-year rolling value increased from 84.3% to 88.2%. RRs for summer and winter on-peak demand showed an increase in non-lighting summer and winter peak demand RRs from PY2020 to PY2021.

The increase in PY2021 energy RRs were due in part to the two largest sites having relatively high energy realization rates (131% and 94%).

5.2 Recommendations

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

Recommendation 1: This study's RI three year rolling non-lighting (88.2%) realization rate results shall replace the previous realization rates used by RI Energy beginning in PY2024. RI Energy should continue using 95.4% (from previous evaluation) RR for lighting. The results from this study should be combined with the next round of custom electric impact evaluation, which will evaluate PY2022 applications and is expected to be applied to the PY2025 tracking savings.

Recommendation 2: DNV recommends the RI Energy Implementation team conduct a thorough review of baseline assumptions and calculations for measures involving dust collection systems. On future dust collection measures, DNV recommends that program implementers request vendors to provide data showing normalized energy use per quantity of dust removed from the filters as this was determined to be a defining metric between dust collection vendors but was not available for this evaluation. The evaluators are concerned that both the tracking and evaluated analysis for this measure are not being performed on an equal dust removal, or air purification level. DNV also recommends that implementers give guidance on whether dust collection systems should be categorized as Process or HVAC.

For example, site RICE21N069 included five dust collection measures. Measurements of quantity of dust removed were not available and baseline performance extrapolation was problematic. Three of the five dust collection measures were categorized as Process and the other two as HVAC, though they were the same measure in the same type of space.

Recommendation 3: DNV recommends that post inspections be performed for all projects regardless of savings. For many small saving projects, post inspections are waived. Several of these small projects occur at grocery stores through the Energy Smart Grocer program, for which reach in coolers and grab and go cases are incentivized. These cases are easy to move and as was documented at a site, the big stores often move these cases to other locations. DNV recommends that a post inspection is performed to confirm installation location or if the customer is planning to relocate equipment.

For example, site RICE21N043 included the installation of two “grab and go” coolers but only one was found on site. The project vendor indicated that the case was likely moved to another store, so evaluators had to estimate an in-service factor to claim savings for the cooler based on the likelihood that it was installed in another store in the service territory.

Recommendation 4. DNV recommends that RIE field staff and implementers interview customers on their type of network security anytime a measure involves network and/or wifi control to understand compatibility, i.e., EMS. As was observed in this round of evaluation, an EMS measure with wifi thermostats was installed at a site, but the sites network security firewall would not allow proper connection with the thermostats and the EMS. For this site, RICE21N094, the measure was uninstalled, and the site received a 0% RR.

Recommendation 5. The evaluator continues to note issues related to proper measure commissioning, which has been a driver for discrepancies in this study. We recommend that RI Energy ensure proper commissioning protocols are followed to ensure that key measure components are installed and are generating savings.

For example, site RICE21N037 was intended to save energy through a production rate increase, where an efficiency gain is achieved dependent on increase production. The evaluator recommends clearly documenting the limiting factors of plant production rates, and how those limitations or bottlenecks would be addressed by a new system and impact savings.

Recommendation 6. DNV recommends RI Energy continue evaluating lifetime savings and reporting them at the site level in all future custom electric evaluations. PY2020 results will be considered year 1 of the rolling-based sample, PY2021 year 2 and PY2022 year 3. A standard 3-year rolling reporting cycle would be available after the PY2022 (year 3) evaluation.

APPENDIX A. SUMMARY OF SAMPLED PROJECTS

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

Site ID	App	Tracking kWh	Weight	Measure	Market Event
RICE21N001	11996709, 11259894	206,052	5	Process Equipment	NC
RICE21N037	8677807, 9065754	246,605	5	Process Equipment	NC
RICE21N043	12590113	7,723	31.75	Refrigeration	NC
RICE21N069	11761473, 10874645, 10476007, 10902885, 11063124, 10874646, 7999525, 11759401	11,129,352	1	Process Equipment, Compressed Air, HVAC	NC
RICE21N087	12018706, 12886490, 11955499	4,221,939	1	Process Equipment, Compressed Air	NC/Retrofit
RICE21N094	11959744	4,343	31.75	HVAC	Retrofit
RICE21N110	12809491, 12600039	298,074	5	Process Equipment	NC
RICE21N120	12730322	295,369	5	Other – Air Purifier	Retrofit

RICE21N149	12106805	5,752	31.75	HVAC	NC
RICE21S053	12623135	64,926	31.75	Transformer	Retrofit

APPENDIX B. SITE SAVINGS SUMMARY

Site ID	RI Energy Application #	TRACKING DATA				EVALUATED RESULTS				Energy Realization Rate
		Annual Energy Savings (kWh)	% On-Peak Savings	Summer On-Peak Demand Savings (kW)	Winter On-Peak Demand Savings (kW)	Annual Energy Savings (kWh)	% On-Peak Savings	Summer On-Peak Demand Savings (kW)	Winter On-Peak Demand Savings (kW)	
RICE21N001	11996709, 11259894	206,052	66.0 %	45.90	45.90	238,895	47.0%	21.5	62.5	116%
RICE21N037	8677807, 9065754	246,605	71.0 %	-	(81.30)	-160,516	78.0%	-	0	-65%
RICE21N043	12590113	7,723	48.0 %	0.91	0.91	3,663	54.0%	0.42	0.42	47%
NICE21N069	11761473, 10874645, 10476007, 10902885, 11063124, 10874646, 7999525, 11759401	11,129,352	85.0 %	1,446.10	1,452.58	10,516,658	53.0%	1,328.00	1519.1	94%
RICE21N087	12018706, 12886490, 11955499	4,221,939	47.7 %	483.10	544.50	5,512,406	48.0%	616.95	633.75	131%
RICE21N094	11959744	4,343	%0.0	-	-	0	0.0%	0	0	0%
RICE21N110	12809491, 12600039	298,074	69.0 %	68.10	68.00	233,380.00	69.0%	53.28	53.28	78%
RICE21N120	12730322	295,369	25.0 %	26.75	14.20	46,396	69.0%	5.15	5.3	16%
RICE21N149	12106805	5,752	52.0 %	1.23	-	15,196	53.0%	4.91	0	264%
RICE21S053	12623135	64,926	45.4 %	7.41	7.41	65,873	45.0%	7.5	7.5	101.5%

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

This appendix explains the process for calculating the current and three-year realization rates. The calculation of the current year realization rate is different from years 1 and 2 as an imputed operational adjustment was not necessary. This section describes the calculation of the current year realization rate, as well as the operational adjustments used for years 1 and 2, which are included in the 3-year rolling result.

1. Basic structure

We have samples for three successive periods: 1, 2, and 3. In this evaluation, these samples are 1) PY2018/19 , 2) PY2020 and 3) PY2021 . Samples 1 and 2 have non-operational results for all sites and operational results for only a subset of sites. Sample 3 has operational results for the full set of sampled sites, and so did not require any operational adjustment.

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

2. Notation

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

S_y = population tracked savings of period y

S_T = population tracked savings for all three periods combined

$= S_1 + S_2 + S_3$

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

$= S_y/S_T$

f_{g1} = fraction of Period-1 savings represented by “good” sites, ie those with operational data

= (full-sample-weighted savings of Period 1 sample sites with operational data)/(total full-sample weighted savings for Period 1)

f_{g2} = fraction of Period-2 savings represented by “good” sites, ie those with operational data

= (full-sample-weighted savings of Period 2 sample sites with operational data)/(total full-sample weighted savings for Period 2)

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

$= f_{g1}S_1 + f_{g2}S_2 + S_3$

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

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

RR_{og1} = operational-only realization rate for the population represented by good sites in the period-1 sample, those with operational data

RR_{og2} = operational-only realization rate for the population represented by good sites in the period-2 sample, those with operational data

RR_{ob1} = imputed operational-only realization rate for the population represented by bad sites in the period-1 sample, those without operational data

RR_{ob2} = imputed operational-only realization rate for the population represented by bad sites in the period-2 sample, those without operational data

SE(X) = standard error of estimate X

RSE(X) = relative standard error of estimate X

=SE(X)/X

3. Period 1 and 2 operational realization rates: RR_{o1} and RR_{o2}

- For the portion of the population represented by sampled sites with operational adjustments ("good" sites g), RR_{og1} and RR_{og2} are directly calculated from the sample, using the full sample weights w_j. That is, RR_{og1} and RR_{og2} are the weighted sum of verified gross savings, divided by the weighted sum of tracked gross savings for each year respectively.
- For sampled sites without operational adjustment ("bad" sites b), RR_{ob1} and RR_{ob2} are imputed as

  $RR_{ob1} = (f_{g\text{-}2}S_{\text{-}2}RR_{o\text{-}2} + f_{g\text{-}1}S_{\text{-}1}RR_{o\text{-}1} + f_{g1}S_1RR_{og1})/S_{(-2,-1,1)g}$ [5]

  $RR_{ob2} = (f_{g\text{-}1}S_{\text{-}1}RR_{o\text{-}1} + f_{g1}S_1RR_{og1} + f_{g2}S_2RR_{og2})/S_{(-1,1,2)g}$

  That is, all available sites with operational data from a particular year, along with two earlier years, are used to impute the RR for the uncovered portion of the period-1 and period-2 populations, with the RR from different periods weighted by the savings it represented. The specific years used to impute ops adjustments where needed for any particular year in the analysis are show in Table 5-2 below, with the year of the annual result shown horizontally, and the years used to inform the ops adjustments shown vertically. Years marked as "full sample" indicate that no ops adjustments were imputed for that particular year, while years marked as "partial sample" indicate that ops adjustment imputations were needed for some sites. For example, the imputed ops adjustment for 2019 is based on ops adjustments from sites evaluated in 2016 and those sites with ops adjustments available in 2018 and 2019.[6]

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[5] RR_{-2} and RR_{-1} denote two earlier years prior to the current 3-year rolling period which were used as part of the operational adjustments for RR_1 and RR_2. The specific years used in the calculations are shown in Table 5-2.

[6] Note that 2016, and not 2017, was used as the first year for the 2019 ops imputation because no evaluation was conducted for 2017.

Table 5-1. Ops adjustment imputation sources for each annual result

		Annual RR Results					
		2016	2017*	2018^	2019^	2020	2021
Ops Adjustment sources	2016	Full Sample		-2) Full Sample	-2) Full Sample		
	2017						
	2018			-1) Partial Sample	-1) Partial Sample	-1) Partial Sample	
	2019			1) Partial Sample	1) Partial Sample	1) Partial Sample	
	2020					2) Partial Sample	
	2021						Full Sample

*No evaluation conducted in 2017.

^The 2018 and 2019 evaluations were completed simultaneously and used the same years for ops adjustment imputation.

- Overall Operational Adjustment for Periods 1 and 2 are calculated as

$RR_{o1} = f_{g1}\, RR_{og1} + (1\text{-}f_{g1})RR_{ob1}.$

$RR_{o2} = f_{g2}\, RR_{og2} + (1\text{-}f_{g2})RR_{ob2}.$

That is, the operational adjustment for the directly represented portions of the population and the remainder are combined in proportion to their shares of period-1 and period-2 tracked savings respectively. This formulae can be expanded as

$RR_{o1} = f_{g1}\, RR_{og1} + (1\text{-}f_{g1})\,(f_{g\text{-}2}S_{\text{-}2}RR_{o\text{-}2} + f_{g\text{-}1}S_{\text{-}1}RR_{o\text{-}1} + f_{g1}S_1RR_{og1})/S_{(-2,-1,1)g}$
$= (1 + (1\text{-}f_{g1})\, S_1/S_{(-2,-1,1g)})f_{g1}RR_{og1} + (1\text{-}f_{g1})(S_{\text{-}2}/S_{(-2,-1,1g)})RR_{o\text{-}2} + (1\text{-}f_{g1})(S_{\text{-}1}/S_{(-2,-1,1g)})RR_{o\text{-}1})$
$= a_{og1}\, RR_{og1} + a_{\text{-}2}RR_{o\text{-}2} + a_{\text{-}1}RR_{o\text{-}1},$

Where

$a_{og1} = (1 + (1\text{-}f_{g1})\, S_1/S_{(-2,-1,1)g})f_{g1}$
$a_{\text{-}2} = (1\text{-}f_{g1})(S_{\text{-}2}/S_{(-2,-1,1)g})$
$a_{\text{-}1} = (1\text{-}f_{g1})(S_{\text{-}1}/S_{(-2,-1,1)g})$

$RR_{o2} = f_{g2}\, RR_{og2} + (1\text{-}f_{g2})\,(f_{g\text{-}1}S_{\text{-}1}RR_{o\text{-}1} + f_{g1}S_1RR_{o1} + f_{g2}S_2RR_{og2})/S_{(-1,1,2)g}$
$= (1 + (1\text{-}f_{g2})\, S_2/S_{(-1,1,2)g})f_{g2}RR_{og2} + (1\text{-}f_{g2})(S_{\text{-}1}/S_{(-1,1,2)g})RR_{o\text{-}1} + (1\text{-}f_{g2})(S_1/S_{(-1,1,2)g})RR_{o1})$
$= a_{og2}\, RR_{og2} + a_{\text{-}1}RR_{o\text{-}1} + a_1RR_{o1},$

Where

$a_{og2} = (1 + (1\text{-}f_{g2})\, S_2/S_{(-1,1,2)g})f_{g2}$
$a_{\text{-}1} = (1\text{-}f_{g2})(S_{\text{-}1}/S_{(-1,1,2)g})$
$a_1 = (1\text{-}f_{g2})(S_1/S_{(-1,1,2)g})$

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

$a_{og1} + a_{-2} + a_{-1} = 1$ for period 1

and

$a_{og2} + a_{-1} + a_{1} = 1$ for period 2

- Standard error of Period 1 and Period 2 realization rates: The standard error is calculated from the individual standard errors as

  $SE(RR_{o1}) = sqrt[a_{og1}^2\ SE^2(RR_{og1}) + a_{-2}^2\ SE^2(RR_{o-2}) + a_{-1}^2\ SE^2(RR_{o-1})]$

  $SE(RR_{o1}) = sqrt[a_{og2}^2\ SE^2(RR_{og2}) + a_{-1}^2\ SE^2(RR_{o-1}) + a_{1}^2\ SE^2(RR_{o1})]$

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

4. Period 3 combined RR

1. **The operation and non-operational realization rates** RR_{N3} and RR_{O3} are calculated from the full sample using the full sample weights and the non-operational and operational adjusted savings for the sample, via the usual formulas.

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

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

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

   This formula is approximately correct, assuming that even though RR_{o3} and RR_{N3} are from a common sample, they are essentially unrelated so can be treated as independent.

   The standard error is then calculated from the RSE.
   b. $SE(RR_3) = RR_3\ RSE(RR_3)$

5. Three-year combined RR

Preferred calculation

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

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

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

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

SE calculation

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

Alternative RR calculation for SE calculation only

4. 3-year operational realization rate
   $RR_{o1-3} = q_1 RR_{o1} + q_2 RR_{o2} + q_3 RR_{o3}$
5. 3-year non-operational realization rate
   $RR_{N1-3} = q_1 RR_{N1} + q_2 RR_{N2} + q_3 RR_{N3}$
6. Combined 3-year realization rate
   $RR_{1-3} = RR_{o1-3} \; RR_{N1-3}$

Standard error calculations for the alternative RR calculation

Non-operational three-period realization rate SE

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

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

Operational three-period realization rate SE

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

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

$= ((a_{-2}\, q_1)\, RR_{o-2} + (a_{-1}\, q_1)\, RR_{o-1} + q_1 a_{og1} RR_{og1}) + ((a_{-1}\, q_2)\, RR_{o-1} + (a_1\, q_2)\, RR_{o1} + q_2 a_{og2} RR_{og2}) + q_3 RR_{o3}$

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

$SE(RR_{o1\text{-}3}) = sqrt[((a_{-2}\, q_1)\, RR_{o\text{-}2} + (a_{-1}\, q_1)\, RR_{o\text{-}1} + q_1 a_{og1})^2\, SE^2(RR_{O1}) + ((a_{-1}\, q_2)\, RR_{o\text{-}1} + (a_1\, q_2)\, RR_{o1} + q_2 a_{og2})^2\, SE^2(RR_{O2}) + (q_3)^2\, SE^2(RR_{O3})]$.

Relative standard error of overall three-period realization rate

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

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

Standard error of the three-year realization rate

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

Level of aggregation for applying the formulas

Calculating Period 3 and three-period realization rates

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

APPENDIX D. LIFETIME SAVINGS ADJUSTMENT FACTORS (LSAFS) METHODOLOGY

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

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

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

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

where:

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

w_i = site weight

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

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

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

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

where:

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

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

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

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

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

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

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

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

where:

$LSRR\%$ = program lifetime savings realization rate

w_i = site weight

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

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

$EUL_i^{Tracking}$ = tracking measure life

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

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

where:

$LSAF$ = lifetime savings adjustment factor

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

$LSRR\%$ = program lifetime savings realization rate

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

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

where:

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

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

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

$RR\%$ = program realization rate

$LSAF$ = lifetime savings adjustment factor

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

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

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

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

Where,

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

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

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

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

As mentioned before, PA calculated LMC adjustment factors should be applied to the published lighting LSAF in Appendix E.

APPENDIX E. SITE REPORTS

Reports will be added to the PDF version of this report upon finalization.

RICE21N149_S

Report Date: 11/29/2023

Program Administrator	RI Energy
Application ID(s)	12106805
Project Type	New Construction
Evaluation Type	Ops
Program Year	2021
Evaluation Firm	DNV
Evaluation Engineer	Matthew Piana
Senior Engineer	George Sorin Ioan

1 EVALUATED SITE SUMMARY AND RESULTS

The evaluated project consists of three packaged RTUs that were installed as part of a new building construction project. The newly constructed building is a food processing facility. The measure saves energy because the as-built units use less energy than units that meet the minimum standards defined by code. The first year tracked savings for this measure were 5,752 kWh. No heating savings were claimed as part of this project.

The applicant used eQUEST modelling software to estimate savings. The applicant determined the baseline energy consumption of the RTUs to be defined by EER values outlined in IECC 2015.

During the meter installation visit, evaluators located the three RTUs listed in the project files (labeled as RTU-2, RTU-3, and RTU-4). The RTUs provide cooling and ventilation to the following spaces: RTU-2 1st floor offices, RTU-3 facility cafeteria, RTU-4 2nd floor offices. Evaluators documented their nameplates and installed DENT power loggers in the electric panel to monitor their power consumption and operation.

Evaluators calculated the measure savings for this application using an 8,760 spreadsheet-based analysis. Each RTU was modeled differently in the 8,760 analysis according to their observed operation through metered data. Further details on the modeling of the RTUs is presented in Section 2.3.2.

The applicant classified the project as a new construction project and with an industry standard practice (ISP) baseline based on IECC 2015. The evaluators classified the measure as a lost opportunity with a code-compliant baseline as defined by the Rhode Island Energy Code that was in place at the time of planning for this project (ASHRAE Standard 90.1-2007).

The site contact indicated that the site's operations were not changed since the project's completion and will remain the same in the future, without any impacts from Covid-19. The site contact was also willing to participate in a site visit. Therefore, the evaluators adopted the full M&V approach. Table 1-1 provides a summary of the evaluation results.

Table 1-1. Evaluation results summary

PA Application ID	Measure Name		Annual Electric Energy (kWh)	% Of Energy Savings On-Peak	Summer On-Peak Demand (kW)	Winter On-Peak Demand (kW)
12106805	High-performance RTUs	Tracked	5,752	52%	1.23	0
		Evaluated	15,196	53%	4.91	0
		Realization Rate	264%	103%	399%	N/A

N/A = Not applicable

1.1 Explanation of Deviations from Tracking

The evaluated savings are more than the applicant-reported savings primarily due to the difference in calculation approach between the applicant and evaluators. Further details regarding deviations from the tracked savings are presented in Section 3.1.

1.2 Recommendations for Program Designers & Implementers

There are no recommendations at this time.

1.3 Customer Alert

There is no relevant customer alert.

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 evaluated project consisted of the installation of three high-performance RTUs.

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.

2.1.1 Applicant Description of Baseline

The applicant classified the project as new construction with an ISP baseline for the three RTUs as defined by IECC 2015. Although the applicant defined the baseline from IECC 2015, evaluators found the relevant code to be defined by the Rhode Island Energy Code which stated that code was ASHRAE Standard 90.1-2007 at the time of project install. Table 2-1 provides a summary of the applicant's baseline parameters. The highlighted rows are the RTUs evaluated as part of this project. Table 2-2 presents the baseline EER values the applicant used for each RTU.

Table 2-1. Applicant baseline summary

	HVAC System Name	HVAC System Type	Cool Capacity (Btu/h)	Cool SH Capacity (Btu/h)	Heat Capacity (Btu/h)	Supply cfm (cfm)	Supply kW/cfm (kW/cfm)	Return Path	Sizing Ratio (ratio)	Sizing Option	Control Zone	Min Supply T (°F)	Max Supply T (°F)	Minimum OA (ratio)	Cooling EIR (Btu/Btu)
1	Shpg Office	Pkgd Single Zone	36,000			1,000	n/a	Duct	1.15	Non Coincident	EL1 East Perim Zn (	55.0	120.0	0.07	0.36
2	Offices 1st	Pkgd Var Vol Var Temp	370,000	280,000	-540,000	12,000	0.001242	Direct	1.00	Non Coincident	EL2 West Perim Zn	55.0	120.0	0.40	0.28
3	Offices 2nd	Pkgd Var Vol Var Temp	560,000	458,000	-540,000	18,000	0.000829	Direct	1.00	Non Coincident	EL3 WSW Perim Zn	55.0	120.0	0.10	0.27
4	Value Added Line+38-R109	Pkgd Var Vol Var Temp	881,264		n/a	33,100	0.000120	Direct	1.00	Non Coincident	EL1 South Perim Zr	25.0	105.0		0.35
5	Value Added Packing+38-R110	Pkgd Var Vol Var Temp	602,197		n/a	33,100	0.000120	Direct	1.15	Non Coincident	EL1 South Perim Zr	25.0	105.0		0.35
6	Finished Goods+33-R112	Pkgd Var Vol Var Temp	1,224,000		n/a	132,400	0.000090	Direct	1.15	Non Coincident	EL1 South Perim Zr	23.0	105.0		0.35
7	Shipping Dock+33-R113	Pkgd Var Vol Var Temp	816,000		n/a	129,500	0.000086	Direct	1.15	Non Coincident	EL1 ESE Perim Zn (	23.0	105.0		0.35
8	Receiving Dock+33-R101	Pkgd Var Vol Var Temp	528,000		n/a	66,000	0.000091	Direct	1.00	Non Coincident	EL1 West Perim Zn	23.0	105.0		0.35
9	Raw Goods+33-R104	Pkgd Var Vol Var Temp	720,000		n/a	117,500	0.000095	Direct	1.00	Non Coincident	EL1 Core Zn (G.C1	23.0	105.0		0.35
10	DeBoxing+33-R105	Pkgd Var Vol Var Temp	288,000		-400,000	47,000	0.000095	Duct	1.00	Non Coincident	EL1 Core Zn (G.C1	23.0	105.0		0.35
11	Main Process Line+38-R106	Pkgd Var Vol Var Temp	5,664,000		n/a	390,000	0.000120	Direct	1.00	Non Coincident	EL1 Core Zn (G.C2	23.0	105.0		0.35
12	Packing+38-R111	Pkgd Var Vol Var Temp	4,458,240		n/a	237,000	0.000425	Direct	1.00	Non Coincident	EL1 North Perim Zn	23.0	105.0		0.35
13	P103	Unit Heater	n/a	n/a	-1,560,000	n/a	n/a	n/a	1.15	n/a	n/a	n/a	120.0	n/a	n/a
14	P108	Unit Heater	n/a	n/a	-307,080	n/a	n/a	n/a	1.15	n/a	n/a	n/a	120.0	n/a	n/a
15	P119	Pkgd Single Zone			-1,800,000	25,000	n/a	Duct	1.15	Non Coincident	EL1 NNE Perim Zn (	55.0	120.0	0.20	0.36
16	U103	Pkgd Single Zone					n/a	Duct	1.15	Non Coincident	EL1 NE Perim Zn (G	55.0	120.0	0.05	0.36
17	U105	Unit Heater	n/a	n/a	-400,000	n/a	n/a	n/a	1.15	n/a	n/a	n/a	120.0	n/a	n/a
18	U108	Pkgd Single Zone					n/a	Duct	1.15	Non Coincident	EL1 North Perim Zn	55.0	120.0	0.05	0.26
19	U109	Pkgd Single Zone					n/a	Duct	1.15	Non Coincident	EL1 NW Perim Zn (	55.0	120.0	0.05	0.26
20	U104	Unit Heater	n/a	n/a	-150,000	n/a	n/a	n/a	1.15	n/a	n/a	n/a	120.0	n/a	n/a
21	P102	Unit Heater	n/a	n/a	-68,240	n/a	n/a	n/a	1.15	n/a	n/a	n/a	120.0	n/a	n/a
22	Blast Tunnel P107 -45F	Pkgd Var Vol Var Temp			n/a		0.000120	Direct	1.00	Non Coincident	EL1 Core Zn (G.C1	-40.0	105.0		0.35
23	UnCond	Pkgd Single Zone			n/a		0.000587	Plenum Zones	1.00	Non Coincident	EL3 North Perim Zn	55.0	105.0		0.36
24	Cafe 1st	Pkgd Var Vol	348,000	242,000	-270,000	8,300	0.000760	Duct	1.00	Non Coincident	n/a	55.0	120.0	0.37	0.29
25	Cafe 2nd	Pkgd Var Vol					n/a	Duct	1.15	Non Coincident	n/a	55.0	120.0		0.26
26	Rcv Office	Pkgd Single Zone	36,000			1,000	n/a	Duct	1.00	Non Coincident	EL1 West Perim Zn	55.0	120.0	0.07	0.26

Table 2-2. Applicant baseline case key parameters

Measure/Application#	Parameter	Value(s)	HVAC System Name	Source of Parameter Value
12106805	RTU-2 EER	10.0	Offices 1st floor	IECC 2015
12106805	RTU-3 EER	11.0	Cafeteria 1st floor	IECC 2015
12106805	RTU-4 EER	10.0	Offices 2nd floor	IECC 2015

2.1.2 Applicant Description of Installed Equipment and Operation

The applicant described the installed equipment as three high-performance RTUs. Table 2-3 provides a summary of the applicant's installed equipment parameters.

Table 2-3. Application proposed case key parameters

Measure	Parameter	Value(s)	HVAC System Name	Source of Parameter Value
12106805	RTU-2 EER	10.7	Offices 1st floor	RTU-2 spec sheet
12106805	RTU-3 EER	12.3	Cafeteria 1st floor	RTU-3 spec sheet
12106805	RTU-4 EER	11.2	Offices 2nd floor	RTU-4 spec sheet

2.1.3 Applicant Energy Savings Algorithm

The applicant used eQUEST modelling to quantify the measure savings for this project. The applicant eQUEST model was informed by the findings of an on-site audit. The findings included a mechanical schedule from the as-built drawing, a variety of building inputs including the operation of refrigeration systems, complex building geometry, lighting systems, and HVAC systems. All of these systems were used in the eQUEST model to estimate energy savings.

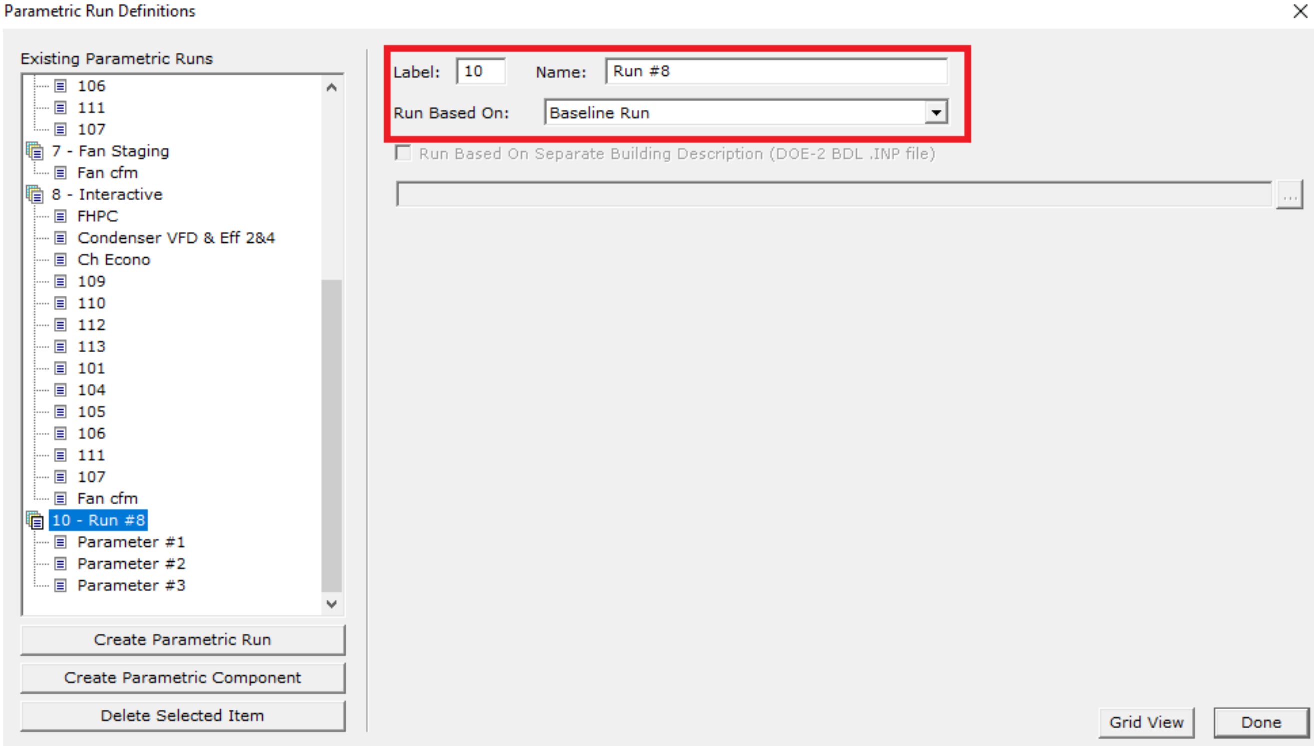
Figure 2-1 shows a screenshot with a key input parameter comparison between the baseline and as-built models (Run #8) from the parametric run in eQUEST. The rest of the runs were not used. The simulation logic is shown in Figure 2-2 below.

Figure 2-1 Applicant savings calculation eQUEST

Parametric Runs Comparison Listing

Component	Reference(s)	Keyword	Array Idx	Baseline	FHPC	VFD & Eff C...	Econo Chiller	Defrost	Fan Staging	Interactive	Run #8
Refrigeration System	Ref Sys All	SCT-CTRL	N/A	FIXED	WETBULB-R...	FIXED	FIXED	FIXED	FIXED	WETBULB-R...	FIXED
Refrigeration System	Ref Sys All	OVERRIDE-MIN-SCT	N/A	85.000	65.000	85.000	85.000	85.000	85.000	65.000	85.000
Refrigeration System	Ref Sys All	OVERRIDE-MAX-SCT	N/A		95.000					95.000	
Refrigeration System	Ref Sys All	BACKFLOOD-SETPT	N/A	83.000	68.000	83.000	83.000	83.000	83.000	68.000	83.000
Refrigeration System	Ref Sys All	SCT-AMBIENT-DT	N/A	17.000	17.000	17.000	17.000	17.000	17.000	17.000	17.000
Condenser	Evap Cond-1(1 of 3)	CAPACITY-CTRL	N/A	TWO-SPEE...	TWO-SPEED...	VAR-SPEED-...	TWO-SPEED...	TWO-SPEED...	TWO-SPEED...	VAR-SPEED-...	TWO-SPEED...
Condenser	Evap Cond-1(1 of 3)	FAN-KW-FAIRFLOW	N/A			Htrej-Fan-P...				Htrej-Fan-P...	
Condenser	Evap Cond-1(1 of 3)	KW/FAN	N/A	37.000	37.000	26.365	37.000	37.000	37.000	26.365	37.000
Compressor	C-3(1 of 4)	COEF-OF-PERFORM	N/A	4.600	4.600	4.600	4.750	4.600	4.600	4.750	4.600
Space	109 Value Added Line +38F	EQUIPMENT-KW	2	28.000	28.000	28.000	28.000	0.000	28.000	0.000	28.000
Space	110 Value Added Packing +38F	EQUIPMENT-KW	2	19.000	19.000	19.000	19.000	0.000	19.000	0.000	19.000
Space	112 Finished goods +33F	EQUIPMENT-KW	2	39.000	39.000	39.000	39.000	0.000	39.000	0.000	39.000
Space	113 Shipping dock +33F	EQUIPMENT-KW	2	26.000	26.000	26.000	26.000	0.000	26.000	0.000	26.000
Space	101 Receiving dock +33F	EQUIPMENT-KW	2	17.000	17.000	17.000	17.000	0.000	17.000	0.000	17.000
Space	104 Raw goods +33F	EQUIPMENT-KW	2	23.000	23.000	23.000	23.000	0.000	23.000	0.000	23.000
Space	105 DeBoxing +33F	EQUIPMENT-KW	2	9.000	9.000	9.000	9.000	0.000	9.000	0.000	9.000
Space	106 Main Processing +38F	EQUIPMENT-KW	2	182.000	182.000	182.000	182.000	0.000	182.000	0.000	182.000
Space	111 Packing +38F	EQUIPMENT-KW	2	143.000	143.000	143.000	143.000	0.000	143.000	0.000	143.000
Space	107 Freez Tunnels -45F	EQUIPMENT-KW	2	33.000	33.000	33.000	33.000	0.000	33.000	0.000	33.000
HVAC System	Packing+38-R111	SUPPLY-FLOW	N/A	237,000.000	237,000.000	237,000.000	237,000.000	237,000.000	195,236.000	195,236.000	237,000.000
HVAC System	Offices 1st	COOLING-EIR	N/A	0.278	0.278	0.278	0.278	0.278	0.278	0.278	0.254
HVAC System	Offices 2nd	COOLING-EIR	N/A	0.267	0.267	0.267	0.267	0.267	0.267	0.267	0.233
HVAC System	Cafe 1st	COOLING-EIR	N/A	0.286	0.286	0.286	0.286	0.286	0.286	0.286	0.228

Figure 2-2 Simulation logic in eQUEST



2.1.4 Evaluation Assessment of Applicant Methodology

The evaluators determined the overall applicant savings methodology to be appropriate. However, evaluators found the selected baseline equipment to be inappropriate due to the incorrect code selected by the applicant. It is also unclear to evaluators how the applicant calculated on-peak kW reductions. Though the applicant model is technically valid, there is some question as to whether an eQUEST model is warranted for such a small project when other more simplified methods for savings calculations are available and approved.

2.2 On-Site Inspection and Metering

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

Evaluators visited the site on March 8th, 2023 to inspect the installed RTUs, install power monitoring devices to determine their energy consumptions, and interview the site contact on the project details. Table 2-4 provides a summary of the on-site verification.

Table 2-4. Measure verification

Measure Name	Verification Method	Verification Result
12106805	Visual verification and metering	Evaluators documented the nameplate information of the three RTUs that were installed and verified that the installed models matched the project documentation. Evaluators installed DENT power loggers in the electrical panel to monitor their operation.

Photo 2-1 depicts the nameplate information for RTU-2 gathered by evaluators while on site.

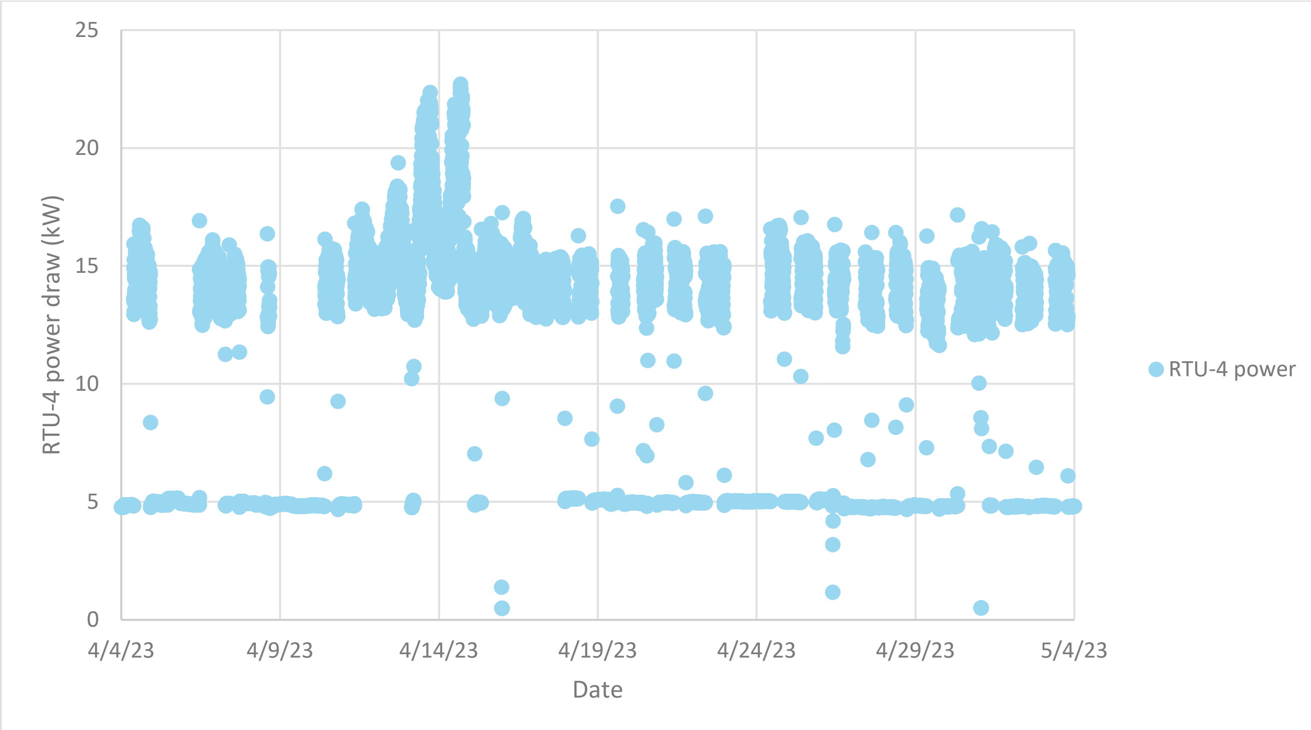
Photo 2-1 Nameplate RTU-2

The evaluator’s metering for this site included:

1. One DENT power logger was installed for each of the three RTUs. The loggers measured active power data in 5-min intervals until their removal on and May 7th, 2023, for a total of 9 weeks of data.
2. Evaluators also installed (3) temperature and relative humidity sensors in the spaces served by each of the three RTUs.

The power loggers deployed to monitor the operation of the 3 RTUs recorded good data. Figure 2-3 provides an sample of the kW power data measured for RTU-4.

Figure 2-3 One month of kW power data for RTU-4 4/4/23 – 5/4/23



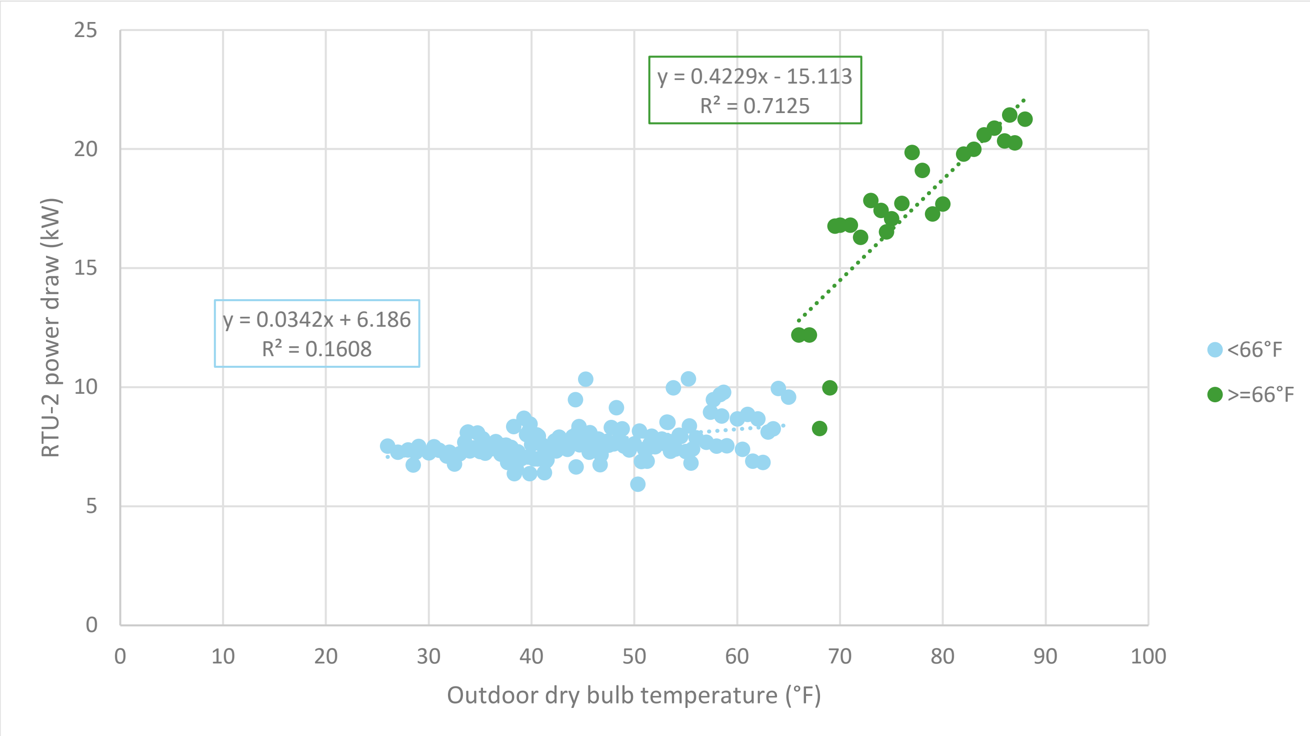
Evaluators analyzed the data for each RTU and found that each RTU was operating differently in relation to outdoor air temperature (OAT). Because of this, evaluators modelled the behavior of each RTU separately in the 8,760 analysis according to their respective metered data. For RTU-3, evaluators developed a daily, hourly operational profile because the unit's operation did not show any correlation with OAT. Figure 2-4 below shows the daily, hourly kW vales for RTU-3.

Figure 2-4 Daily, hourly kW operational profile of RTU-3

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Sunday	6.72	6.78	6.48	6.18	6.57	7.07	6.95	7.62	7.10	7.64	7.46	7.15	6.58	6.37	6.41	6.20	6.17	6.04	6.00	5.95	6.04	6.62	6.50	6.16
Monday	7.31	6.11	7.06	6.56	5.95	5.94	5.95	5.94	5.90	5.86	5.90	5.95	5.84	5.85	5.85	5.84	5.84	5.83	5.85	5.84	5.87	5.89	6.00	6.01
Tuesday	6.05	6.06	6.03	6.07	5.93	5.89	5.91	5.90	5.87	5.86	5.84	5.82	5.82	5.82	5.92	5.95	6.21	6.43	6.01	5.94	5.86	5.96	6.84	7.07
Wednesday	7.08	6.37	6.74	6.83	5.98	6.32	6.19	6.29	6.69	6.56	6.37	6.20	6.55	6.31	6.34	6.33	6.12	5.99	6.01	5.96	5.93	5.96	6.44	6.09
Thursday	6.19	6.83	6.28	6.58	6.09	5.97	6.01	6.15	6.30	6.08	6.26	6.54	6.47	6.51	6.26	6.27	6.31	6.16	6.22	5.90	6.16	5.88	5.92	5.98
Friday	6.05	6.12	6.76	6.70	6.15	5.90	5.92	5.92	6.02	6.38	6.28	6.47	6.38	6.44	6.71	6.39	6.82	6.18	6.03	5.86	5.88	5.89	5.88	6.67
Saturday	6.80	6.66	6.38	6.78	6.18	5.90	5.91	5.90	6.06	5.91	5.93	6.02	5.88	5.88	5.86	5.84	5.92	5.82	5.83	5.84	6.17	6.67	6.58	6.40

Evaluators found through analyzing the data for RTU-2 and RTU-4 that the operation of both units showed strong correlation with OAT. Because of this, evaluators developed kW vs. OAT regressions for RTU-2 and RTU-4. The behavior of RTU-2 was broken down into two separate regressions: kW vs. OAT for temperatures less than 66°F and kW vs. OAT for temperatures greater than or equal to 66°F. Evaluators observed through metered data that at an OAT of 66°F, RTU-2 begins to operate at higher kW values. For this reason, evaluators chose 66°F as the threshold value between the two regressions. Figure 2-5 below shows the two regressions evaluators developed for RTU-2 based on metered data. Only the regression for temperatures 66°F and above was used in the 8,760 analysis because that is the regression corresponding to temperatures where RTU-2 is providing cooling and therefore saving energy compared to the baseline.

Figure 2-5 kW vs. OAT regressions for RTU-2



For RTU-4 evaluators observed a schedule of operation (day, 10AM-8PM vs. night, 8PM-10AM) as well as a kW vs. OAT correlation. Evaluators observed through metered data that at an OAT of 55°F, RTU-4 begins to operate at higher kW values. For this reason, evaluators chose 55°F as the threshold value between the two regressions. Figure 2-6 below shows the day vs. night schedule of operation for RTU-4.

Figure 2-6 Daily, hourly kW operational profile of RTU-4

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Sunday	5.94	5.97	5.98	5.97	5.95	5.90	5.86	6.13	7.16	7.20	7.19	8.11	8.49	8.53	9.22	9.88	9.80	8.75	8.53	8.42	8.33	8.08	7.14	7.10
Monday	7.12	6.23	7.11	7.13	7.10	7.10	7.10	6.81	5.81	6.64	9.89	11.06	11.26	11.23	11.17	11.24	10.57	10.21	10.12	9.63	7.64	5.89	5.89	4.76
Tuesday	4.65	4.65	4.66	4.65	4.66	4.66	4.65	4.65	6.13	9.37	11.34	11.72	11.46	10.72	11.87	11.82	11.80	11.72	11.59	9.20	7.95	6.97	5.89	5.85
Wednesday	5.88	5.85	5.87	5.87	5.86	5.84	5.80	5.84	5.88	6.47	7.65	8.75	9.51	11.17	10.29	11.48	11.37	10.13	9.43	6.27	5.92	5.87	5.82	5.80
Thursday	5.76	5.74	5.71	5.02	4.61	5.61	5.71	5.74	5.82	6.06	8.21	10.56	9.79	9.29	11.66	11.82	11.07	11.11	10.78	9.08	7.75	7.21	7.46	8.15
Friday	8.08	8.05	7.65	7.01	6.98	6.96	6.59	5.93	6.03	9.46	10.95	11.13	11.17	12.15	11.94	12.35	12.24	10.31	8.03	7.07	6.71	5.81	5.81	5.80
Saturday	5.77	5.77	5.56	4.62	4.63	4.61	4.61	5.14	7.65	9.06	9.34	9.45	10.46	10.68	12.47	12.75	11.75	11.47	10.11	9.42	8.78	8.14	8.17	6.71

For this reason, evaluators broke down the operation of RTU-4 into four separate regressions:

- 10AM to 8PM, OAT <55°F (day-1)
- 10AM to 8PM, OAT ≥55°F (day-2)
- 8PM to 10AM, OAT <55°F (night-1)
- 8PM to 10AM, OAT ≥55°F (night-2)

Evaluators only used the day-2 and night-2 regressions to calculate savings in the 8,760 analysis because those are the regressions corresponding to temperatures where RTU-4 is providing cooling and therefore saving energy compared to the baseline. Figure 2-7 and Figure 2-8 below show the day and night regressions evaluators developed for RTU-4.

Figure 2-7 kW vs. OAT day regressions for RTU-4

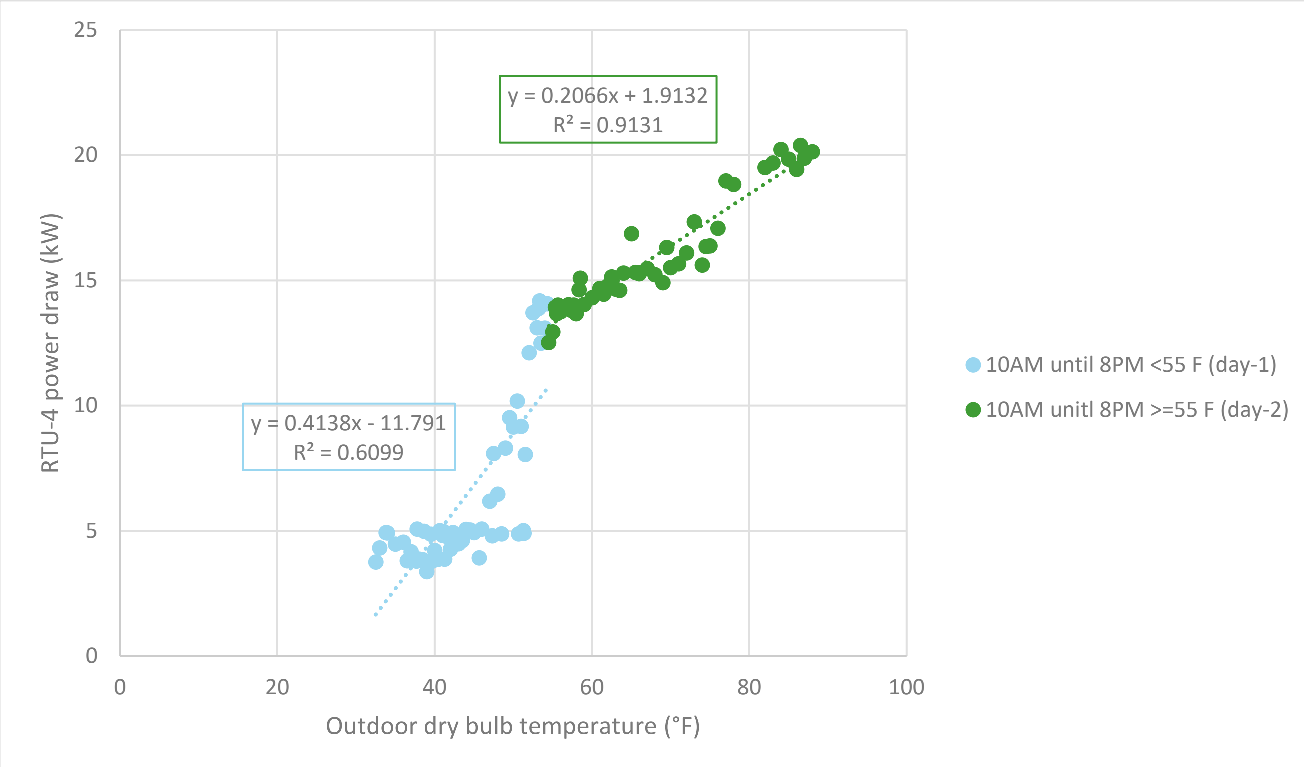
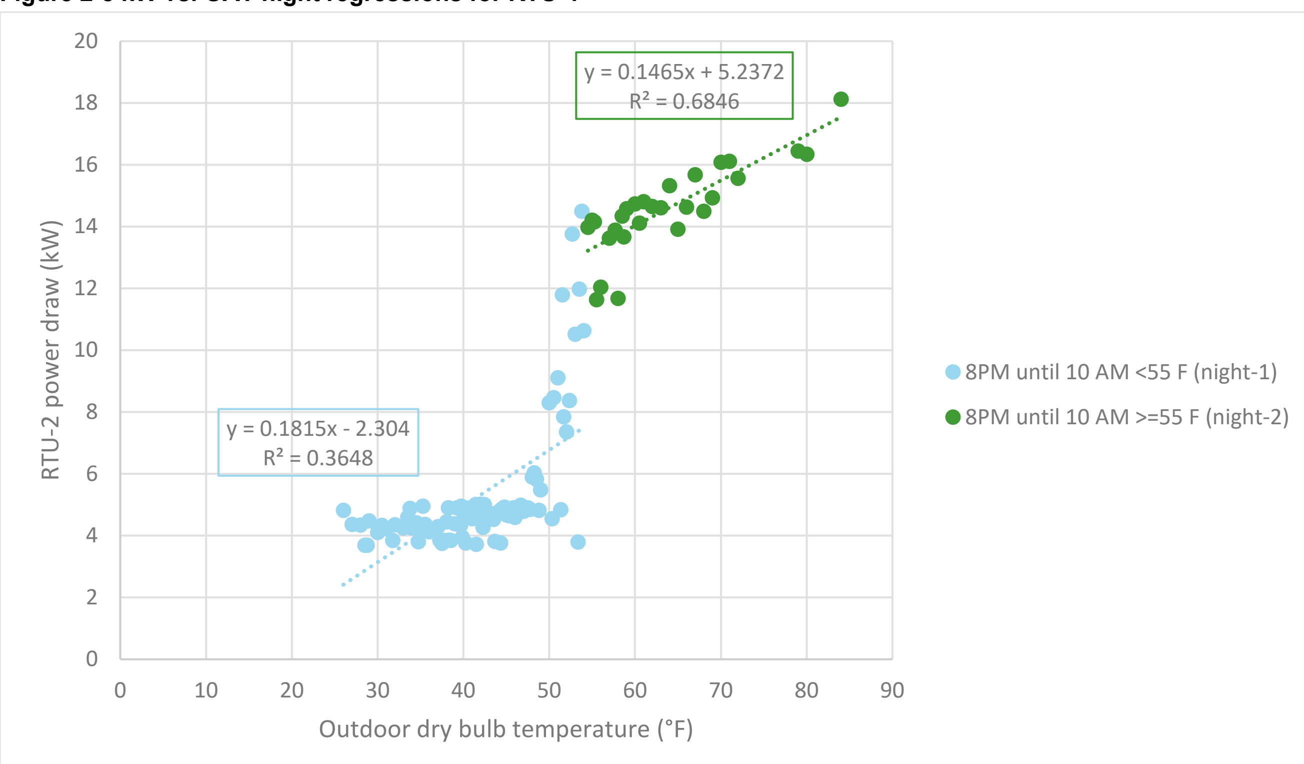


Figure 2-8 kW vs. OAT night regressions for RTU-4



Evaluators observed OAT temperatures ranging from 26°F to 88°F during the metering period from March 8th to May 7th, 2023. Evaluators used Providence TMY3 data in the 8,760 analysis in order to apply the developed kW vs. OAT regressions for RTU-2 and RTU-4. In the Providence TMY3 data there are 71 hours or 2.96 days where temperatures exceed 88°F. Evaluators also applied the kW vs. OAT regressions to these 2.96 days of temperatures exceeding 88°F and assumed that the developed regressions were valid for those temperatures.

2.3 Evaluation Methods and Findings

This section describes the evaluator methods and findings.

2.3.1 Evaluation Description of Baseline

The evaluators classified the measure as a lost opportunity with a code-compliant baseline as defined by the RI Energy Code that was in place at the time of planning for this project (ASHRAE Standard 90.1-2007). The evaluated baseline is different than the baseline used by the applicant (IECC 2015). Table 2-5 shows the key evaluator baseline parameters.

Table 2-5. Evaluator baseline key parameters

Parameter	Value(s)	Source of parameter value
RTU-2 EER	9.8	ASHRAE Standard 90.1-2007, Table 6.8.1A
RTU-3 EER	10.8	ASHRAE Standard 90.1-2007, Table 6.8.1A
RTU-4 EER	9.8	ASHRAE Standard 90.1-2007, Table 6.8.1A

2.3.2 Evaluation Calculation Method

The evaluators calculated the measure savings using an 8,760 spreadsheet-based analysis. For RTU-3 evaluators used metered data to develop a weekly, hourly kW power draw operating profile (presented in Figure 2-4). For RTU-2 and RTU-4, evaluators developed kW-OAT regressions (RTU-2: Figure 2-5, RTU-4: Figure 2-7, Figure 2-8) based on metered data. Evaluators then applied these regressions according to TMY3 temperature data to determine the operation of these two RTUs according to OAT. Based on the observed operation of the RTUs, evaluators determined that if the OAT is below 55°F, no savings take place for RTU-3 and RTU-4, and if the OAT is below 66°F, no savings take place for RTU-2. No savings take place for any of the RTUs outside of the cooling season that was defined based the interview with the site contact. Evaluators calculated summer on-peak kW savings by averaging the kW savings for the three RTUs during the relevant time frames. Table 2-6 below shows the key values used by evaluators in the 8,760-analysis.

Table 2-6. Evaluator analysis key parameters

Parameter	Value(s)	Source of parameter value
Cooling start date	April 15th	Site contact
Cooling end date	October 1st	Site contact
RTU-2 EER	10.7	RTU-2 spec sheet
RTU-2 baseline EER	9.8	ASHRAE Standard 90.1-2007, Table 6.8.1A
RTU-3 EER	12.3	RTU-3 spec sheet
RTU-3 baseline EER	10.8	ASHRAE Standard 90.1-2007, Table 6.8.1A
RTU-4 EER	11.2	RTU-4 spec sheet
RTU-4 baseline EER	9.8	ASHRAE Standard 90.1-2007, Table 6.8.1A

Evaluators used the following algorithm to calculate the baseline power draw of each RTU according to metered data and EER values:

$$kW_{Baseline} = kW_{as-built} \times \frac{EER_{as-built}}{EER_{baseline}}$$

Evaluators then summed the energy usage over 8,760 hours for all three as-built RTUs and subtracted their energy usage from the usage of the three baseline RTUs in order to determine the savings for this measure:

$$kW_{Baseline} = \sum_{1}^{8760} kW_{baseline} - \sum_{1}^{8760} kW_{as-built}$$

3 FINAL RESULTS

The evaluated project consists of three RTUs. The three RTUs were installed as part of a new building construction project. The measure saves energy because the as-built units use less energy than the minimum standards defined by code.

The applicant used an eQUEST simulation to calculate the measure savings for this project. The evaluator used an 8,760 spreadsheet-based analysis to calculate the savings, utilizing metered data in addition to spec sheets and ASHRAE code. The evaluated savings are more than the reported savings. The key parameters that impact the analysis are summarized in Table 3-1.

Table 3-1. Summary of key parameters

Parameter	BASELINE		PROPOSED / INSTALLED	
	Tracking Value(s)	Evaluation Value(s)	Tracking Value(s)	Evaluation Value(s)
RTU kWh (proxy for cooling load)	52,600	135,266	46,900	120,070
RTU-2 EER	10.0	9.8	10.7	10.7
RTU-3 EER	11.0	10.8	12.3	12.3
RTU-4 EER	10.0	9.8	11.2	11.2

3.1 Explanation of Differences

The applicant simulated the monthly consumption for each of the three RTUs in eQUEST. The resulting cooling loads for RTU-2, RTU-3, and RTU-4 are shown in Figure 3-1, Figure 3-2, and Figure 3-3 below, respectively.

Figure 3-1 eQUEST simulation output RTU-2

S&S D4

REPORT- SS-A System Loads Summary for Offices 1st

MONTH	COOLING ENERGY (MBTU)	TIME OF MAX DY	TIME OF MAX HR	DRY-BULB TEMP	WET-BULB TEMP	MAXIMUM COOLING LOAD (KBTU/HR)
JAN	0.00000	31	24	31.F	29.F	0.000
FEB	0.01524	22	15	56.F	46.F	5.396
MAR	0.29686	6	13	58.F	56.F	20.450
APR	1.70627	25	15	65.F	46.F	44.120
MAY	26.40765	31	16	91.F	74.F	228.257
JUN	46.75968	17	16	78.F	72.F	193.720
JUL	90.78527	19	14	89.F	79.F	280.837
AUG	82.41538	15	12	89.F	81.F	301.820
SEP	50.18031	5	15	87.F	75.F	236.533
OCT	15.35392	1	7	74.F	71.F	162.664
NOV	1.48039	18	3	62.F	62.F	68.340
DEC	0.27314	2	5	62.F	62.F	62.863
TOTAL	315.674					
MAX						301.820

Figure 3-2 eQUEST simulation output RTU-3

S&S D4

REPORT- SS-A System Loads Summary for Cafe 1st

MONTH	COOLING ENERGY (MBTU)	TIME OF MAX DY	TIME OF MAX HR	DRY-BULB TEMP	WET-BULB TEMP	MAXIMUM COOLING LOAD (KBTU/HR)
JAN	0.00000	31	24	31.F	29.F	0.000
FEB	0.12892	24	14	70.F	57.F	15.845
MAR	0.15688	2	14	62.F	54.F	8.513
APR	0.96863	27	14	70.F	53.F	15.943
MAY	8.42860	31	16	91.F	74.F	75.077
JUN	15.78592	9	18	88.F	76.F	62.986
JUL	30.63858	19	14	89.F	79.F	98.368
AUG	28.01237	15	12	89.F	81.F	105.922
SEP	17.03399	5	15	87.F	75.F	78.523
OCT	5.00544	4	13	77.F	67.F	48.529
NOV	0.71145	18	5	63.F	62.F	22.573
DEC	0.08970	2	5	62.F	62.F	22.411
TOTAL	106.961					
MAX						105.922

Figure 3-3 eQUEST simulation output RTU-4

```
S&S D4

REPORT- SS-A System Loads Summary for       Offices 2nd
---------------------------------------------------------


       - - - - - - - - C O O L I N G - - - - - - - -

                                                  MAXIMUM
         COOLING     TIME   DRY-   WET-           COOLING
          ENERGY   OF MAX   BULB   BULB              LOAD
MONTH     (MBTU)   DY  HR   TEMP   TEMP        (KBTU/HR)


JAN      0.00000   31  24   31.F   29.F           0.000

FEB      0.04252   25   5   60.F   52.F          10.623

MAR      0.25821    6  16   58.F   56.F          18.831

APR      1.53204   25  15   65.F   46.F          46.892

MAY     23.06074   31  18   87.F   74.F         185.200

JUN     39.26491   17  16   78.F   72.F         158.017

JUL     74.38918   19  17   91.F   78.F         219.119

AUG     68.84770   15  12   89.F   81.F         232.288

SEP     42.60970    4  18   81.F   76.F         190.494

OCT     13.39927    1   7   74.F   71.F         136.577

NOV      1.29513   18  10   65.F   62.F          59.747

DEC      0.16292    2   5   62.F   62.F          42.797
       ---------                             ----------

TOTAL    264.863

MAX                                             232.288
```

Evaluators found based on metered data that RTU operation, which is a proxy for cooling load, presented in Figure 3-1, Figure 3-2, and Figure 3-3 were underestimated by the applicant. Figure 3-4 below presents the approximate kWh usage of all three RTUs (RTU-2, RTU-3, and RTU-4) in both the applicant and evaluator baseline and as-built scenarios. Figure 3-4 illustrates the difference in kWh estimated by the applicant versus the kWh measured by evaluators.

Figure 3-4 Estimated kWh usage of all three RTUs, applicant and evaluator as-built and baseline

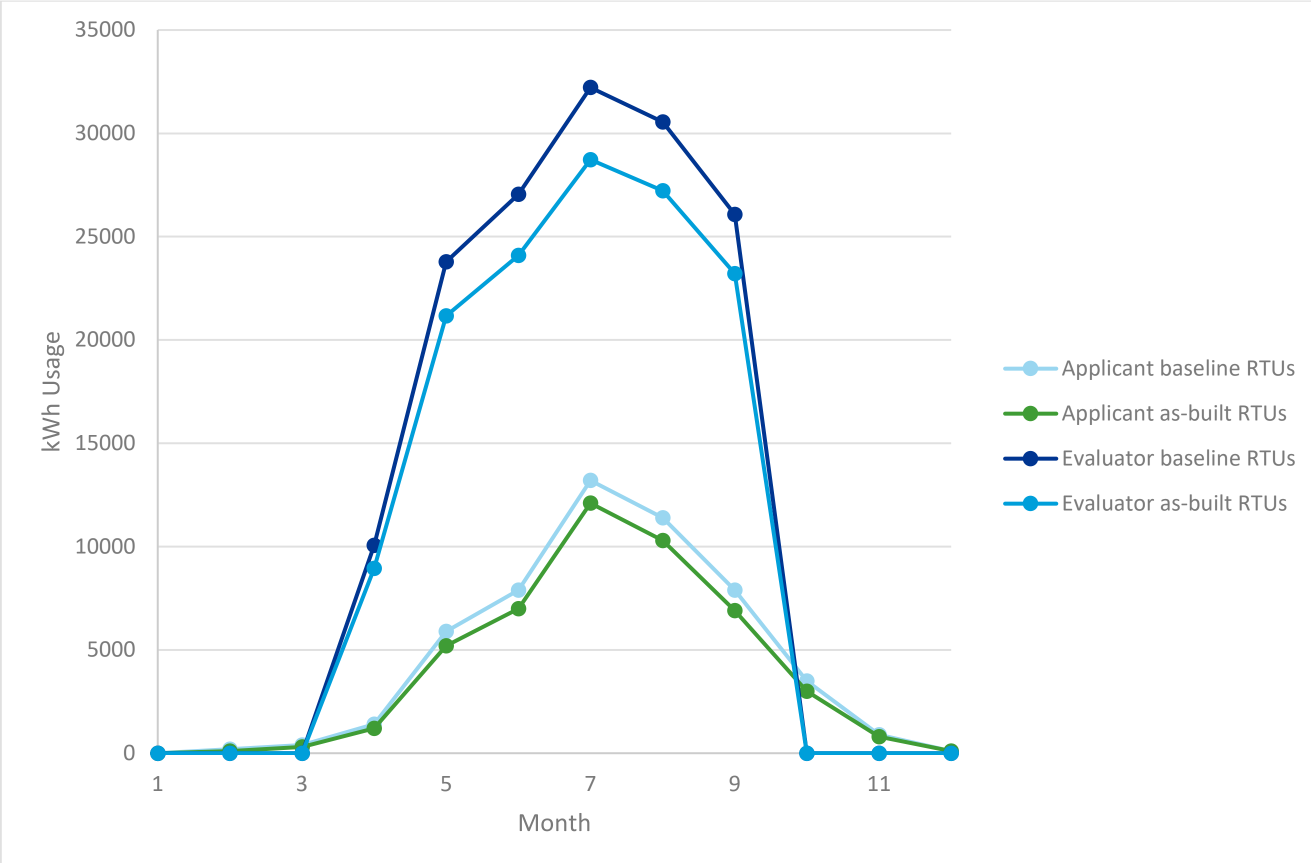


Table 3-2 below provides a summary of savings deviations.

Table 3-2. Summary of deviations

Measure	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
RTUs	Baseline	Baseline EER values	46%	**Increased savings –** The corrected evaluator baseline EER values resulted in more savings than the applicant analysis.
RTUs	Operational	Cooling Setpoint	77%	**Increased Savings –** The applicant cooling setpoint was modelled at 76°F for all RTUs but evaluators observed an avg. set point of 70°F which increased savings.
RTUs	Methodology	Miscellaneous parameters	41%	**Increased savings –** The evaluator 8,760 model based off metered data resulted in more savings than the applicant analysis.
	Final RR			**264%**

Native analysis eQUEST files were reviewed by evaluators to better understand the reasons for such a significant increase in evaluated savings. Evaluators reviewed the inputs to these files that incorporate the entire building, from lighting to domestic hot water loads. While on site, evaluators focused primarily on collecting operational data on the RTUs and did not collect full building details to recalibrate the eQUEST model. For this reason, evaluators are not able to discern miscellaneous building parameters that would affect energy use and savings.

3.2 Lifetime Savings

This measure has been classified as a lost opportunity. The baseline is code-defined for the RTUs.

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

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

where:

LAGI	=	lifetime adjusted gross impact (kWh)
FYS	=	first year savings (kWh)
EUL	=	measure life (years)

Table 3-3 provides a summary of key factors that influence the lifetime savings. The RI 2020 TRM which would have been in effect at the time of this project, indicated that custom HVAC projects have multiple measure life choices. The 2020 TRM also lists prescriptive HVAC projects with a measure life of 20 years. However, evaluators believe that the applicant for this custom measure decided to use a more conservative 15 year measure life which evaluators deem more appropriate than 20 years.

Table 3-3. Measure 12590113 - lifetime savings summary

Factor	Tracking	Application	Evaluator
Lifetime savings	86,280	86,280	227,940
First year savings	5,752	5,752	15,196
Measure lifetime	15	15	15
Baseline classification	New construction	New construction	Lost opportunity

3.2.1 Ancillary impacts

There were no ancillary impacts associated with the evaluated measure.

RICE21N110

Report Date: 11/14/2022

Program Administrator	RI Energy
Application ID(s)	12600039 (parent), 12809491 (child)
Project Type	New Buildings & Major Renovation
Evaluation Type	Ops
Program Year	2021
Evaluation Firm	DNV
Evaluation Engineer	Max Ma
Senior Engineer	Joseph St John

1 EVALUATED SITE SUMMARY AND RESULTS

The evaluated project consists of the installation of LED process lighting fixtures in a new-construction cannabis indoor growth facility. The impacted facility operates with a consistent schedule throughout the year. Both the baseline and proposed fixtures are tuned (dimmed) to the same required photosynthetic output to meet process needs. This evaluated project installed 128 LED fixtures (2 sections of 64 fixtures each) in the flower room which operate 12 hours per day. All installed fixtures have rated inputs of 636W each. All baseline fixtures have high-pressure sodium (HPS) lamps with rated inputs of 1,070W each.

Because the rated photosynthetically active radiation (PAR) output for the baseline fixtures (1,688 mmol/s) is lower than the proposed fixtures (1,700 mmol/s), the applicant estimated one more baseline fixture per section than the proposed, resulting in an applicant-reported 130 baseline fixtures. The evaluators determined that 128 baseline fixtures (same quantity as the as-built) are sufficient to meet the process requirements, and instead adjusted the baseline dimming factor to achieve the same PAR output in the baseline and as-built configurations.

Because of the high insulation, no outdoor air (to minimize biohazard contamination) and high humidity load, mechanical cooling is required year-round.

The site contact indicated that the site's operations were not changed since the project's completion and will remain the same in the future, without any impacts from Covid-19. The site contact was also willing to participate in a site visit. Therefore, the evaluators adopted the full M&V approach with operational and non-operational parameter updates, based on on-site findings and metered data. Table 1-1 provides a summary of the evaluation results.

Table 1-1. Evaluation results summary

PA Application ID	Measure Name		Annual Electric Energy (kWh)	% Of Energy Savings On-Peak	Summer On-Peak Demand (kW)	Winter On-Peak Demand (kW)
		Tracked	298,074	69%	68.05	68.05
12600039 (parent) 12809491 (child)	LED Fixtures	Evaluated	233,380	69%	53.28	53.28
		Realization Rate	78%	100%	78%	78%

1.1 Explanation of Deviations from Tracking

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

1.2 Recommendations for Program Designers & Implementers

There are no recommendations currently.

1.3 Customer Alert

There is no relevant customer alert.

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 evaluated project consists of the installation of a total of 128 LED process lighting fixtures in a new-construction agricultural indoor growth facility with year-round mechanical cooling.

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.

2.1.1 Applicant Description of Baseline

The applicant classified the project as new construction with an industry standard practice (ISP) baseline. The applicant described the baseline as high-pressure sodium (HPS) fixtures of the same quantity and rated lumens output as the installed fixtures. The applicant assigned baseline percentage dimming to the desired output (assuming input wattage is also proportional to the percentage dimming). Table 2-1 provides a summary of the applicant's baseline parameters.

Table 2-1. Applicant baseline summary

Measure/Application#	Parameter	Value(s)	Source of Parameter Value
12600039, 12809491	Fixture quantity in flower room	130	TA study – two more than installed to account for PAR differences
12600039, 12809491	Fixture technology	HPS	TA study
12600039, 12809491	Fixture wattage	1,070W	TA study, baseline specifications
12600039, 12809491	Fixture discharge PAR	1,688 mmol/s	TA study – marginally lower than installed
12600039, 12809491	Flower room dimming	95%	TA study – same as installed
12600039, 12809491	Flower room daily hours	12	TA study – same as installed
12600039, 12809491	Annual operating days for all fixtures	365	TA study – same as installed
12600039, 12809491	HVAC cooling efficiency	0.85 kW/ton	TA study – same as installed

2.1.2 Applicant Description of Installed Equipment and Operation

The applicant described the installed equipment as LED fixtures dimmed to provide the required photosynthetic output. Table 2-2 provides a summary of the applicant's installed equipment parameters.

Table 2-2. Application proposed case key parameters

Measure	Parameter	Value(s)	Source of Parameter Value
12600039, 12809491	Fixture quantity in flower room	128	TA study – two fewer than baseline to account for PAR differences
12600039, 12809491	Fixture technology	LED	TA study
12600039, 12809491	Fixture wattage	636W	TA study, installed specifications
12600039, 12809491	Fixture discharge PAR	1,700 mmol/s	TA study – marginally higher than baseline

12600039, 12809491	Flower room dimming	95%	TA study – same as baseline
12600039, 12809491	Flower room daily hours	12	TA study – same as baseline
12600039, 12809491	Annual operating days for all fixtures	365	TA study – same as baseline
12600039, 12809491	HVAC cooling efficiency	0.85 kW/ton	TA study – same as baseline

2.1.3 Applicant Energy Savings Algorithm

The applicant used a custom spreadsheet-based analysis to calculate energy savings for the measure. For all calculations, the applicant applied the same average dimming factor to both the baseline and installed fixtures.

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

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

where,

kW_{Ltg} = kW reduction from flower room lighting

kW_{clg} = kW reduction from flower room cooling

$$kW_{Ltg} = (kW_{Base} \times Qty_{Base} - kW_{As-built} \times Qty_{As-built}) \times Dim$$

where,

kW_{Base} = baseline HPS fixture input power, 1.070 kW/fixture

Qty_{Base} = fixture quantity in the baseline, 130

$kW_{As-built}$ = installed LED fixture input power, 0.636 kW/fixture

$Qty_{As-built}$ = fixture quantity in the as-built scope, 128

Dim = estimated dimming factor, 95%

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

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

2.1.4 Evaluation Assessment of Applicant Methodology

The evaluators found the applicant's analysis methodology appropriate and well substantiated given the information available at the time of the savings development during this new construction. However, the evaluators were able to collect site-specific information ex-post to update the applicant's assumptions and estimates.

2.2 On-Site Inspection and Metering

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

Evaluators visited the site on September 30th, 2022 to inspect the installed LED fixtures, collect information on the fixtures' operations, conduct metering, and interview the site contact on the project details. Table 2-3 provides a summary of the on-site verification.

Table 2-3. Measure verification

Measure Name	Verification Method	Verification Result
12600039, 12809491	Visual verification – LED fixtures	A total of 128 LED fixtures are installed and operational in the flower room as reported. The model numbers matched the invoices and specifications provided in the project documentation.
12600039, 12809491	Visual verification – internal heat gain	The flower has high internal heat gain, including LED fixtures, self-contained dehumidifiers, ceiling-mounted circulation fans, hydroponic temperature-controlling heat pumps (condenser located indoors) and plant metabolic activities. Therefore, the applicant's estimate that the space requires year-round mechanical cooling is reasonable.
12600039, 12809491	Visual verification – HVAC equipment	The site (the flower room as well as vegetation rooms and processing spaces) is collectively served by one 12.5-ton and five 5-ton split AC units, without economizers. The observed equipment matched the applicant's descriptions; however, the evaluators updated the cooling efficiency based on the weighted average of the rated IEER and SEER values.
12600039, 12809491	Site contact interview – operating schedules and dimming	The site contact confirmed the LED fixtures in the flower room are on 12 hours per day, 365 days per year, and that the dimming levels are maintained for each flower area at a constant level since the products are consistent year-round.
12600039, 12809491	Photo documentation of lighting controllers	There are a total of four controllers each with two independent circuits, for a total of eight circuits. Each circuit controls an equal number of fixtures. All circuits showed a consistent lighting schedule (7 am to 7 pm each day). More details on the dimming levels are provided below.

Photo 2-1 through Photo 2-7 provide details on the site visit findings.

Photo 2-1. Flower room LED fixtures

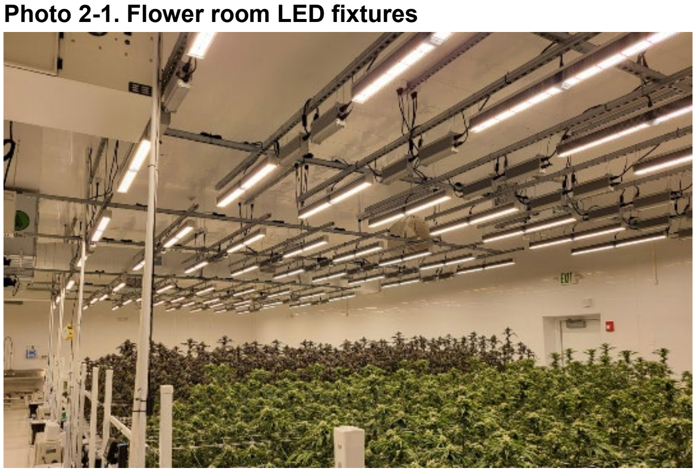


Photo 2-2. Flower room LED fixture controller – one example of eight circuits

Photo 2-3. Lighting percentage on time logger deployed in flower room

Photo 2-4. 5-ton split HVAC units (three of five shown)

Photo 2-5. 5-ton split HVAC units nameplate (identical for five units)

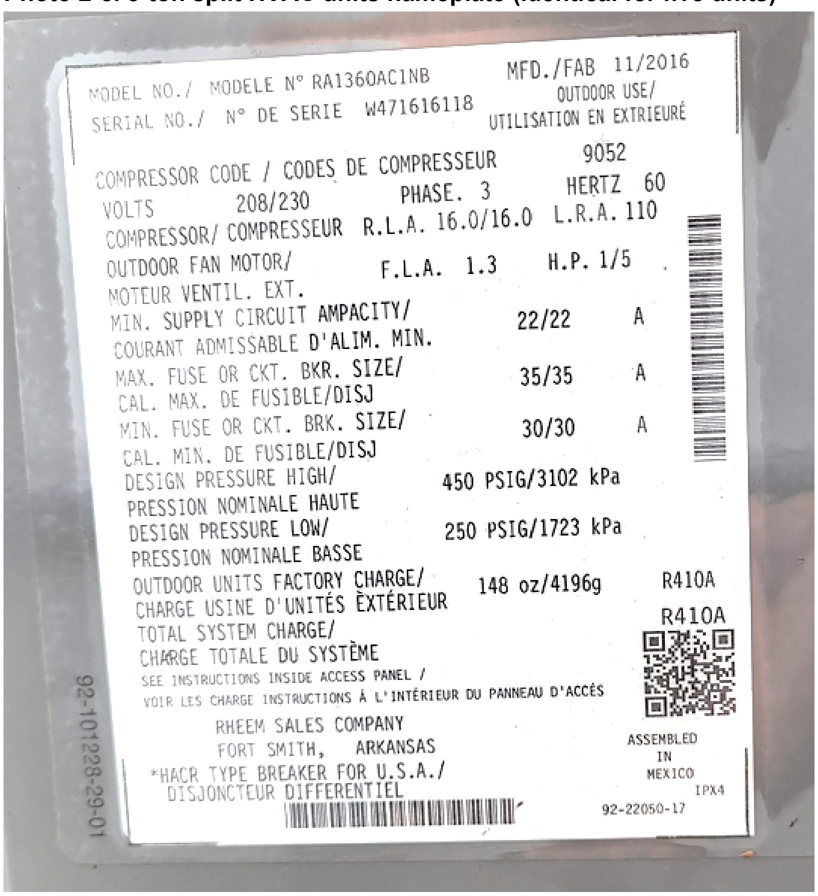
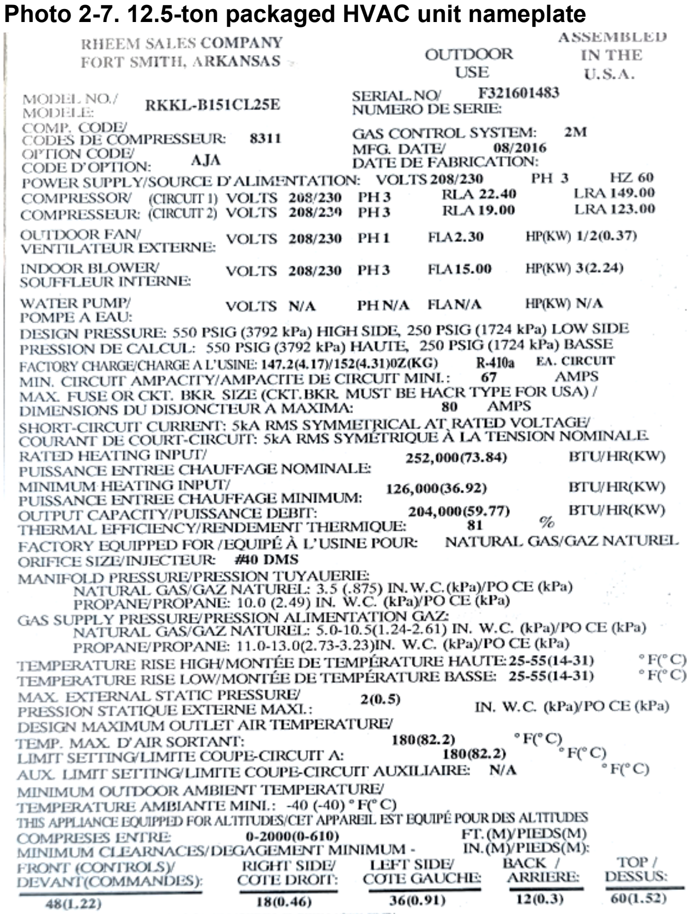


Photo 2-6. 12.5-ton packaged HVAC unit

Photo 2-7. 12.5-ton packaged HVAC unit nameplate



RHEEM SALES COMPANY
FORT SMITH, ARKANSAS

OUTDOOR USE

ASSEMBLED IN THE U.S.A.

MODEL NO./ MODELE: RKKL-B151CL25E

SERIAL NO/ NUMERO DE SERIE: F321601483

COMP. CODE/ CODES DE COMPRESSEUR: 8311

GAS CONTROL SYSTEM: 2M

OPTION CODE/ CODE D'OPTION: AJA

MFG. DATE/ DATE DE FABRICATION: 08/2016

POWER SUPPLY/SOURCE D'ALIMENTATION: VOLTS 208/230 PH 3 HZ 60

COMPRESSOR/ (CIRCUIT 1) VOLTS 208/230 PH 3 RLA 22.40 LRA 149.00

COMPRESSEUR: (CIRCUIT 2) VOLTS 208/230 PH 3 RLA 19.00 LRA 123.00

OUTDOOR FAN/ VENTILATEUR EXTERNE: VOLTS 208/230 PH 1 FLA 2.30 HP(KW) 1/2(0.37)

INDOOR BLOWER/ SOUFFLEUR INTERNE: VOLTS 208/230 PH 3 FLA 15.00 HP(KW) 3(2.24)

WATER PUMP/ POMPE A EAU: VOLTS N/A PH N/A FLA N/A HP(KW) N/A

DESIGN PRESSURE: 550 PSIG (3792 kPa) HIGH SIDE, 250 PSIG (1724 kPa) LOW SIDE
PRESSION DE CALCUL: 550 PSIG (3792 kPa) HAUTE, 250 PSIG (1724 kPa) BASSE

FACTORY CHARGE/CHARGE A L'USINE: 147.2(4.17)/152(4.31)OZ(KG) R-410a EA. CIRCUIT

MIN. CIRCUIT AMPACITY/AMPACITE DE CIRCUIT MINI.: 67 AMPS

MAX. FUSE OR CKT. BKR. SIZE (CKT.BKR. MUST BE HACR TYPE FOR USA) / DIMENSIONS DU DISJONCTEUR A MAXIMA: 80 AMPS

SHORT-CIRCUIT CURRENT: 5kA RMS SYMMETRICAL AT RATED VOLTAGE/
COURANT DE COURT-CIRCUIT: 5kA RMS SYMÉTRIQUE À LA TENSION NOMINALE

RATED HEATING INPUT/ PUISSANCE ENTREE CHAUFFAGE NOMINALE: 252,000(73.84) BTU/HR(KW)

MINIMUM HEATING INPUT/ PUISSANCE ENTREE CHAUFFAGE MINIMUM: 126,000(36.92) BTU/HR(KW)

OUTPUT CAPACITY/PUISSANCE DEBIT: 204,000(59.77) BTU/HR(KW)

THERMAL EFFICIENCY/RENDEMENT THERMIQUE: 81 %

FACTORY EQUIPPED FOR /EQUIPÉ À L'USINE POUR: NATURAL GAS/GAZ NATUREL

ORIFICE SIZE/INJECTEUR: #40 DMS

MANIFOLD PRESSURE/PRESSION TUYAUERIE:
NATURAL GAS/GAZ NATUREL: 3.5 (.875) IN. W.C.(kPa)/PO CE (kPa)
PROPANE/PROPANE: 10.0 (2.49) IN. W.C. (kPa)/PO CE (kPa)

GAS SUPPLY PRESSURE/PRESSION ALIMENTATION GAZ:
NATURAL GAS/GAZ NATUREL: 5.0-10.5(1.24-2.61) IN. W.C. (kPa)/PO CE (kPa)
PROPANE/PROPANE: 11.0-13.0(2.73-3.23)IN. W.C. (kPa)/PO CE (kPa)

TEMPERATURE RISE HIGH/MONTÉE DE TEMPÉRATURE HAUTE: 25-55(14-31) °F(°C)
TEMPERATURE RISE LOW/MONTÉE DE TEMPÉRATURE BASSE: 25-55(14-31) °F(°C)

MAX. EXTERNAL STATIC PRESSURE/ PRESSION STATIQUE EXTERNE MAXI.: 2(0.5) IN. W.C. (kPa)/PO CE (kPa)

DESIGN MAXIMUM OUTLET AIR TEMPERATURE/ TEMP. MAX. D'AIR SORTANT: 180(82.2) °F(°C)

LIMIT SETTING/LIMITE COUPE-CIRCUIT A: 180(82.2) °F(°C)

AUX. LIMIT SETTING/LIMITE COUPE-CIRCUIT AUXILIAIRE: N/A °F(°C)

MINIMUM OUTDOOR AMBIENT TEMPERATURE/ TEMPERATURE AMBIANTE MINI.: -40 (-40) °F(°C)

THIS APPLIANCE EQUIPPED FOR ALTITUDES/CET APPAREIL EST EQUIPÉ POUR DES ALTITUDES COMPRESES ENTRE: 0-2000(0-610) FT.(M)/PIEDS(M)

MINIMUM CLEARNACES/DEGAGEMENT MINIMUM - IN.(M)/PIEDS(M):

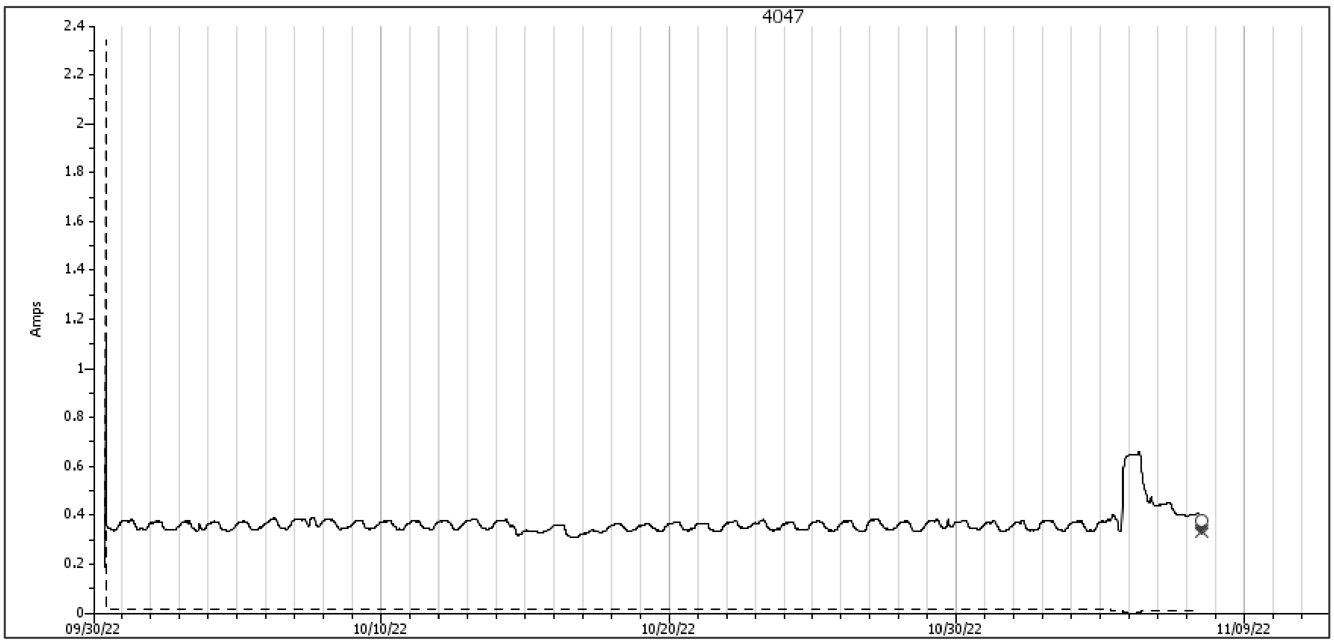
FRONT (CONTROLS)/ DEVANT(COMMANDES):	RIGHT SIDE/ COTE DROIT:	LEFT SIDE/ COTE GAUCHE:	BACK / ARRIERE:	TOP / DESSUS:
48(1.22)	18(0.46)	36(0.91)	12(0.3)	60(1.52)

The evaluator's metering for this site included:

1. Three amperage loggers in the electric panel on circuits serving the flower room lighting. The loggers measured amperage data in 15-min intervals between September 30th and November 3rd, 2022, for a total of 34 days.
2. Four lighting on/off loggers in the flower room. The loggers measures percentage on time for the LED fixtures for each hour between September 30th and November 3rd, 2022, for a total of 34 days.

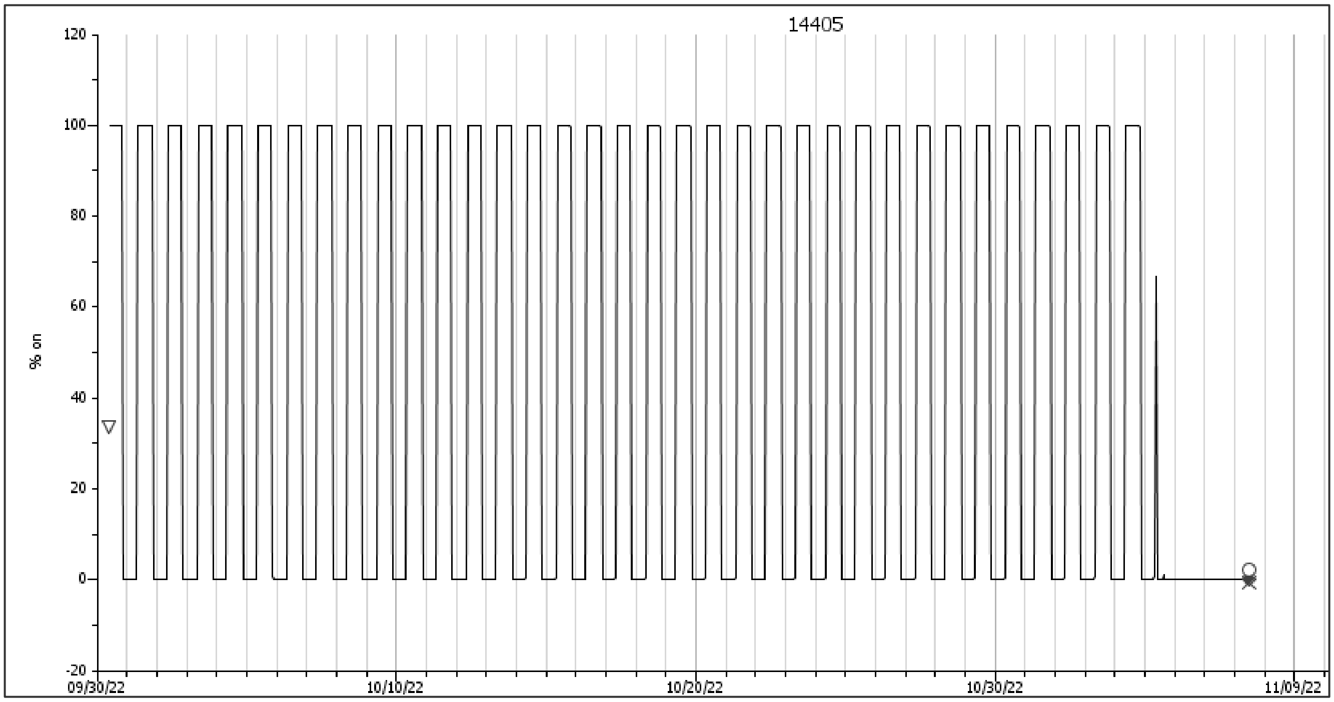
All amperage loggers returned faulty data, potentially due to mis-labelling or mis-identification of the circuits in the panel. Figure 2-1 provides an example of the faulty amperage data. As a result, the evaluators could not use the metered amperage data in the evaluator's analysis.

Figure 2-1. Faulty metered data – amperage too low for expected loads



The lighting on/off loggers returned consistent data verifying that the fixtures turned on each day at 7 am and off at 7 pm. Figure 2-2 provides an example of the metered lighting percentage on data.

Figure 2-2. Metered lighting percentage on time data



2.3 Evaluation Methods and Findings

This section describes the evaluator methods and findings.

2.3.1 Evaluation Description of Baseline

The evaluator reviewed the project files and interviewed the site contact to gather information on the baseline. The evaluators determined that the measure is a lost opportunity (new construction) with an ISP baseline. Per ISP guidance in effect in RI, the baseline for agricultural lighting is HPS fixtures that produce equivalent PPFD (or equivalent PAR if installation locations are consistent). Therefore, the evaluators agree with the applicant's baseline fixture selection. However, the evaluators adjusted the baseline fixture quantity from the applicant-reported 130 to the same as the as-built quantity of 128, which are sufficient to meet the process needs. The evaluators adjusted the baseline dimming levels to be higher than the as-built fixture dimming levels, to normalize to the same PAR output.

2.3.2 Evaluation Calculation Method

The evaluators used the same overall analysis methodology as the applicant did, with updates to baseline and operational parameters as described below.

The evaluators corroborated the metered lighting on/off data with the lighting controller settings and verified that the LED fixtures are on for 12 hours per day, 365 days per week, the same as what the applicant reported. Table 2-4 provides a summary of the lighting percentage on time metering results.

Table 2-4. Summary of lighting percentage on time metering results

Hour of Day	Lighting On-Time Percentage
1	0.00
2	0.00
3	0.00

Hour of Day	Lighting On-Time Percentage
4	0.00
5	0.00
6	0.00
7	0.41
8	99.99
9	100.00
10	99.99
11	100.00
12	100.00
13	100.00
14	100.00
15	100.00
16	100.00
17	100.00
18	100.00
19	99.61
20	0.04
21	0.00
22	0.00
23	0.00
24	0.00
22	0.00

The evaluators calculated the as-built fixture dimming using the average of the eight controlled circuit settings, since the site contact confirmed that the dimming settings are not expected to change. The evaluators used the same assumptions as the applicant – that the fixture input wattages are proportional to the dimming level. Table 2-5 provides a summary of the as-built dimming level calculations – note that each controller circuit controls an equal number of fixtures.

Table 2-5. Average as-built dimming level calculations based on LED controller settings

Controller Circuit ID	Percentage Dimming
A1	60
A2	65
B1	80
B2	75
C1	75
C2	80
D1	80
D2	75
Average	**73.8**

Because the evaluators' baseline fixture quantity is the same as the as-built fixture quantity, the evaluators calculated the baseline dimming level to provide the same level of PAR output as the as-built fixtures, using the following formula:

$$Dim_{Base} = Dim_{As-built} \times \frac{PAR_{As-built}}{PAR_{Base}}$$

where,

Dim_{Base} = calculated baseline dimming level, 74.3%

$Dim_{As-built}$ = as-built dimming level as calculated in Table 2-5, 73.8%

$PAR_{As-built}$ = rated PAR output of as-built fixture, 1,700 mmol/s per fixture

$PAR_{As-built}$ = rated PAR output of baseline fixture, 1,688 mmol/s per fixture

The evaluators calculated the average cooling efficiency based on the site-verified nameplate information. Table 2-6 provides a summary of the evaluator-calculated average cooling efficiency, equivalent to 0.98 kW/ton.

Table 2-6. Evaluated average cooling efficiency calculations

Make/Model	Rated IEER/SEER	Rated Cooling Capacity (tons)	Quantity
Rheem RA1360AC1NB	13.0	5	5
Rheem RKKL-B151CL25E	10.8	12.5	1
Weighted average	**12.3**	**N/A**	**N/A**

Table 2-7 provides a summary of the parameters used in the evaluators' analysis.

Table 2-7. Evaluators' analysis parameters summary

Measure	Parameter	Baseline	As built	Source of Parameter Value
12600039, 12809491	Fixture quantity in flower room	128	128	Site-verified as-built quantity; equal quantity applied to baseline.
12600039, 12809491	Fixture technology	HPS	LED	Site and ISP verified.
12600039, 12809491	Fixture wattage	1,070W	636W	Fixture specifications.
12600039, 12809491	Fixture discharge PAR	1,688 mmol/s	1,700 mmol/s	Fixture specifications.
12600039, 12809491	Flower room dimming	74.3%	73.8%	Site verified for as-built; normalized PAR output for calculating baseline.
12600039, 12809491	Flower room daily hours	12	12	Verified with metered data and controller settings.
12600039, 12809491	Annual operating days for all fixtures	365	365	Verified with site contact interview and controller settings.
12600039, 12809491	HVAC cooling efficiency	0.98 kW/ton	0.98 kW/ton	Calculated based on HVAC nameplate data.

The evaluators' calculations resulted in LED fixture savings of 182,592 kWh/yr (78% of project total) and interactive cooling savings of 50,788 kWh/yr (22% of project total), for a total energy savings of 233,380 kWh/yr. The evaluated energy savings are lower than the tracking savings of 298,074 kWh/yr.

The evaluators calculated winter and summer demand savings using the same methodology as that used by the applicant – as the average demand reduction calculated using a seasonal average cooling efficiency value. This is because the site's internal heat gain is consistent year-round and for all hours during the summer and winter peak demand hours.

3 FINAL RESULTS

The evaluated project consists of the installation of 128 LED fixtures in a cannabis indoor growth facility. The project resulted in lighting and interactive cooling savings. The evaluator used the same custom spreadsheet-based analysis as the applicant did, with updates to the baseline and operational parameters based on evaluation findings. Table 3-1 provides a comparison of the key parameters.

Table 3-1. Summary of key parameters

Parameter	BASELINE		PROPOSED / INSTALLED	
	Tracking Value(s)	Evaluation Value(s)	Tracking Value(s)	Evaluation Value(s)
Fixture quantity in flower room	130	128	128	128
Fixture technology	HPS	HPS	LED	LED
Fixture wattage	1,070W	1,070W	636W	636W
Fixture discharge PAR	1,688 mmol/s	1,688 mmol/s	1,700 mmol/s	1,700 mmol/s
Flower room dimming	95%	74.3%	95%	73.8%
Flower room daily hours	12	12	12	12
Annual operating days for all fixtures	365	365	365	365
HVAC cooling efficiency	0.85 kW/ton	0.98 kW/ton	0.85 kW/ton	0.98 kW/ton

1.1 Explanation of Differences

The evaluated savings are lower than the applicant-reported values predominantly because the evaluated dimming levels are lower than what the applicant estimated. Table 3-2 provides a summary of savings deviations.

Table 3-2. Summary of deviations

Measure	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
12600039 (parent) 128094941 (child)	Operations	Flower room dimming	-21.7%	**Decreased savings -** evaluated dimming factor of 74% is lower than applicant-estimated 95%, resulting in proportionally lower baseline and proposed energy consumptions, and therefore lower savings.
12600039 (parent) 128094941 (child)	Interactivity	HVAC cooling efficiency	3.0%	**Increased savings -** evaluated average cooling efficiency of 0.98 kW/ton is less efficient than applicant-reported 0.85 kW/ton, resulting in higher interactive cooling savings.
12600039 (parent) 128094941 (child)	Baseline	Baseline fixture quantity	-3.0%	**Decreased savings -** evaluators adjusted the baseline fixture quantity to match the as-built fixture quantity, which is sufficient to provide the required lighting output. This adjustment decreased the baseline energy

				consumption, resulting in lower energy savings.
	Final RR			**78%**

1.2 Lifetime Savings

This measure has been classified as a lost opportunity. The baseline is ISP which consists of HPS fixtures.

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

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

where:

LAGI =	lifetime adjusted gross impact (kWh)
FYS =	first year savings (kWh)
EUL =	measure life (years)

Table 3-3 provides a summary of key factors that influence the lifetime savings.

Table 3-3. Measure 12600039 (parent), 12809491 (child) - lifetime savings summary

Factor	Tracking	Application	Evaluator
Lifetime savings	2,980,740	2,980,740	2,333,803
First year savings	298,074	298,074	233,380
Measure lifetime	10	10	10
Baseline classification	New construction	New construction	New Construction

1.2.1 Ancillary impacts

There were no ancillary impacts associated with the evaluated measure.

RICE21N094_S

Report Date: 5/31/2023

Program Administrator	Rhode Island Energy
Application ID(s)	11959744
Project Type	Existing Building Retrofit
Evaluation Type	Ops
Program Year	2021
Evaluation Firm	DNV
Evaluation Engineer	Laeng Khoun
Senior Engineer	Max Ma

1 EVALUATED SITE SUMMARY AND RESULTS

This retrofit project was installed at an approximately 10,000 sq. ft. office building that is occupied by administrative staff for a public school district. The building typically operates year-round including times when school is not in-session. The project included a single measure which connected existing RTUs (packaged DX units) to its existing remote energy management system including the following reported sub-measures:

- 7-day schedule
- Optimal Start/Stop
- Night-time setback
- DDC Temperature

The school district has a remote EMS software which was intended to be connected to the RTUs through the newly installed smart thermostats with Wi-Fi capability. The energy savings comes from the reduction in run-time of the RTUs by implementing the EMS controls. The site contact indicated that the building and HVAC schedules have not been affected by COVID.

The evaluators went on-site and determined from interviewing the site contact and observing the EMS display that the EMS system was not implemented. The site contact reported that despite having installed the Wi-Fi thermostats, the site was unsuccessful with the EMS control point installation due to network security issues. Therefore, the applicants never created scheduling controls or set up trending capabilities. Furthermore, due to space heating issues stemming from a malfunctioning Wi-Fi thermostat, the thermostat for the impacted RTU 4 was reverted back to a non-Wi-Fi thermostat with no capability to connect to the EMS system.

The evaluators visited the site on September 9th, 2022 but could not install true power meters due to weather preventing roof access and space constraints in the electrical panel. The evaluators returned on March 8th, 2023 and were able to install power meters in the RTUs 1,2, and 3. The evaluators analysed the data from the RTUs and found that the data corroborates the findings that the EMS system was not implemented. Table 1-1 provides a summary of the evaluation results.

Table 1-1. Evaluation results summary

PA Application ID	Measure Name		Annual Electric Energy (kWh)	Summer On-Peak Demand (kW)	Winter On-Peak Demand (kW)
		Tracked	4,343	0	0
11959744	EMS Control Points	Evaluated	0	0	0
		Realization Rate	0%	100%	100%

1.1 Explanation of Deviations from Tracking

The evaluated savings are zero because the measure was not implemented. Further details regarding deviations from the tracked savings are presented in Section 3.1.

1.2 Recommendations for Program Designers & Implementers

Evaluators recommend that program implementers follow up with installations where savings are significantly dependent on controls, so that the applicant-reported control sequences are programmed, and remote EMS systems are confirmed to be connected.

1.3 Customer Alert

There is no relevant customer alert.

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 the installation of four EMS control points which were smart thermostats with Wi-Fi connectivity.

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.

2.1.1 Applicant Description Baseline

The applicant described the project as a retrofit with the existing conditions as the baseline. The applicant baseline consists of 4 pre-existing RTUs which serve the office building. The RTUs did not have EMS controls. According to the applicant provided documentation, the 4 RTUs have a combined connected wattage of 94 kW. The applicant claims the RTUs run 60 hours / week and 22 weeks / year. The applicant claims the facility baseline energy use is 46,720 kWh. Table 1-2 provides a summary of the applicant's baseline parameters. The RTUs are described below:

- RTU 1: 6-ton York-brand RTU serving zone 1: community engagement office
- RTU 2: 9-ton York-brand RTU serving zone 2: back office
- RTU 1: 9-ton York-brand RTU serving zone 3: conference room
- RTU 1: 10-ton Rheem-brand RTU serving zone 4: transportation office

The baseline system controlled the RTUs using thermostats with no EMS or wi-fi capability. The facility manager reported that existing thermostats had basic setpoints for occupied and unoccupied temperatures but no advanced controls. The contact reported that the facility in the cooling season was set to 74 °F in occupied times and 80 °F in unoccupied times.

Table 1-2. Applicant baseline summary

Measure	Parameter	Value(s)	Source of Parameter Value
11959744	RTU Connected Wattage	94 kW	Applicant savings analysis
11959744	Operating Hours	1320	Applicant savings analysis
11959744	Thermostat type	Non-Wi-Fi thermostat	Site-contact interview

2.1.2 Applicant Description of Installed Equipment and Operation

The applicant described the installed equipment as smart thermostats which serve as the control points that communicate with the remote EMS software. The EMS software would consist of 4 sub-measures which change the operating schedule of the RTUs. The sub-measures are as follows:

- 7-day schedule
- Optimal Start/Stop
- Night-time setback
- DDC Temperature

The evaluators noted that the applicant calculator showed that the proposed hours were still the same as the baseline of 60 hours / week, 22 weeks / year. Furthermore, the evaluators found that the sub-measures shown in the applicant's application / TA study conflicts with the sub-measures shown in the applicant savings calculator. The applicant savings calculator shows only savings for DDC Temperature and "Enthalpy" controls. The applicant calculator does not calculate savings for 7-day schedule, optimal start / stop, or night-time setback. Table 1-3 provides a summary of the applicant's installed equipment parameters.

Table 1-3. Application proposed case key parameters

Measure	Parameter	Value(s)	Source of Parameter Value
11959744	RTU Connected Wattage	94 kW	Applicant savings analysis
11959744	Operating Hours	1320	Applicant savings analysis
11959744	Thermostat type	Wi-Fi thermostat	Applicant savings analysis
11959744	DDC savings factor	2.5%	Applicant savings analysis
11959744	Enthalpy savings factor	1.0%	Applicant savings analysis

2.1.3 Applicant Energy Savings Algorithm

The applicant uses the RI Energy EMS calculator to estimate the energy savings from connecting the RTUs to the EMS. In the TA memo, 7-day schedule, optimal start/stop, night-time setback, and DDC temperature were claimed to be installed. In the native analysis that matched tracking savings, the saving components included only "DDC temperature" controls and "enthalpy" controls. The evaluator reviewed the savings methodology and found that the applicant used a deemed savings approach. The energy savings are calculated using the formulas shown:

$$DDC\ Energy\ Savings\ (kWh) = Connected\ kW \times Hours\ \times DDC\ Savings\ Factor$$

$$Enthalpy\ Savings\ (kWh) = Connected\ kW \times Hours\ \times Enthalpy\ Savings\ Factor$$

$$Total\ Savings\ (kWh) = DDC\ Energy\ Savings\ +\ Enthalpy\ Savings$$

where,

$Connected\ kW$ = kW ratings of the RTU units, 94 kW
$Hours$ = Annual cooling hours, 1,320 hours
$DDC\ Savings\ Factor$ = Deemed ratio for DDC measures 0.025
$Enthalpy\ Savings\ Factor$ = Deemed ratio for Enthalpy measures 0.01

The applicant files did not specify the scope covered in installation so the evaluators could not speculate as to what "enthalpy" controls entails. On-site findings did not support any dual-enthalpy economizer controls. Further on-site findings are shown in Section 2.2.

2.1.4 Evaluation Assessment of Applicant Methodology

Upon review of the analysis, the evaluators determined the applicant methodology to be not the most precise method for energy savings estimation based on generic assumptions built into the tool for which no documentation could be found (DDC and enthalpy savings factors). Although the use of the RI Energy EMS calculator is valid and appropriate for savings based on general estimations of EMS sub-measures installed, an OAT-bin analysis based approach would be more appropriate if there were metered data available.

2.2 On-Site Inspection and Metering

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

The evaluators conducted a site visit on September 9th, 2022 and met with a representative from Aramark that was responsible for the installation of the control points. The evaluators interviewed the site contact / applicant and determined that they believed the project to never have been implemented. The facility installed Wi-Fi but the RTUs could not connect to the EMS software due to network security issues. The site contact indicated that they implemented similar projects in other school buildings but for this administration building, there were network security issues that prevented them from connecting the RTUs to the EMS so they considered the project a failure.

The site contact also indicated that the Wi-Fi card inside the thermostat for RTU 4 (zone 4: transportation office) was exhibiting issues with overheating which caused the thermostat to read higher than actual space temperatures. Since the thermostat was malfunctioning, the occupants reported issues with space temperatures being too cold and humidity causing the space to be clammy. The facility staff rectified the issue by reverting the smart thermostat back to a non-smart thermostat with no wi-fi card and no capability to connect to the EMS system. Figure 1-1 through Figure 1-3 shows identical smart thermostats for zones 1-3 and Figure 1-4 shows the thermostat with the Wi-Fi card exposed. Figure 1-5 shows the non-smart wi-fi with no EMS connection capability.

Figure 1-1. Zone 1 community engagement office Wi-Fi thermostat

Figure 1-2. Zone 2 back office Wi-Fi thermostat

Figure 1-3. Zone 3 conference room Wi-Fi thermostat

Figure 1-4. Zone 1 thermostat with Wi-Fi card exposed

Figure 1-5. Zone 4 transportation office non-smart thermostat

The evaluators requested to see the EMS software while on-site with the Aramark representative. The evaluators found that RTU 1 had established a connection with the EMS but found that scheduling controls were not working. The site contact indicated that the thermostat must have been able to bypass prior security issues and connect to the EMS at some point after project implementation, but the staff had not programmed the schedules for the RTUs because they assumed RTUs were not connected. After discovering RTU 1 was connected, the site contact attempted to launch the EMS controls for RTU 2 and 3 but the connection was not successful. Reconnecting RTU 4 to the EMS was not possible because the Wi-Fi thermostat was removed. Figure 1-6 shows the EMS display when attempting to connect to RTU 4. Figure 1-7 shows a summary screen of all the RTUs and shows that the status for RTU 4 was “down" since connection was not possible without a Wi-Fi enabled thermostat.

Figure 1-6. RTU 4 EMS display

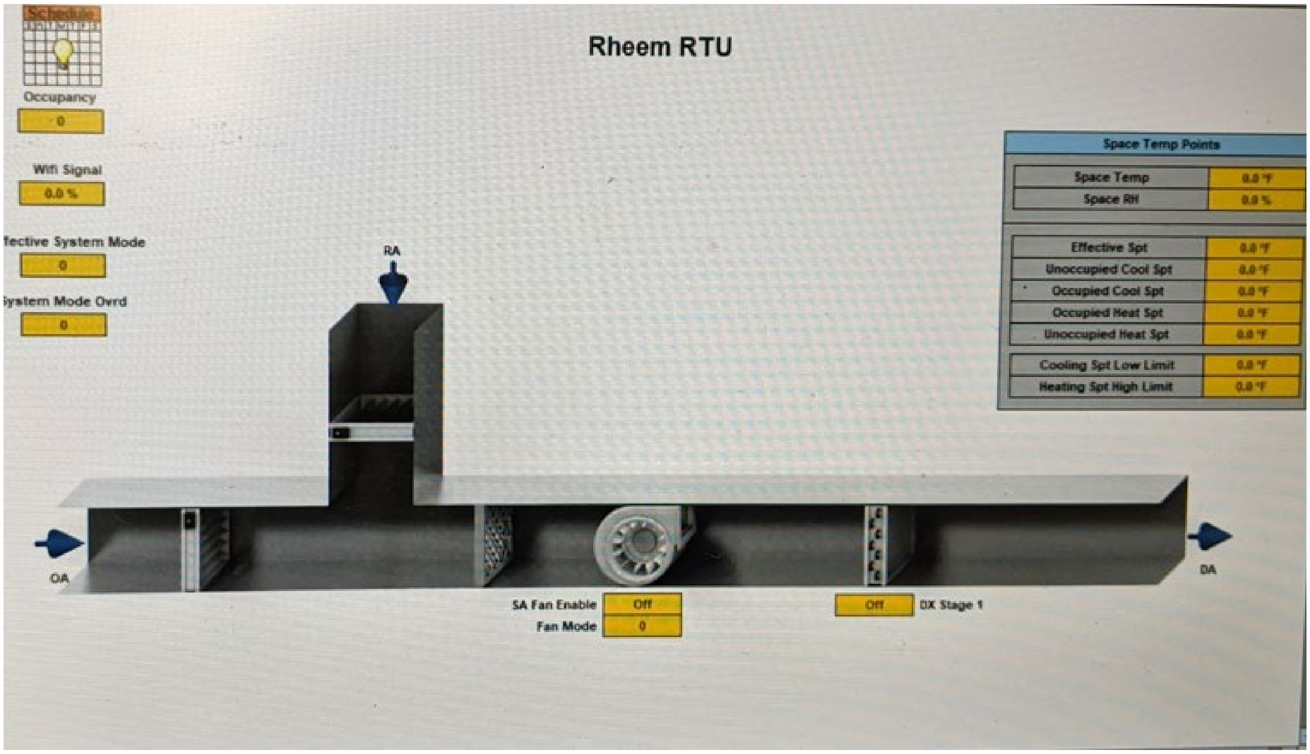


Figure 1-7. RTU status summary

Name	Exts	Device ID	Status	Netwk	MAC Addr
WashingtonSt379_RheemRTU		device:580012	{down}	65000	10.58.9.12:0xBAC0
WashingtonSt379_RTU_1		device:580013	{unackedAlarm}	65000	10.58.9.13:0xBAC0
WashingtonSt379_RTU_2		device:580014	{unackedAlarm}	65000	10.58.9.14:0xBAC0
WashingtonSt379_RTU_3		device:580015	{unackedAlarm}	65000	10.58.9.15:0xBAC0

The evaluators noted that RTU 4 which was controlled by the non-smart thermostat was not connected to the EMS and thus can not yield any savings for the claimed measure. To attempt to corroborate the on-site findings, the evaluators installed metering equipment to monitor the RTUs.

The evaluators conducted the initial visit on September 9th, 2022 to attempt to install metering equipment on the RTUs while the facility was still in cooling mode. During the initial visit, there was a thunderstorm which the site contact and evaluator deemed not safe to access the roof via extension ladder. The evaluator attempted to install Dent Elite true power meters for all 4 RTUs at the electrical panel located indoors. However, the Elites could not physically fit in the panel and the site staff did not feel safe to run wires out of the panel to the Elites on the outside of the panel. Instead of the Elites, the evaluator installed the backup HOBO amp loggers but found that the panel still did not close shut. Due to the limited space in the panel only 1 HOBO amp logger was able to be installed which meters RTU 3.
The evaluators installed temperature loggers in each zone to monitor the conditioned space temperature. The evaluators attempted to request trend data but no EMS trending was ever set up because the applicant assumed the project was a failure. Since the initial visit could only capture a small window of the cooling season and the weather prevented installation of true power meters, the evaluators planned to return after the heating season.

On March 8th, 2023 the evaluators returned to the site to install additional metering equipment. The evaluators were able to install the following metering equipment:

- Dent ElitePro data logger on RTU 1
- Dent ElitePro data logger on RTU 2
- Dent ElitePro data logger on RTU 3
- Hobo Amp data logger on RTU 4 (due to space restrictions).

The evaluators found during the pick-up that the battery for the amp logger in RTU 4 had exploded and damaged the logger internals. No data could be retrieved from the amp logger since the logger could not connect to the computer. However, since the there is no capability for RTU 4 to communicate with the EMS system (no Wi-Fi card in the thermostat), there would have been no savings attributable for RTU 4. Table 1-4 shows a summary of the methods used to verify the measure and the results.

Table 1-4. Measure verification

Measure Name	Verification Method	Verification Result
EMS Control Points	Interview site contact	The contact indicated the project was not successfully implemented.
EMS Control Points	Inspection of equipment	RTUs matched the specifications in applicant documentation. One thermostat was removed and reverted to a thermostat with no EMS communication capability. The EMS showed there were no scheduling controls implemented or no connection to the RTU.
EMS Control Points	Equipment metering	The metered data indicates that no EMS controls were implemented. There is no evidence to support the implementation of EMS with 7-day schedule, optimal start/stop, night-time setback, and DDC temperature controls.

The evaluators collected space temperature data spanning September 9th, 2022, to May 8th, 2023. Power data was collected between March 8th, 2023 and May 8th, 2023. The RTU power logged was total RTU power including supply fans, compressors, and condenser fans. Figure 1-8 through Figure 1-10 show the power (kW) over the metered period for RTUs 1-3.

Figure 1-8. Metered power data for RTU 1

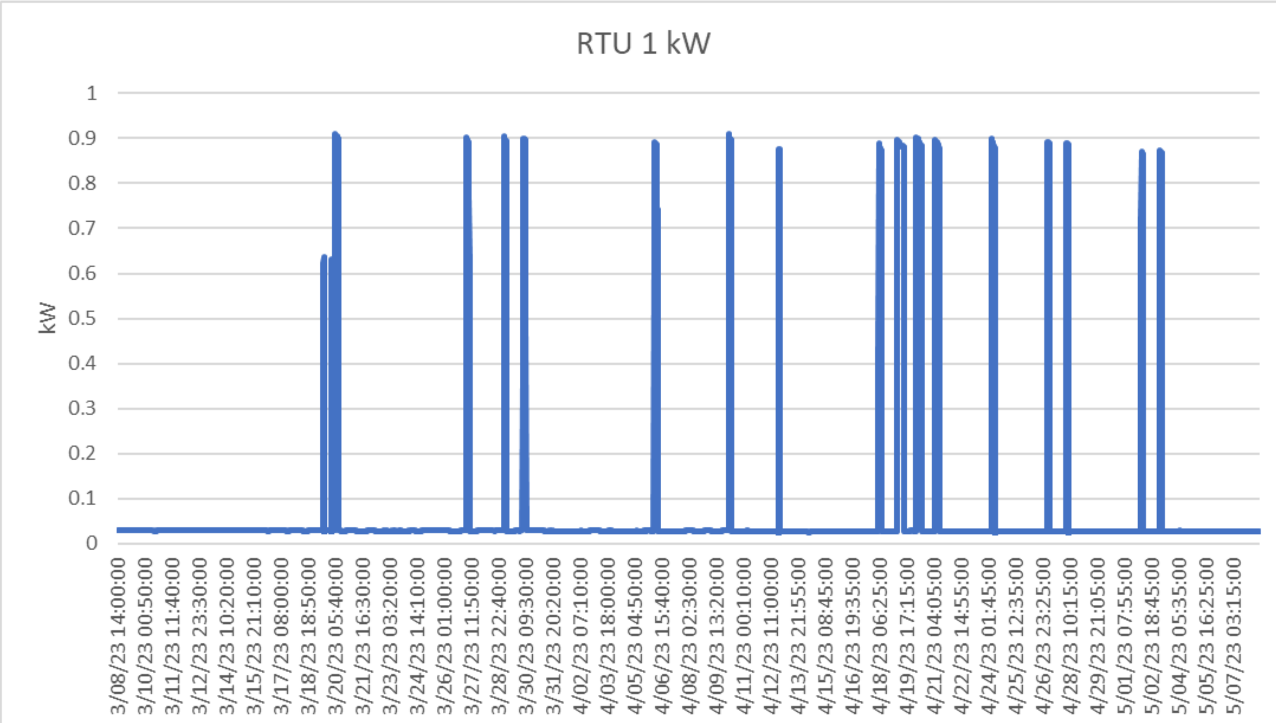


Figure 1-9. Metered power data for RTU 2

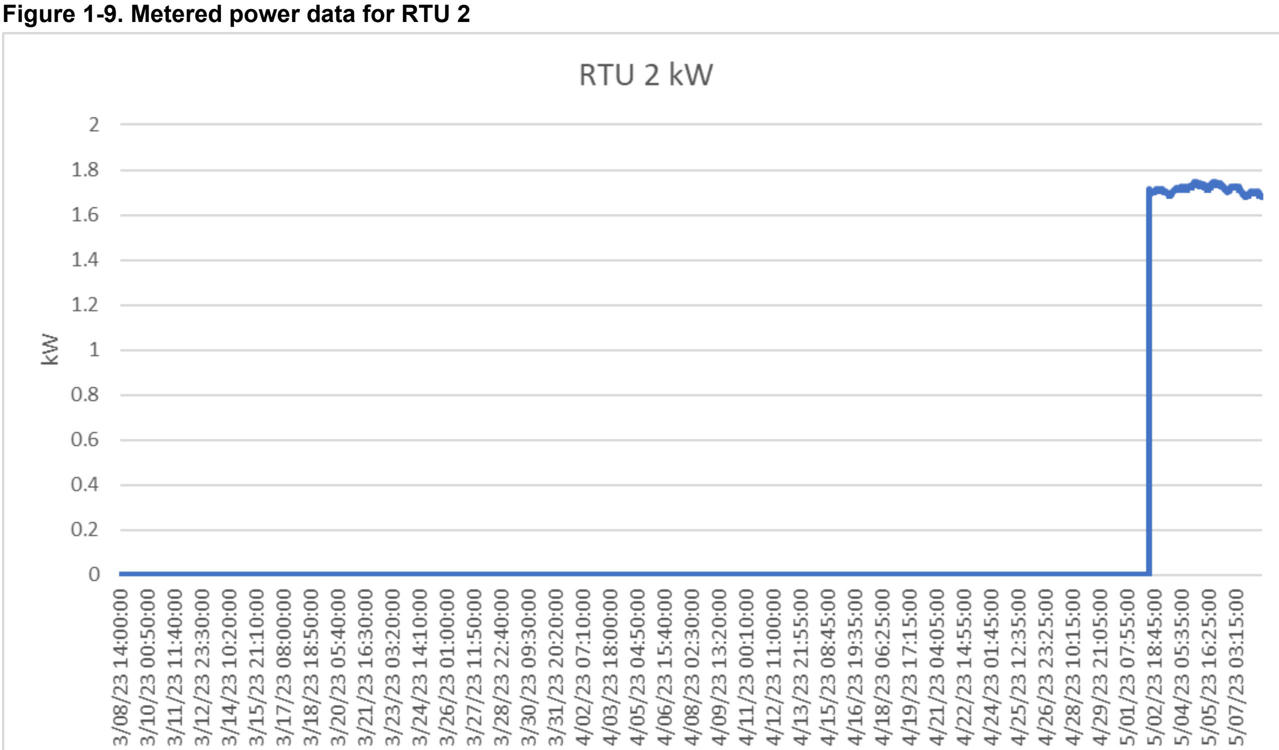
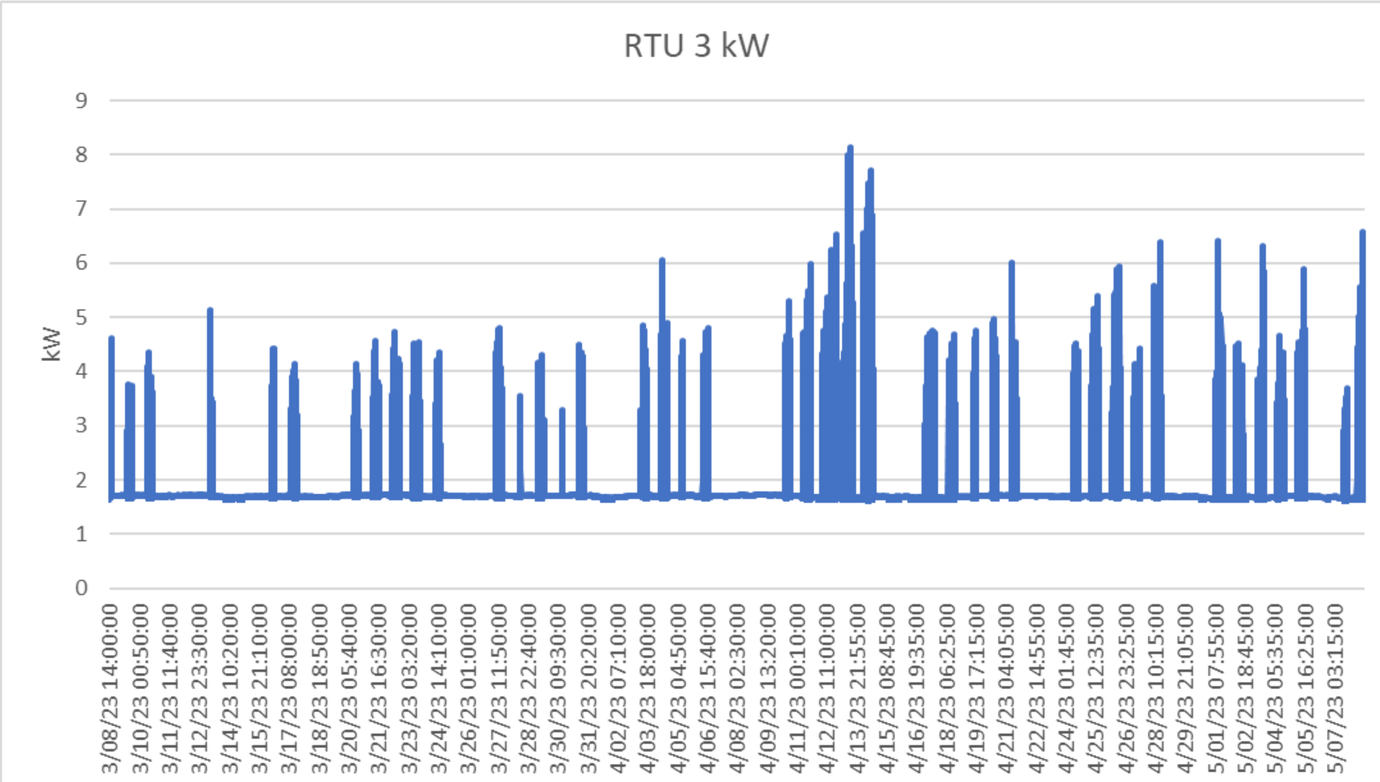


Figure 1-10. Metered power data for RTU 3



Metered data showed RTU-1 cycled fans but did not go into cooling mode during the metering period. RTU-3 exhibit basic scheduling controls that are common with standard digital thermostats but are not indicative of being connected the EMS system with 7-day schedule, night-time setback, optimal start / stop or DDC temp as claimed in the application. RTU 2 remains off until May 1st at which point it turns on and stays on with no down-time. The findings from the metered data are discussed further in Section 2.3.2.

2.3 Evaluation Methods and Findings

This section describes the evaluator methods and findings.

2.3.1 Evaluation Description of Baseline

The evaluators have classified this measure as an add-on retrofit. The baseline is the pre-existing condition which consisted of the RTUs being the underlying equipment with no advanced scheduling controls. The building is typically occupied for 60 hours / week for 50 weeks / year. The baseline system controlled the RTUs using thermostats with no EMS or wi-fi capability. The facility manager reported that existing thermostats had basic setpoints for occupied and unoccupied temperatures but no advanced controls. The contact reported that the facility in the cooling season was set to 74 °F in occupied times and 80 °F in unoccupied times.

2.3.2 Evaluation Calculation Method

The evaluators analysed the metered data and generated weekly operating schedules for each RTU. The evaluators created on/off operation schedules based on the power (kW data) for each RTU. Table 1-5 through Table 1-7 shows the weekly schedule for RTUs 1, 2 and 3.

Table 1-5. RTU 1 average on-time schedule

Day	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%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	2%	3%	0%	0%	0%	0%	0%	0%	0%
2	1%	3%	0%	0%	0%	4%	44%	44%	44%	31%	19%	4%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
3	0%	0%	0%	0%	0%	1%	25%	25%	23%	5%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
4	0%	0%	0%	0%	0%	3%	38%	38%	31%	19%	13%	13%	13%	13%	7%	0%	0%	0%	0%	0%	0%	1%	8%	3%
5	0%	0%	0%	0%	0%	3%	44%	44%	40%	33%	21%	11%	11%	6%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
6	0%	0%	0%	0%	0%	2%	22%	22%	20%	12%	11%	6%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
7	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Table 1-6. RTU 2 average on-time schedule

Day	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	11%	11%	13%	11%	11%	11%	11%	11%	11%	11%	11%	6%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	8%
2	10%	5%	0%	0%	1%	8%	6%	5%	4%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
3	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	5%	0%	0%	4%	9%	11%	13%	13%	13%	13%	13%
4	13%	13%	13%	13%	13%	13%	13%	10%	10%	7%	9%	4%	0%	0%	0%	0%	0%	0%	6%	11%	11%	11%	11%	11%
5	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%
6	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%
7	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%	11%

Table 1-7. RTU 3 average on-time schedule

Day	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%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	2%	2%	0%	1%	0%	0%	0%	0%	0%
2	0%	0%	0%	0%	0%	1%	5%	6%	9%	9%	16%	24%	27%	30%	25%	33%	25%	15%	0%	0%	0%	0%	0%	0%
3	0%	0%	0%	0%	0%	0%	0%	1%	4%	15%	18%	19%	22%	19%	21%	26%	23%	11%	0%	0%	0%	0%	0%	0%
4	0%	0%	0%	0%	0%	1%	2%	2%	6%	9%	19%	17%	16%	17%	21%	25%	23%	19%	0%	0%	0%	1%	3%	1%
5	0%	0%	0%	0%	0%	0%	2%	2%	10%	10%	16%	14%	22%	23%	29%	29%	23%	13%	0%	0%	0%	0%	0%	0%
6	0%	0%	0%	0%	0%	1%	5%	7%	10%	12%	13%	21%	27%	30%	35%	30%	24%	12%	0%	0%	0%	0%	0%	0%
7	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

The evaluators observed that in RTU 1 and 3 have consistent 0% operation through unoccupied times on weekdays and weekends on fixed schedules. Rather than having a night-time temperature setback, the schedule indicates that the RTUs are completely off during the unoccupied periods. Since there is no setback at night, the evaluators determined that there is no 7-day schedule or night-time setback measure implemented. The evaluators also noted that there are consistent starts and stops in the schedules rather than gradual starts and stops that would be indicative of optimal start/stop controls. The evaluators noted that RTU 2 was offline for the majority of the metering period, only coming on 5/1 and staying consistently on with no scheduling controls. Based on these findings, the evaluators determined that the EMS measure was not implemented. Table 1-8 through Table 1-11 below provide metered temperature profiles which are consistent with the findings from the amperage loggers. Please note this site also has perimeter heat which maintains space temperature during unoccupied hours (this feature is not part of the EMS scope).

Table 1-8. RTU 1 temperature profile

Day	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	71.4	71.3	71.2	71.1	71.0	71.0	70.9	70.9	71.0	71.1	71.1	71.2	71.4	71.5	71.7	71.7	71.7	71.7	71.6	71.5	71.4	71.3	71.2	71.1
2	71.1	71.0	71.0	70.9	70.9	70.8	70.7	70.6	70.9	71.5	72.4	73.2	73.8	74.3	74.6	74.7	74.8	74.7	74.5	74.5	74.1	73.7	73.2	72.9
3	72.6	72.5	72.4	72.3	72.3	72.2	72.3	72.3	72.5	73.0	73.6	74.1	74.6	75.0	75.3	75.5	75.6	75.4	75.2	75.0	74.5	73.9	73.4	73.0
4	72.7	72.6	72.5	72.3	72.2	72.1	72.0	71.9	72.1	72.7	73.5	74.2	74.8	75.2	75.6	75.9	76.0	76.0	75.8	75.5	74.9	74.4	73.9	73.6
5	73.3	73.1	72.9	72.8	72.6	72.5	72.4	72.4	72.8	73.3	74.0	74.6	75.0	75.3	75.6	75.8	75.9	75.8	75.8	75.7	75.2	74.7	74.2	73.8
6	73.3	73.0	72.7	72.5	72.4	72.2	72.0	72.1	72.4	73.1	73.7	74.3	74.7	75.0	75.3	75.5	75.5	75.4	75.3	75.1	74.5	73.9	73.3	72.9
7	72.6	72.3	72.1	71.9	71.7	71.6	71.5	71.4	71.5	71.6	71.6	71.6	71.8	71.9	72.0	72.1	72.2	72.1	72.1	72.0	71.9	71.8	71.6	71.5

Table 1-9. RTU 2 temperature profile

Day	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	66.7	66.5	66.3	66.2	66.0	65.8	65.6	65.5	65.4	65.4	65.5	65.6	65.9	66.1	66.4	66.6	66.8	66.9	66.8	66.7	66.5	66.4	66.2	66.0
2	65.9	65.8	65.6	65.5	65.4	65.3	65.7	67.9	70.5	71.7	72.3	72.7	73.1	73.5	73.7	73.9	74.0	73.9	73.3	72.3	71.3	70.5	69.8	69.2
3	68.7	68.4	68.2	67.9	67.6	67.3	67.5	69.5	71.7	72.7	73.3	73.8	74.2	74.5	74.8	74.9	75.0	74.7	74.2	73.2	72.0	71.1	70.4	69.8
4	69.3	68.9	68.6	68.2	68.0	67.7	67.9	69.8	72.2	73.1	73.5	73.9	74.3	74.6	74.8	75.0	75.1	74.9	74.2	73.3	72.3	71.5	70.9	70.2
5	69.8	69.4	69.1	68.8	68.5	68.3	68.5	70.4	72.4	73.1	73.4	73.8	74.2	74.5	74.7	74.9	74.9	74.8	74.2	73.3	72.4	71.6	71.0	70.5
6	70.0	69.6	69.3	69.0	68.7	68.4	68.7	70.4	72.3	73.1	73.4	73.8	74.2	74.5	74.7	74.8	74.9	74.6	74.1	73.2	72.2	71.4	70.8	70.2
7	69.7	69.3	68.9	68.5	68.2	68.0	67.9	67.7	67.5	67.5	67.5	67.7	67.9	68.0	68.1	68.1	68.1	68.1	68.0	67.8	67.6	67.4	67.2	67.0

Table 1-10. RTU 3 temperature profile

Day	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	68.8	68.7	68.5	68.3	68.2	68.0	67.9	67.8	67.7	67.8	68.0	68.3	68.7	69.1	69.4	69.7	69.8	69.6	69.4	69.2	69.0	68.9	68.7	68.5
2	68.4	68.3	68.1	68.0	67.9	67.8	67.7	67.9	68.5	69.4	70.2	70.9	71.6	72.0	72.4	72.6	72.6	72.5	72.3	72.1	71.5	71.1	70.7	70.3
3	69.9	69.6	69.4	69.1	68.9	68.7	68.5	68.8	69.6	70.3	71.1	71.8	72.3	72.7	72.8	73.1	73.1	73.0	72.8	72.5	71.9	71.4	70.9	70.5
4	70.2	69.9	69.6	69.4	69.1	68.9	68.7	69.0	69.8	70.5	71.4	72.0	72.6	72.9	73.0	73.1	73.1	73.1	73.1	72.9	72.4	72.0	71.6	71.2
5	70.9	70.6	70.4	70.2	70.0	69.8	69.6	69.9	70.5	71.0	71.8	72.4	72.8	73.1	73.2	73.3	73.4	73.5	73.5	73.3	72.8	72.3	72.0	71.7
6	71.4	71.1	70.9	70.7	70.5	70.3	70.1	70.3	70.9	71.5	72.1	72.4	72.7	72.9	73.1	73.2	73.3	73.3	73.3	73.0	72.5	72.0	71.5	71.1
7	70.7	70.4	70.0	69.7	69.4	69.2	69.0	68.8	68.7	68.7	69.0	69.2	69.5	69.9	70.0	70.2	70.3	70.2	70.1	69.9	69.7	69.5	69.3	69.0

Table 1-11. RTU 4 temperature profile

Day	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	70.9	70.7	70.6	70.5	70.5	70.4	70.3	70.3	70.4	70.6	71.1	72.0	72.6	72.5	72.1	71.7	71.4	71.2	71.1	71.0	70.9	70.8	70.7	70.6
2	70.5	70.4	70.3	70.3	70.7	70.7	71.3	72.1	72.7	73.4	74.1	74.5	74.8	74.7	74.5	74.2	74.1	74.0	73.8	73.1	72.6	72.1	71.8	71.5
3	71.2	71.0	70.8	70.6	70.6	70.8	71.7	72.6	73.2	73.6	74.1	74.8	75.1	74.9	74.6	74.4	74.3	74.2	74.0	73.4	72.9	72.5	72.1	71.8
4	71.5	71.3	71.1	71.0	70.9	70.9	71.4	72.5	73.1	73.6	74.5	75.1	75.1	74.9	74.7	74.5	74.3	74.2	74.2	73.5	73.0	72.6	72.2	71.9
5	71.6	71.4	71.1	71.0	71.0	71.0	71.6	72.8	73.5	73.8	74.5	75.3	75.6	75.3	75.0	74.7	74.4	74.3	74.1	73.4	72.8	72.3	71.8	71.5
6	71.2	70.9	70.6	70.4	70.3	70.2	70.9	72.2	73.0	73.6	74.5	75.1	75.3	75.1	75.0	74.7	74.3	74.0	73.8	73.2	72.6	72.3	71.9	71.6
7	71.3	71.0	70.8	70.5	70.3	70.3	70.2	70.1	70.2	70.5	71.1	72.3	73.4	73.5	73.3	72.7	72.3	72.1	71.9	71.7	71.5	71.3	71.2	71.0

3 Final Results

The project consisted of the installation of EMS control points for 4 RTUs. The evaluators determined from the site interview and analysis of metered data that EMS controls were not implemented resulting in zero savings. Table 1-12 provides a comparison of the key parameters.

Table 1-12. Summary of key parameters

Parameter	BASELINE		PROPOSED / INSTALLED	
	Tracking Value(s)	Evaluation Value(s)	Tracking Value(s)	Evaluation Value(s)
RTU Connected Wattage	94 kW	94 kW	94 kW	94 kW
Operating Hours of RTUs	1320	3,000	1320	1320
Thermostat type	4 Non-Wi-Fi thermostats	4 Non-Wi-Fi thermostats	4 Wi-Fi thermostats	3 Wi-Fi thermostats 1 Non-Wi-Fi thermostat
EMS connection status	N/A	N/A	Connected	Not connected
DDC Deemed Savings factor	N/A	N/A	0.025	N/A
Enthalpy Deemed Savings factor	N/A	N/A	0.01	N/A

3.1 Explanation of Differences

The evaluated savings are lower than the applicant-reported values because the measure was not implemented. Table 1-13 provides a summary of savings deviations.

Table 1-13. Summary of deviations

Measure	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
11959744	Other	Measure Installation	-100%	**Decreased savings –** The evaluation findings indicate the measure was not installed.
	Final RR			**0%**

3.2 Lifetime Savings

This measure has been classified as an add-on retrofit. The baseline is the pre-existing condition which consisted of RTUs without an EMS system. Since the first year savings are zero, the lifetime savings were determined to be zero.

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

$$LAGI = FYS \times EUL$$

where:

LAGI = lifetime adjusted gross impact (kWh)

FYS = first year savings (kWh)

EUL = measure life (years)

Table 1-14 provides a summary of key factors that influence the lifetime savings.

Table 1-14. Measure 11959744 - lifetime savings summary

Factor	Tracking	Application	Evaluator
Lifetime savings	22,154.51 kWh	43,430 kWh	0 kWh
First year savings	4,343 kWh	4,343 kWh	0 kWh
Measure lifetime	10 years	10 years	10 years
Baseline classification	Retrofit	Retrofit	Add-on retrofit

3.2.1 Ancillary impacts

There were no ancillary impacts associated with the evaluated measure.

RICE21N087

Report Date: 06/01/2023

Program Administrator	National Grid
Application ID(s)	11955499, 12018706 and 12886490
Project Type	NC/Retrofit
Evaluation Type	Ops
Program Year	2021
Evaluation Firm	DNV
Evaluation Engineer	Shravan Iyer
Senior Engineer	Max Ma

1 Evaluated Site Summary and Results

The evaluated site is a roughly 3 million ft^2 (70 acres) plastic fabrication facility that manufactures Polyethylene Terephthalate (PET) and Polypropylene films for various end-use applications. The facility uses various methods of casting to manufacture the films. In 2019, the facility added a new production line called Line A6 to manufacture multilayer bi-axially oriented polypropylene film. The facility installed a new compressed air system, a new nitrogen generation system, and a new condenser water booster pump to support this new production line. The evaluated project includes the following energy efficiency measures were installed at the site:

EEM-1: Install New Compressed Air system- The measure involved installing a new compressed air system to serve production line A6. The installed compressed is a 100 horsepower (HP) two-stage variable speed rotary screw compressor with a rated capacity of 460 cubic feet per minute (CFM) of air. The compressor has an integrated zero purge heat-of-compression dryer (HOC) with a capacity of 470 CFM and can provide 100 psig air.

The measure saves energy because the installed variable speed compressor has a better operating efficiency (kW/CFM) than the baseline ISP compressor considered by the facility. Additionally, the installed compressor has an integrated dryer that does not require any heat for purging compared to a purge desiccant dryer that a baseline ISP compressor would use, resulting in additional energy savings.

EEM-2: Installing a new Nitrogen Generation System- The measure involves installing a new cryogenic nitrogen generation system (HPN15) for the new production line A6 as part of a capacity expansion project. The existing nitrogen generation system does not have adequate capacity to serve the new production line.

The measure saves energy owing to the reduced kW demand of the cryogenic nitrogen generation system and the increased efficiency of the new nitrogen generation system due to reduced air to nitrogen ratio from 5.04 to 2.26. Refer to Section 2.1.3 and 2.3.2 for additional information about the N2 generation system.

EEM-3: Installing New 50HP Condenser Water Booster Pump- The measure involves installing a new 50HP booster pump to the condenser water line that serves the process cooling unit. This is to increase the pressure of the 880GPM of tower water supplied to the cooling unit from 15 psig to 50 psig and to supply it to the existing cooling unit that serves line A6.

The measure saves energy by reducing the pressure differential of the (3) 250HP pumps from 50 psi to 15 psi for the two 1,100-ton chillers in the central chilled water plant and running the 50HP booster pump at 50 psi. The energy savings come from the difference between running a 250HP pump at 50 psi vs running a 50HP pump at 50 psi.

The evaluators verified the installation of the new 100HP compressor, the new nitrogen generation system and the new 50HP booster pump. The evaluators confirmed that there are no COVID-19 related impacts on this site and the site contact was available for an on-site visit, so the evaluators proposed to evaluate the site using a Full M&V approach. Table 1-1 provides a summary of the evaluation results.

Table 1-1. Evaluation results summary

PA Application ID	Measure Name		Annual Electric Energy (kWh)	% Of Energy Savings On-Peak	Summer On-Peak Demand (kW)	Winter On-Peak Demand (kW)
11955499	Compressed Air	Tracked	164,607	48%	20.60	20.60
		Evaluated	230,008	48%	24.98	26.21
		Realization Rate	140%	100%	118%	124%
12018706	N2 Generation System	Tracked	3,148,324	48%	393.54	393.54
		Evaluated	4,355,197	48%	497.17	497.17
		Realization Rate	138%	100%	126%	126%
12886490	50HP Booster Pump	Tracked	909,008	47%	69.00	130.40
		Evaluated	927,201	47%	94.80	110.37
		Realization Rate	102%	100%	137%	85%
Total		**Tracked**	**4,221,939**	**48%**	**483.10**	**544.50**
		Evaluated	**5,512,406**	**48%**	**616.95**	**633.75**
		Realization Rate	**131%**	**100%**	**127%**	**116%**

1.1 Explanation of Deviations from Tracking

The evaluated savings are 31% more than the applicant reported savings primarily because: For EEM-1, the base case kW was found to be higher than the applicant reported value, because the evaluators used the appropriate compressed air storage curve based on the storage ratio of 3 Gallons/CFM. Additionally, the evaluators used the actual site reported operating pressure value of 100 psig whereas the applicant reported value of 105 pig was found to be incorrect. For EEM-2: The evaluators used updated N2 production data for the new HPN 15 system to estimate the new N2 loads, which was found to be higher than in the tracking analysis and resulted in higher base case kW. For EEM-3 the post case kW of the booster pump was found to be lower than the applicant reported value and the baseline kW for 1 chiller operation was re-adjusted based on the ratio of pump flow rates for one and two chiller operation. Further details regarding deviations from the tracked savings are presented in Section 3.1.

1.2 Recommendations for Program Designers & Implementers

The evaluators recommend the re-energizing of the free-cooling system during the winter to offset the use of the chiller.

1.3 Customer Alert

There is no relevant customer alert.

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 the installation of one new air compressor, a new nitrogen generation system and a 50HP booster pump to support the operation of the facility's newly added A6 production line.

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.

2.1.1 Applicant Description of Baseline

The applicant baseline as explained in the project documentation is described below:

EEM-1: Install New Compressed Air system-

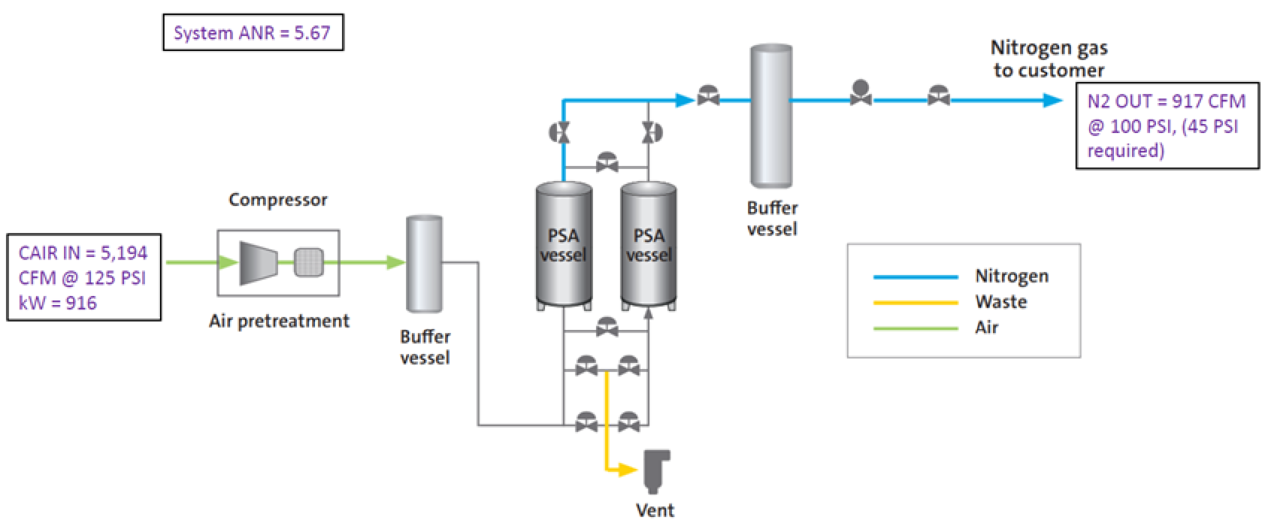
The applicant categorized this project as a new construction measure with an ISP baseline. The new line A6 did not have a pre-existing compressed air system. The baseline system that was considered for this new line was a 100 HP two stage oil free load/unload rotary screw compressor with a rated capacity of 460 CFM and a 550 CFM heatless desiccant dryer. The compressor to be installed would serve Line A6 only.

EEM-2: Installing a new Nitrogen Generation System-

The applicant categorized this project as a new construction measure with an ISP baseline. A new nitrogen generation system was required since the existing system did not have adequate capacity to serve the new production line A6. This system is independent of the compressed air system detailed in EEM 1. The base case system under consideration was a Pressure Swing Adsorption (PSA) system. The system uses an air compressor to provide pressurized air at 125 psig to an adsorption tower, which consists of an activated carbon medium that serves as the adsorbent and adsorbs the oxygen, CO_2 and other hydrocarbons from the air which is the adsorbate in this case and thus filters out pure nitrogen. The baseline system that was proposed for this site consisted of installing (2) PSA systems, with each system having two compressors in parallel providing 27,000 SCFH (450 CFM) each and therefore providing a combined flow rate of 55,000 SCFH (917 CFM) of nitrogen to cater to the increased demand from the new production line A6.

The following figure illustrates the working of the PSA system:

Figure 2-1 Base Case PSA Nitrogen Generation System (1 of 2)



EEM-3: Installing New 50HP Condenser Water Booster Pump-

The applicant categorized this measure as a retrofit with the existing equipment as the baseline. The base case consisted of the facility operating the (3) 250 HP condenser water pumps at 50 psi pressure, such that the pumps would provide condenser water from the cooling tower to the two 1,100-ton chillers that exclusively serves the production line A6.

Table 2-1 provides a summary of the applicant's baseline parameters.

Table 2-1. Applicant baseline summary

Measure	Parameter	Value(s)	Source of Parameter Value
EEM-1	Compressor HP	101	Applicant Calculation, CAGI sheet
EEM-1	Compressor Rated Capacity	460 CFM	Applicant Calculation, CAGI sheet
EEM-1	Compressor Rated Operating Pressure	100 psig	Applicant Calculation, CAGI sheet
EEM-1	Dryer Type	Heatless Desiccant	Applicant Calculation, Spec sheet
EEM-1	Base Case Dryer kW	0.09 kW	Applicant Calculation, Spec sheet
EEM-1	Dryer Purge CFM	88.2 CFM	Applicant Calculation, Spec sheet
EEM-1	Compressor Control Type	Load/Unload	Applicant Calculation, CAGI sheet
EEM-2	N2 system compressor HP	300 HP	Applicant Calculation, Spec sheet
EEM-2	N2 Compressor Rated Capacity	1,571 CFM at 125 psig	Applicant Calculation, Spec sheet
EEM-2	N2 Compressor Rated full load kW	273.4 kW	Applicant Calculation, Spec sheet
EEM-2	N2 Compressor Rated Pressure	125 psig	Applicant Calculation, CAGI sheet
EEM-2	N2 Compressor Operating Pressure	100 psig	Applicant Calculation, Spec sheet
EEM-3	Chilled Water Pump #1 HP	250 HP	Applicant Calculation, Spec sheet
EEM-3	Chilled Water Pump #2 HP	250 HP	Applicant Calculation, Spec sheet
EEM-3	Chilled Water Pump #3 HP	250 HP	Applicant Calculation, Spec sheet
EEM-3	Chilled Water Pump discharge pressure	50 psi	Applicant Calculation
EEM-3	Rated Flow (GPM) for each pump	3,450 GPM	Applicant Calculation, Spec sheet
EEM-3	Chiller Capacity (Tons)	1,100 Tons	Applicant Calculation, Spec sheet

2.1.2 Applicant Description of Installed Equipment and Operation

The installed equipment for each measure is described below:

EEM-1: Install New Compressed Air system-

The installed equipment for this measure involves installing a new compressed air system for the new production line A6. The new system is an oil-free 100 HP two stage variable speed rotary screw compressor with a rated capacity of 460 CFM along with an integrated zero purge heat-of-compression dryer. The system can provide 100 psig pressure at a dew point of -40° F.

EEM-2: Installing a new Nitrogen Generation System-

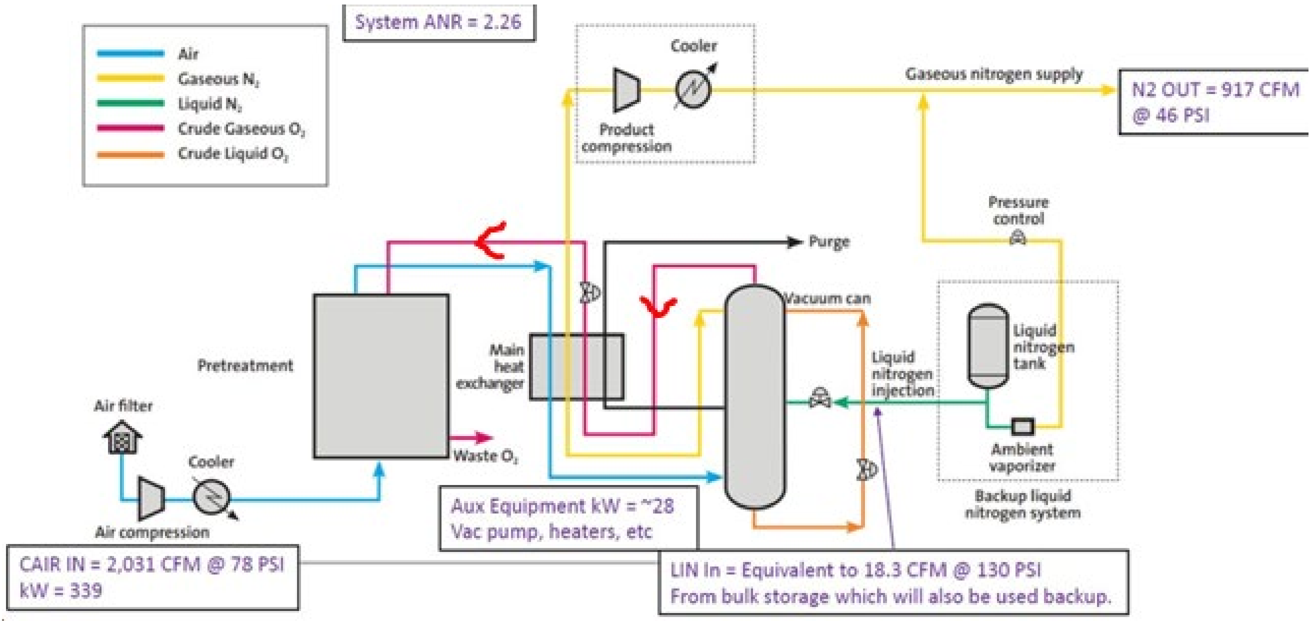
The installed equipment involves installing a new cryogenic nitrogen generation system for the new production line A6 as part of a capacity expansion project. The existing nitrogen generation system does not have adequate capacity to serve the new production line.

For context, a brief explanation of the cryogenic Nitrogen generation system is as follows: atmospheric air is compressed by an air compressor and is cooled in the aftercooler. The aftercooler does the initial cooling of the compressed air, wherein the atmospheric air is first compressed by the compressor and then cooled by the aftercooler. Next, the air is passed through the pre-treatment process where it is treated to remove moisture, CO_2, hydrocarbons and other components. The air is then passed through a heat exchanger where it is liquified and enters a distillation column where the liquid nitrogen is separated from the air. Here, the main prime mover in the system is the air compressor-after cooler system (which acts as a single packaged unit) and drives the energy savings for this measure.

The measure saves energy owing to the reduced kW demand of the cryogenic nitrogen generation system and the increased efficiency of the new nitrogen generation system due to reduced air to nitrogen ratio from 5.04 to 2.26.

The new system is illustrated in the figure below:

Figure 2-2 Installed Cryogenic Nitrogen Generation System



Here, it should be noted that the primary energy consuming component of this system is the air compressor and the aftercooler/cooling package which is the area of concern for the evaluation since the energy savings that was claimed for this project revolves around the operation of the compressor-aftercooler system.

It is also important to note that the compressor serving the nitrogen system is separate and different from the air compressor that serves line A6. The nitrogen plant is one integrated system that does not interact with other outside systems such as the compressors that supply the compressed air for production purposes.

EEM-3: Installing New 50HP Condenser Water Booster Pump-

The measure involves installing a new 50HP booster pump to the condenser water line that serves the process cooling unit. The measure saves energy by reducing the pressure differential of the (3) 250HP pumps from 50 psi to 15 psi for the two 1,100-ton chillers in the central chilled water plant and running the 50HP booster pump at 50 psi. The energy savings comes from the difference between running a 250HP pump at 50 psi vs running a 50HP pump at 50 psi.

Table 2-2 provides a summary of the applicant's installed equipment parameters.

Table 2-2. Application proposed case key parameters

Measure	Parameter	Value(s)	Source of Parameter Value
EEM-1	Compressor HP	101	Applicant Calculation, CAGI sheet

EEM-1	Compressor Rated Capacity	470 CFM	Applicant Calculation, CAGI sheet
EEM-1	Compressor Rated Operating Pressure	100 psig	Applicant Calculation, CAGI sheet
EEM-1	Dryer Type	Heat of Compression (HOC)	Applicant Calculation, Spec sheet
EEM-1	Dryer Purge CFM	0 CFM	Applicant Calculation, Spec sheet
EEM-1	Compressor Control Type	VFD	Applicant Calculation, CAGI sheet
EEM-2	N2 system compressor HP	378 HP	Applicant Calculation, Spec sheet
EEM-2	N2 Compressor Rated Capacity	2,118 CFM at 125 psi	Applicant Calculation, Spec sheet
EEM-2	Aftercooler kW	17 kW	Applicant Calculation, Spec sheet
EEM-3	Chilled Water Pump #1 HP	250 HP	Applicant Calculation, CAGI sheet
EEM-3	Chilled Water Pump #2 HP	250 HP	Applicant Calculation, Spec sheet
EEM-3	Chilled Water Pump #3 HP	250 HP	Applicant Calculation, Spec sheet
EEM-3	Chilled Water Pump discharge pressure	15 psi	Applicant Calculation, Spec sheet
EEM-3	Rated Flow (GPM) for each pump	3,450 GPM	Applicant Calculation, Spec sheet
EEM-3	Chiller Capacity (Tons)	1,100 Tons	Applicant Calculation

2.1.3 Applicant Energy Savings Algorithm

The applicant savings algorithm as described in the applicant documentation is described below:

EEM-1: Install New Compressed Air system

The applicant documentation listed the following parameters for the compressed air system operation:

Operating Hours per Year= 8,000 Hrs./yr.
Avg Operating CFM[1]= 235 CFM

Base Case (Fixed speed) Compressor Data:

The following data was obtained from the baseline compressor's CAGI sheet:

Table 2-3 Base Case and Post Case Compressor Data (From CAGI sheet)

Base case compressor	
Parameter	Value
Nameplate HP	*101*
Rated capacity (cfm)	*460*
Rated operating pressure	*100 psig*
Rated Full Load Power	*90.1 kW*
Rated Zero Flow Power	*22.9 kW*
Actual Operating pressure required	*105 psig*
Operating Full load Power	$0.995^{(100-105)} \times 90.1$ kW =92.4 kW

[1]This was claimed to be an estimate since at the time of installation when the new line was not operational.

Post-case compressor	
Parameter	Value
Nameplate HP	*101*
Rated capacity (cfm)	*470*
Rated operating pressure	*100 psig*
Rated Full Load Power	*95.6 kW*
Rated Zero Flow Power	*10.4 kW*
Actual Operating pressure required	*100 psig*

Figure 2-3 Screenshot showing Applicant Calculation

Base Case Compressor			
Brand	Atlas		
Model	ZR75-105		
Qty	1		
Nameplate HP	101	HP	From CAGI ------>
Rated Capacity SCFM:	460.0	CFM	From CAGI ------>
Rated Pressure:	100	psi	From CAGI ------>
Rated Full Load kW:	90.1	kW	From CAGI ------>
Rated Zero Flow kW:	22.9	kW	From CAGI ------>
Zero Load kW input percentage:	25.4%		
Operational Pressure:	105	psi	Per Customer
Operational Full Load kW:	92.4	kW	
Air Storage	1500	gallons	
Storage ratio	3	Gallons/CFM	

Flow (CFM)	kW
460	92.4
-	22.9

*Used for chart inputs

Based on the above, a regression model was created based on the flow (cfm) and input power (kW) as shown below:

Table 2-4 Base Case CFM flow and kW

Flow (CFM)	kW
460	92.4
0	22.9

The regression coefficients are shown in the table below:

Table-2-5 Regression coefficients for Base Case compressor

f(x)	C x X	Constant	R^2
% KW input	0.1511	22.9	0.99

The following table shows the variation of the installed compressor's input power (kW) with the load (CFM) which was obtained from the compressor's CAGI sheet:

Table 2-6 kW v/s Load for Post Case compressor

Operating Pressure	Load (CFM)	kW
100 psig	470	95.6
	392	79.4
	314	64.7
	236	51.2
	158	38.6

A regression model was created using the above data to model the compressor input power (kW) with the load (CFM) as shown below:

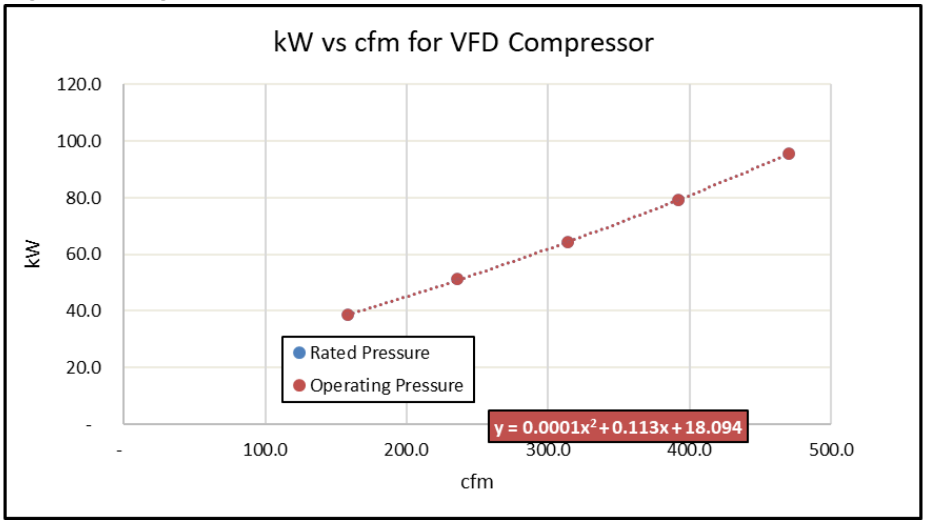
The regression coefficients are shown in the table below:

Table 2-7 Regression coefficients for Post Case compressor

f(x)	A x X^2	B x X	Constant	R^2
Operating Pressure input	0.0001	0.113	18.094	0.99

The graph below shows the regression model for the post case compressor. In this plot, the rated and operating pressures are the same.

Figure 2-4 Regression for Post Case variable speed compressor



Savings Analysis

The annual electric consumption was estimated for the base and post case systems and was inclusive of both the compressor and the dryer for each case respectively.

Base Case (Fixed Speed) Compressor and Dryer kWh Consumption:

We know:
Dryer kW= 0.09 kW
Dryer Capacity= 551 CFM
% Purge air= 16%
Dryer Purge CFM[2]= 16% x 551 CFM
= 88.2 CFM
Compressor Motor HP= 101 HP
Compressor Rated capacity= 460 CFM
Average Operating CFM of the system= Average Operating CFM of Compressor + Dryer CFM
= 235 CFM + 88.2 CFM
= 323.2 CFM

Base Case Compressor kW= 0.1511 x 323.2 CFM + 22.9
Base Case Compressor kW= 71.8 kW

[2] https://moistureboss.com/blog/how-much-energy-is-my-compressed-air-dryer-using/

Base Case Annual Energy Consumption= Base Case System kW x Operating Hours
Base Case Annual Energy Consumption= 71.8 kW x 8,000 Hours/yr
Base Case Annual Energy Consumption= 574,556 kWh/yr.

Post Case (Variable Speedl) Compressor and Dryer kWh Consumption:

Dryer kW= 0.5 kW
Dryer Capacity= 470 CFM
% Purge air= 0%
Dryer Purge CFM= 0% x 551 CFM
= 0 CFM
Compressor Motor HP= 101 HP
Compressor Rated capacity= 470 CFM
Average Operating CFM of the system= Average Operating CFM of Compressor + Dryer CFM
= 235 CFM + 0 CFM
= 235 CFM

Post Case Compressor kW= $(0.0001 \times (235\ CFM)^2) + (0.1130 \times 235\ CFM) + 18.0936$
Post Case Compressor kW= 51.2 kW

Post Case Annual Energy Consumption= Post Case System kW x Operating Hours
Post Case Annual Energy Consumption= 51.2 kW x 8,000 Hours/yr.
Post Case Annual Energy Consumption= 409,949 kWh/yr.

Total Savings= Base Case Consumption – Post Case Consumption
Total Savings= 574,556 kWh – 409,949 kWh
Total Savings= 164,607 kWh/yr.

Therefore, the measure saves 164,607 kWh/year.

EEM-2: Installing a new Nitrogen Generation System-

The energy savings for this measure consists of estimating the base case and post case energy consumption for the two air compressors that are used in the base case and post case Nitrogen generation system i.e., the PSA and cryogenic systems respectively.

Base Case Compressor performance:

The base case Nitrogen generation system consisted of (2) PSA systems which consist of two 300HP air cooled single stage rotary screw compressors each i.e., a total of four compressors across the two systems. The two systems work in conjunction to meet the additional Nitrogen load for the new production Line A6 and have a total rated capacity of 55,000 SCFH (916 cfm) N_2 and operate at 100 psig. The base case compressor performance is therefore estimated as shown below:

The following data was obtained from the compressor CAGI sheet:
For each of 4 compressors:
Compressor HP= 300HP
Compressor Rated Capacity= 1,571 cfm
Compressor Rated Pressure= 125 psig
Rated Full Load Power= 273.4 kW
Rated Zero Flow Power= 54 kW
Operating Pressure= 100 psig
Compressed Air storage= 1,550 Gallons
Zero load input kW percentage= 54 kW / 273.4 kW

= 19.8%
Operating kW= $0.995^{(125-100)}$ x 273.4 kW
= 241.2 kW
Compressor Storage Ratio= $\frac{1,550 \text{ Gallons}}{1,571 \text{ CFM}}$
= 1 Gallon/CFM

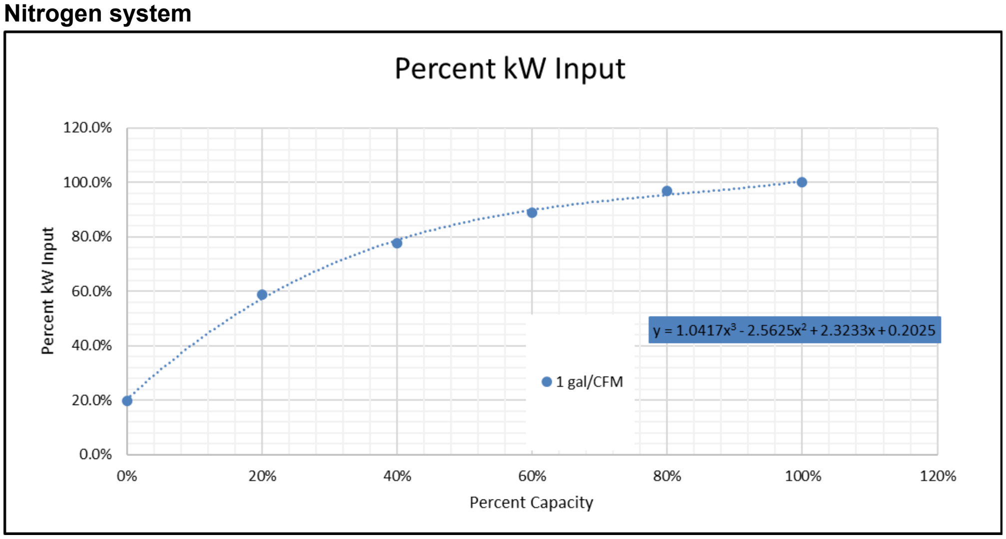
Using the above compressor storage ratio and the results from a study conducted by the Compressed Air Challenge[3] to model the effects of compressor receiver tank capacity with percent input kW for a load/unload control type, the percent input kW was modelled for different part load capacities that the compressor operates at as shown below:

Table 2-8 Percent Input kW vs. Percent Capacity

Percent Capacity	Percent Input kW
0%	19.8%
20%	59%
40%	78%
60%	89%
80%	97%
100%	100%

A regression model was created to determine the correlation between the percent input kW and percent compressed air load (cfm) and the results are shown below:

Figure 2-5 Regression Model showing percent input kW and percent capacity of air compressor for base case Nitrogen system



The regression coefficients are summarized in the table below:

Table 2-9 Regression coefficients for Base Case compressor

f(x)	A x X^3	B x X^2	C x X	Constant	R^2
% Input kW	1.0417	-2.5625	2.3233	0.2025	0.99

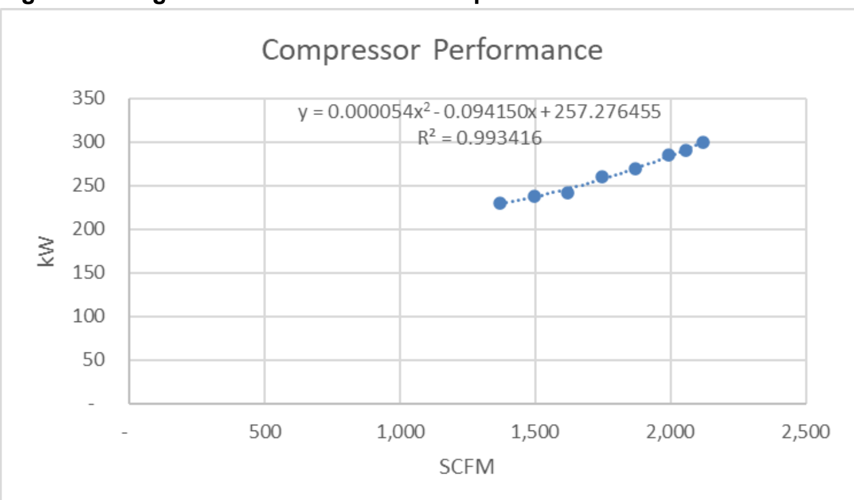
[3] *Fundamentals Of Compressed Air Systems,* Compressed Air Challenge, 2017

Post Case Air Compressor Performance for Nitrogen system:
For the post case compressor, the applicant calculated compressor and after-cooler kWh consumption. Using the compressor spec sheet, the applicant created a regression model to determine the correlation between the compressor capacity (cfm) and the input power (kW) which is described below:

Table 2-10 Post Case Air Compressor Performance data for cryogenic Nitrogen system

kW	cfm
230	1,371
238	1,495
242	1,620
260	1,745
270	1,869
285	1,994
290	2,056
300	2,118

Figure 2-6 Regression for Post Case Compressor



The regression coefficients are tabulated below:

Table 2-11 Regression Coefficients for Post Case Compressor

f(x)	A x X^2	B x X	Constant	R^2
Operating Pressure input	0.000054	-0.094150	257.27645	1

The kW consumed by the aftercooler system is estimated by calculating the total fan kW and the total pump kW for the system as shown below:

Qty. of fans= 10
Fan Motor HP= 1.5 HP
Fan Motor Efficiency= 80%
Pump Motor HP= 15 HP
Pump Motor Efficiency= 95%

Total Cooling system kW= Fan kW + Pump kW

$$\text{Total Cooling system kW} = \frac{\text{Fan Qty.} \times \text{Fan Motor HP} \times 0.746 \times 0.34^{4}}{\text{Fan Motor Efficiency}} + \frac{\text{Pump HP} \times 0.746}{\text{Pump Efficiency}}$$

$$\text{Total Cooling system kW} = \frac{10 \times 1.5\ \text{HP} \times 0.746 \times 0.34}{80\%} + \frac{15\ \text{HP} \times 0.746}{95\%}$$

Total Cooling system kW= 17 kW

Savings Analysis:

Base Case kWh Consumption (For PSA Nitrogen Generation System)

Here, it is important to note the facility conducted a load analysis of their Nitrogen generation system wherein the amount of Nitrogen that the new system would have to generate was determined. Here, the facility tabulated data from January to December of 2019 pertaining to the amount of Nitrogen generated from the pre-existing system and the amount of liquid nitrogen purchased in addition to what was generated onsite. Based on the analysis of existing and proposed Nitrogen loads (from the new line A6) the facility determined that the load on the new nitrogen generation system will be 38,649 SCFH (644 CFM).
Some general input parameters used in the savings analysis are:

Annual Operating Hours= 8,000 hours
System Capacity= 55,000 SCFH
Nitrogen demand= 38,649 SCFH (644 CFM)

Therefore, the Nitrogen demand would be met by the two systems where one system will be run at full capacity i.e., provide 27,500 CFH or 66% of the requirement and the other would provide the rest which is 11,149 SCFH.

Therefore, from the system spec-sheet, we know:
Each of two:
Nitrogen Capacity (SCFH)= 27,500
Compressed Air Req'd/System (SCFH)= 138,600
Compressed Air Req'd/System (CFM)= 2,310

$$\text{Air to Nitrogen Ratio} = \frac{138{,}600\ \text{SCFH}}{27{,}500\ \text{SCFH}} = 5.04$$

Qty of Systems= 2
Total System Capacity (SCFH)= 55,000

Air Compressor data:
Supply Air (SCFM)= 1,571
Operating Pressure (psig)= 100
Qty Per System= 2

[4] Ratio of compressor load (Btuh) to dry cooler capacity -> 985,405 Btuh/ 2,899,875 = 34%

Figure 2-7 Equipment Spec for Base Case N2 system

PRISM® N2 PSA GENERATOR SPECIFICATIONS

Account Name:	Toray Plastics	**Min. Rqd N2 Flow:**	27,500 738	SCFH (68°F) Nm3/hr	
Opportunity Name:	PSA	**Min. Rqd N2 Purity:**	99.999%	N2 + inerts	
Location:	Rhode Island, USA	**Min. Rqd N2 Pressure:**	45	psig	ex-PSA skid
Contract Type:	SOG	**Commercial Lead:**	Alison Krick		
Date:	01 September 2019	**Generated by:**	Alison Krick		

PSA

Device Type		**HP PSA63-200-4**	
Minimum Purity (Nitrogen + Argon & Inerts)	99.9990	vol%	
Normal N2 Delivery Pressure	100	psig	ex-PSA skid
N2 Dew Point at Atmospheric Conditions	-40	°F	(not measured)
Noise Level	87	dBA @ 3 ft	from plant boundary, free field conditions, time weighted average
Plant On-stream Reliability	97%		

Air Requirement

Minimum Required Delivered Air Flow	138600	scfh (68°F)	
Minimum Required Air Pressure	125	psig	
Minimum Required Compressor FAD	2597	acfm	
Compressor Qty/Make/Model	**2 x Kaeser ESD300-125**	SCCR rating	50kA
Actual Compressor FAD	1501	acfm	(per compressor)
NOTE: in accordance with the CAGI/PNEUROP PN2CPTC2 Test Code (Annex C to ISO1217)			
Carbon Filter	2xPSA-CF-350		
Mist Eliminator	HDF-2400		

Table 2-12 Calculation of Total system kW for Base Case PSA system

	N_2 Demand SCFH (A)	CAIR Demand (A)x5.04/60 CFM (B)	Comp 1 CAIR Demand CFM (C)	Comp 2 CAIR Demand CFM (B)-(C) (D)	Comp 1 % Load (C)/1571 (E)	Comp 2 % Load (D)/1571 (F)	Comp 1 Demand (kW) $(1.0417 \times E^3) - (2.5625 \times E^2) + (2.3233 \times E) + 0.2025 \times 241.2$ (G)	Comp 2 Demand (kW) $(1.0417 \times F^3) - (2.5625 \times F^2) + (2.3233 \times F) + 0.2025 \times 241.2$ (H)
PSA System 1	27,500	2,310	1,571	739	100%	47%	242	202
PSA System 2	11,149	937	937	0	60%	0%	216	49

Total Demand= 242 kW + 216 kW + 202 kW + 49 kW
Total Demand= 710 kW

Base Case kWh Consumption= 710 kW x 8,000 Hours/yr.
Base Case kWh Consumption= 5,676,626 kWh/Yr.

Post Case kWh Consumption (For Cryogenic Nitrogen Generation System)

In the post case, there would be only one cryogenic system (with one compressor and aftercooler) that serves the nitrogen load i.e., 38,649 SCFH (644 CFM). The nitrogen load was estimated using the nitrogen purchase data provided by the site. The amount of liquid N2 purchased by the site to balance the overall plant loads was used to adjust the nitrogen used by the site and was used to determine the average hourly nitrogen usage. Using the average hourly nitrogen usage, the applicant estimated the new nitrogen loads for the HPN15 plant. The following screenshots show the applicant analysis of the facility's nitrogen loads for clarity:

Figure 2-8 Screenshot of Applicant Calculation

2019 Mth	HPN20 (SCF)**	Purchased Liquid N2 (SCF)	Adjusted Liquid N2 (SCF)*	Total N2 Used (liquid + Gen) (SCF)	% Liquid N2
January	49,046,850	No Data			
February	43,654,627	No Data			
March	49,088,076	6,566,955	4,112,551	53,200,627	7.7%
April	45,132,130	8,444,332	6,187,726	51,319,856	12.1%
May	47,946,255	3,228,962	831,649	48,777,904	1.7%
June	45,705,219	3,476,541	1,191,280	46,896,499	2.5%
July	40,330,463	13,286,145	11,269,622	51,600,085	21.8%
August	48,385,976	3,024,958	605,659	48,991,635	1.2%
September	46,983,370	2,401,400	52,231	47,035,602	0.1%
October	48,397,198	3,124,642	704,782	49,101,980	1.4%
November	45,175,234	2,385,310	126,549	45,301,783	0.3%
December	47,795,616	3,100,191	710,410	48,506,026	1.5%
			Average Monthly Usage	**49,073,200**	**SCF**
			Annual Usage	**588,878,397**	**SCF**
			Avg Hourly Usage	**67,224**	**SCFH**

Using the above average hourly usage as described above, the new nitrogen loads for the new plant was estimated as shown below:

Figure 2-9 Screenshot of Applicant Load calculation

	Current System Operation		
Existing Capacity	70,000	SCFH	Existing HPN20
Connected Load	77,340	SCFH	All equipment design loads
Current HPN20 Supply	63,657.65	SCFH	Based on HPN20 data for 1 year.
% Liquid N2 Supplement	10.55%		Supplement from Bulk Liquid N2 ---->
Avg Usage	67,224	SCFH	Both produced and purchased N2
% of Connected Load	87%		
	Estimated System Operation		
New HPN15 Capacity	55,000	SCFH	
New System Capacity	125,000	SCFH	
Est % Connected Load	87%		Assumes same percent as current system
New Avg Usage	108,649	SCFH	
% Increase in Load	71%		
HPN20 avg Load	70,000	SCFH	HPN20 will operate at full capacity
New HPN15 Load	**38,649**	**SCFH**	**HPN15 will trim load**

From the system spec sheet, we know:

Qty of Systems= 1

Total System Capacity (SCFH)= 55,000 Nitrogen

Compressed Air Req'd/System (SCFH)= 121,871

Compressed Air Req'd/System (SCFM)= 2,031

Air to Nitrogen Ratio= $\dfrac{121{,}871 \text{ SCFH}}{55{,}000 \text{ SCFH}}$

= 2.22

Figure 2-10 Equipment Spec For Post Case System

HPN System Specification

Account Name	Toray Plastics (America), Inc.	**Required N2 Flow**		55,000	SCFH
Opportunity Name	North Kingston	**Required purity**		10	ppm
Country	USA	**Required N2 Pressure**		45.8	psig
Date	18-Nov-19	**Generated by**	Dorothea Tsang		
City/ State	North Kingston, RI	**HPN Size**	15HPN	24.1	TEPSA Vessels
		Delivery Time	13	Months	

Design Conditions				
	Average	2% Annual High		
Ambient Temp. (dry bulb) °F	53	81	°F	
Relative Humidity	68		%	
Atmospheric Pressure	14.501		psia	
Site elevation	10		ft above sea level	
Seismic conditions	UBC Zone 4, Importance Factor 1, Source Type B, 5 km from source			
Wind Loading	110 miles/hr, Importance Factor 1, Exposure Category D.			
Snow Loading	see PPL600 PROD 0012,required when the annual snowfall is greater than 60 inches/year			
Hazardous Area	Non-Hazardous			
Regulation/code requirement	0			

HPN Performance				
	Average	2% Annual High		
N2 Flowrate	55,000	xxxx	SCFH	+/-5% tolerance
Purity	10	xxxx	ppm(v)-O2 in N2	
N2 Delivery Pressure	45.8	xxxx	psig	Ex-backup
Product water content	xxxx	xxxx	ppm	Moisture analyzer optional
Min. Product Temp	xxxx	xxxx	°F	Normally temp is ambient temp
Noise Level	90 dBA			dBA at 3ft away from plant boundary
On stream Guarantee	98.5%			

Air Requirement		
Required dry MAC air flow	121871	SCFH
Required air pressure Ex-MAC	77.6	psi
Compressor Model	TA3000M2 - 400 HP / 800 HP	

Air Compressor data:

Supply Air (SCFM)= 2,031

Operating Pressure (psig)= 78

Qty Per System= 1

CCCW (kW) (Aftercooler kW)= 17

Table 2-13 Calculation of Total system kW for Post Case Cryogenic system

	N_2 Demand SCFH (A)	CAIR Demand (This system is assumed to run at rated CFM) (B)	Comp 1 CAIR Demand $(0.000054 \times B^2) - (0.094150 \times B) + 257.276$ (kW) (C)	CCCW power (kW) From spec sheet (D)	Regen Heater (kW) From spec sheet (E)	Misc. (kW) From spec sheet (F)	Total Demand (kW) From spec sheet (G)
Cryogenic System	38,649	2,031	289	17	5.6	5.1	316

Post Case kWh Consumption= 316 kW x 8,000 Hrs./yr.
Post Case kWh Consumption = 2,528,302 kWh/yr.

Annual Energy Savings= Base Case kWh Consumption – Post Case kWh Consumption
Annual Energy Savings= 5,676,626 kWh – 2,528,302 kWh
Annual Energy Savings= 3,148,324 kWh/yr.

Therefore, the measure saves 3,148,324 kWh/yr.

EEM-3: Installing New 50HP Condenser Water Booster Pump-

The savings for this measure was calculated using trend data obtained from the facility's SCADA system. Trend data was obtained for each 250HP pump wherein the facility simulated the operation of the pumps under different operating conditions for the base case and post case operation as described below:

Base Case Operation-

For the base case, the simulation using the SCADA system included running (3) condenser water pump for two 1,100 Ton chillers. There is no booster pump operation associated in this case. The pressure differential provided by the pumping system is 50 psi which is higher than the pressure required for the chiller. The base case operation involves running the (3) 250 HP condenser water pumps at 50 psi pressure differential to provide 3,200 GPM of water to the chillers and 880 GPM of water to the cooling unit serving Line A6. The savings for this measure basically comes from running the 250HP pumps at 50 psi vs running a 50HP pump at 50 psi.

Proposed Case Operation-

The proposed case operation involved two scenarios namely: a) The data was obtained that showed the average condenser water pump kW when one chiller and the booster pump is running. b) This scenario showed the average kW of the condenser water pumps when both chillers and the booster pump were running.

We know:

No. of Chillers= 2
Single Chiller Rated Tonnage= 1,100.0 Tons
Max Cooling Load Design= 2,200.0 tons
Free-Cooling Engages at= 38.0°F
Booster Pump BHP= 39.6HP From pump datasheet
Booster Pump Motor Efficiency= 95%
Booster Pump Electric Usage= 39.6 HP x 0.746
= 31.1 kW
Base Case 1 Chiller Condenser Water Pump Electric Usage[5]= 224 kW
Proposed Case 1 Chiller Condenser Water Pump Usage[6]= 62 kW
Proposed Case 2 Chillers Condenser Water Pump Usage[7]= 124 kW
Number of hours of free cooling: 2,587 hrs/yr.
Number of hours with 1 chiller, 1 @ 250-hp pump and booster pumps: 5,934/yr
Number of hours with 2 chillers 2 @ 250-hp pump and booster pumps: 2,066/yr

[5] From trend data obtained from SCADA system
[6] Ibid
[7] Ibid

Figure 2-11 Screenshot of Applicant Chiller Bin Analysis

WEATHER DATA *from Peak Savings Tab (5)				ESTIMATED PUMP LOADS							EXISTING CASE CHILLER POWER AND ENERGY CONSUMPTION		PROPOSED CASE CHILLER POWER AND ENERGY CONSUMPTION	
Mid-pts	Dry Bulb (°F)	WB °F	Hrs	Total Chilled Water Load (Tons)	Number of Chiller Running	Free Cooling?	Existing Cond Pump kW	Proposed Cond Pump kW	Proposed Booster Pump kW		Pump Power (kW)	Total Pump Energy (kWh)	Pump Power (kW)	Total Pump Energy (kWh)
97.5	95 to 100	71.0	3	2,001.5	2.0	No	220.1	123.7	31.1		220.1	603	154.8	424
92.5	90 to 95	74.1	37	2,209.1	2.0	No	220.1	123.7	31.1		220.1	8,241	154.8	5,795
87.5	85 to 90	72.7	69	2,120.1	2.0	No	220.1	123.7	31.1		220.1	15,275	154.8	10,742
82.5	80 to 85	69.6	272	1,938.4	2.0	No	220.1	123.7	31.1		220.1	59,895	154.8	42,121
77.5	75 to 80	68.0	434	1,788.8	2.0	No	220.1	123.7	31.1		220.1	95,470	154.8	67,139
72.5	70 to 75	65.8	508	1,678.6	2.0	No	220.1	123.7	31.1		220.1	111,751	154.8	78,588
67.5	65 to 70	62.6	742	1,388.9	2.0	No	220.1	123.7	31.1		220.1	163,405	154.8	114,914
62.5	60 to 65	57.2	826	942.3	1.0	No	223.9	62.3	31.1		223.9	184,827	93.4	77,138
57.5	55 to 60	52.1	591	654.0	1.0	No	223.9	62.3	31.1		223.9	132,282	93.4	55,208
52.5	50 to 55	47.6	692	654.0	1.0	No	223.9	62.3	31.1		223.9	154,976	93.4	64,680
47.5	45 to 50	43.2	563	654.0	1.0	No	223.9	62.3	31.1		223.9	125,944	93.4	52,563
42.5	40 to 45	38.8	676	654.0	1.0	No	223.9	62.3	31.1		223.9	151,296	93.4	63,144
37.5	35 to 40	33.9	841	654.0	1.0	Yes	223.9	62.3	31.1		223.9	188,302	93.4	78,589
32.5	30 to 35	29.2	735	654.0	1.0	Yes	223.9	62.3	31.1		223.9	164,586	93.4	68,691
27.5	25 to 30	24.3	353	654.0	1.0	Yes	223.9	62.3	31.1		223.9	79,124	93.4	33,023
22.5	20 to 25	19.7	342	654.0	1.0	Yes	223.9	62.3	31.1	Free-Cooling Range	223.9	76,670	93.4	31,999
17.5	15 to 20	15.1	205	654.0	1.0	Yes	223.9	62.3	31.1		223.9	45,798	93.4	19,114
12.5	10 to 15	10.2	88	654.0	1.0	Yes	223.9	62.3	31.1		223.9	19,628	93.4	8,192
7.5	5 to 10	5.8	22	654.0	1.0	Yes	223.9	62.3	31.1		223.9	4,907	93.4	2,048
2.5	0 to 5	2.1	1	654.0	1.0	Yes	223.9	62.3	31.1		223.9	204	93.4	85
		Annual Hours:	**8,000**								**Annual Energy Consumption**	1,783,185	**Annual Energy Consumption**	874,197

Using the above data, the applicant used a weather bin analysis to model the hours and chiller load (tons) that the chillers would operate at for each temperature bin. The analysis was modeled to reflect free cooling when the wet bulb temperature of the outdoor air went below 38°F. Here, it should be noted that the applicant factored in the free cooling savings in their analysis, the evaluation found that the free cooling system was not operational during the site visit. The base case and post case kWh was modeled from the data. The difference between the base case and post case kWh consumption is the savings.

2.1.4 Evaluation Assessment of Applicant Methodology

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

2.2 On-Site Inspection and Metering

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

The evaluators conducted a site visit on 10/04/2022 to verify the installation of the new compressed air system on Line A6, the new cryogenic Nitrogen generation system and the new 50HP booster pump for the site's chilled water system and to install ElitePRO power loggers to capture trend data (voltage, amperage, and power factor) on the above systems. The evaluators had an initial discussion with the main site contact who is the Senior Director of Engineering at the site who explained to the evaluators that the new production Line A6 was installed and commissioned in 2019 as part of a capacity expansion project, and the nitrogen plant was installed in around December 2020.

The new Line A6 required its own compressed air system, and the new 100HP variable speed compressor exclusively serves just this line. The operating pressure of the compressed air system is 100 psig. Figure 2-13 below shows the new 100HP variable speed compressor onsite:

Figure 2-12 New 100 HP VFD Compressor

Additionally, the evaluators confirmed with the site contact that the new Nitrogen generation system was installed because the existing system was not adequate to serve the nitrogen loads of the facility. The facility installed a cryogenic Nitrogen generation system as part of the project and the purpose of the new Nitrogen plant was to serve as a trim to meet the additional loads of the facility as required. The new system can provide an additional 55,000 SCFH of nitrogen and consists of a compressor that can provide up to 2,031 CFM of air. The Nitrogen generation system at the site consists of one receiver head that carries the Nitrogen from both the existing and the new system. The following Figure shows the facility's new Nitrogen plant:

Figure 2-13 New Cryogenic Nitrogen Generation plant

The site contact described the facility's chilled water system which consists of a central chilled water plant. The chilled water plant consists of two 1,100 Ton water cooled chillers that serve the facility's chilled water requirements for process cooling. The chillers are looped to a cooling tower and a plate-and-frame heat exchanger that helps enable free cooling when the temperature falls below 38°F. The chillers are served by three 250HP condenser water (tower water) pumps that circulate water from the cooling tower to the chillers. Additionally, the 250HP tower water pumps serve a process cooling unit that only serves Line A6. The pumps operate in the following manner: Only one pump runs when the chiller is operating, and the free-cooling system is not operational because the facility had multiple issues with the controls and the way it was wired to the heat exchanger. Two pumps run when both chillers are operational, and the third pump comes on as needed. The booster pump is operational and provides the added pressure up to 50 psig of tower water to the cooling unit. The chillers are said to operational continuously with at least one chiller running constantly.

The following Figure shows the different components of the chilled water system, including the two chillers and the plate-and-frame heat exchanger.

Figure 2-14 Chillers 1 and 2 along with heat exchanger

The operating parameters of the chillers are as follows: Chiller Entering water temperature (EWT)= 47.6F, Chiller leaving Water Temperature (LWT)= 41F, and condenser water temperature (CWT)= 81.9F.

Table 2-14 provides a summary of the on-site verification.

Table 2-14. Measure verification

Measure Name	Verification Method	Verification Result

New 100HP Compressor for Line A6	Physical Inspection of the unit's nameplate data, make and model	Compressor was verified to be installed
New Nitrogen generation System	Physical Inspection of the Nitrogen plant	Nitrogen plant was found to be installed as described in the project files
50HP Booster pump for chilled water system	Physical inspection of pump's nameplate data	Pump was verified to be installed

The evaluator's metering for this site included:

Table 2-15 Summary of Data Loggers

Index Number	Logger Type	Logger ID	Installed System
1	Dent ElitePRO kW Data Logger	XC1803038	100HP Compressor
2	Dent ElitePRO kW Data Logger	XC1610048	250HP Condenser Water Pump
3	Dent ElitePRO kW Data Logger	XC1803072	250HP Condenser Water Pump
4	Dent ElitePRO kW Data Logger	XC1610066	250HP Condenser Water Pump
5	Dent ElitePRO kW Data Logger	XC1803075	50HP Booster Pump

2.3 Evaluation Methods and Findings

This section describes the evaluator methods and findings.

2.3.1 Evaluation Description of Baseline

The evaluators reviewed the project files, interviewed the site contact to gather information on the baseline for the three measures, which the evaluators have categorized as described below:

EEM-1: Install New Compressed Air system- The evaluators agree with the applicant classification of this measure to be a new construction measure with an ISP baseline. The baseline is a fixed speed load/unload compressor.

EEM-2: Installing a new Nitrogen Generation System- The evaluators agree with the applicant classification of this measure to be a new construction with site specific baseline, which in this case is a Pressure Swing Adsorption (PSA) system that has an efficiency (air to nitrogen ratio) of 5.04 at 99.99% nitrogen purity.

EEM-3: Installing New 50HP Condenser Water Booster Pump- The evaluators agree with the applicant classification of this measure to be a retrofit. The base case consisted of the pre-existing condition where the facility operated the (3) 250 HP condenser water pumps at 50 psi, such that the pumps would provide condenser water from the cooling tower to the two 1,100 Ton chillers at 3,200 GPM each and another 880 GPM of tower water to the process cooling unit that exclusively serves the production line A6.

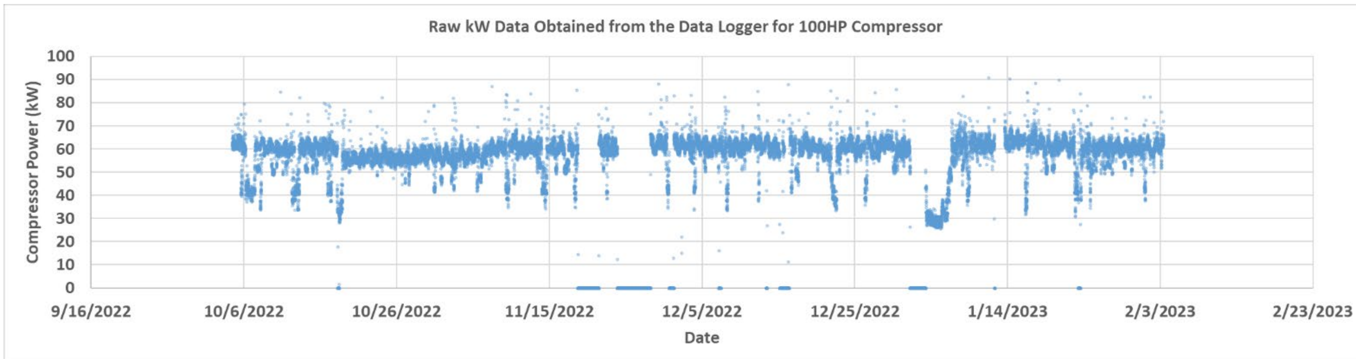
2.3.2 Evaluation Calculation Method

The evaluation calculation method for each of the measures is described below:

EEM-1: Install New Compressed Air system

The evaluators used metered data obtained from the data loggers to model the operating profile of the new 100HP compressor that serves the new production line A6. The raw kW data obtained from the logger is shown in the Figure below:

Figure 2-15 Raw kW Data Obtained from Data Logger



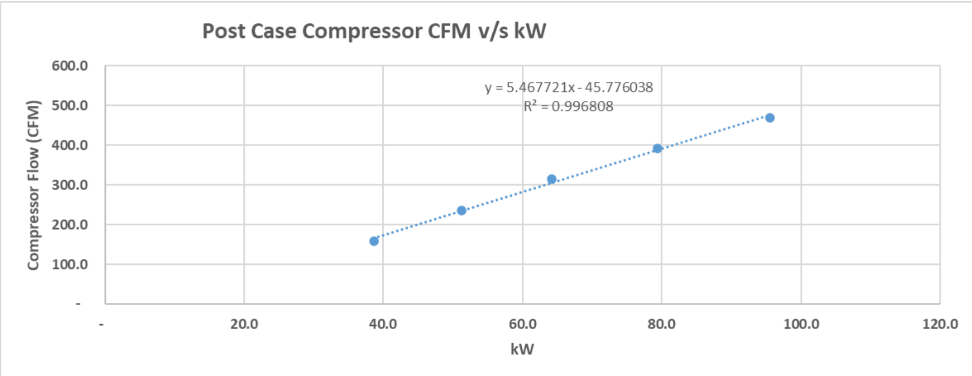
The above Figure shows that the compressor was operating almost continuously for most of the time during the metering period. The evaluators verified that the facility has continuous operation throughout the year and that the operating profile shown above is representative of typical operation. So the data was averaged into a typical 168-hour weekly profile for every hour of the day during a typical weekly period. The data from the logger was aggregated into a typical 168-hour weekly profile as shown in the Figure below:

Figure 2-16 Heat Map showing typical weekly profile of the compressor during the Metering period

Average Weekly kW Profile							
	Sun	Mon	Tue	Wed	Thu	Fri	Sat
0	48.40	43.64	53.40	53.51	46.70	47.21	49.69
1	48.43	44.42	53.43	53.42	46.68	45.97	49.64
2	48.61	45.15	53.66	53.24	46.27	44.93	49.47
3	48.56	45.54	52.72	54.46	45.38	45.33	49.99
4	49.34	45.73	53.37	54.91	45.44	46.33	48.56
5	49.77	45.20	53.69	51.88	43.96	47.07	48.70
6	48.52	45.80	52.67	52.67	41.71	47.96	49.26
7	48.47	48.49	54.47	52.93	42.06	48.27	50.73
8	48.22	42.89	53.88	53.28	43.41	46.81	51.56
9	47.83	43.11	52.91	54.47	45.52	47.27	51.47
10	48.40	42.03	52.70	54.16	45.68	49.63	51.49
11	48.35	41.83	50.53	51.39	46.83	51.22	51.34
12	47.79	45.88	52.68	51.91	46.92	52.84	51.44
13	48.15	48.91	54.05	54.01	46.91	53.80	50.91
14	48.09	52.41	54.18	54.23	50.56	53.61	49.60
15	48.22	53.05	55.73	52.58	50.81	53.89	49.30
16	47.12	54.29	55.85	51.83	51.55	53.37	50.57
17	47.36	54.48	55.13	50.16	50.98	53.14	51.01
18	45.75	53.64	54.37	49.91	49.14	49.60	50.91
19	44.50	53.52	53.39	49.98	46.76	48.98	49.90
20	44.08	52.88	52.56	50.17	46.20	49.09	49.60
21	44.25	52.92	52.62	50.18	46.58	49.15	49.82
22	44.12	53.06	53.88	48.52	46.76	49.62	50.04
23	44.13	53.22	53.98	47.04	47.25	50.11	48.97

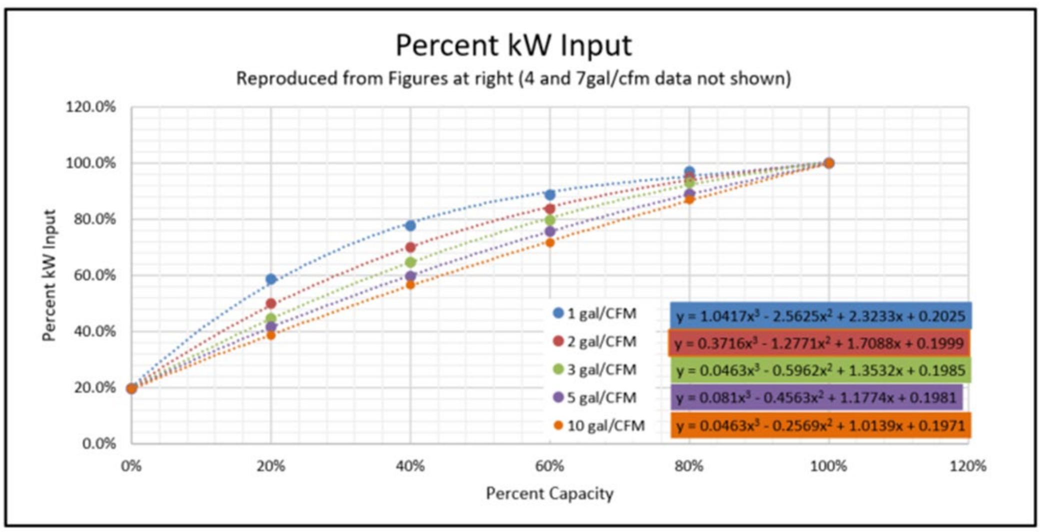
The above heat map shows the typical operating profile of the compressor during the metering period. The post case annual kW was estimated by annualizing the above data using an 8,760 spreadsheet. Now, the post case CFM was modelled using the compressor curve for the post case compressor using data obtained from the compressor CAGI sheet. The curve used to determine the post case CFM is shown below:

Figure 2-17 Post Case Compressor Curve from CAGI sheet



The average post case CFM for the compressor was estimated to be 225 CFM. Now, the applicant analysis used an average CFM value of 235 CFM to model the base case and post case CFM requirements for the production Line A6. The evaluators used the same methodology as the applicant to estimate the baseline kW wherein the evaluators calculated the base case purge CFM for the baseline heatless desiccant dryer by multiplying the rated compressor capacity with the percent purge air as explained in Section 2.1.3 above. The base case compressor CFM was modelled based on the average post case CFM of 225 CFM and the purge CFM of the dryer was added to estimate the total base case CFM of the system. The base case compressor kW was estimated using the curves from the Compressed Air Challenge. The evaluators used a storage ratio of 3 Gallons/CFM (based on 1500-gallon storage for a compressor capacity of 460 CFM) as shown in the Figure below to estimate the base case compressor kW.

Figure 2-18 Compressed Air Curves for baseline



Here, the evaluators used an operating pressure of 100 psig to estimate the base case compressor kW because the evaluators found onsite that the operating pressure of the compressors was 100 psig. This is different from the applicant reported value of 105 psig. The base case dryer kW of 0.09 kW was added to the base case compressor kW to calculate the total base case kW of the system. The difference between the base case and post case kW is the savings. The measure generates 230,008 kWh in savings.

EEM-2: Installing a new Nitrogen Generation System

The evaluators used the same savings calculation methodology used by the applicant to estimate the evaluated savings for this measure because the evaluators feel that the applicant savings methodology is reasonable and comprehensive. However, the evaluators re-adjusted some key parameters such as the post case compressor and aftercooler kW and the nitrogen load at the plant from data obtained on site.

Here, it is to be noted that the evaluators used metered data provided by the site for the whole nitrogen plant and did not install their own. This is because the Nitrogen plant is leased from the vendor and the vendor alone has access to the plant and they did not give the evaluators permission to access the plant and install meters on the compressor which is the primary driver of energy savings. So, the site contact installed a data logger of their own on the main panel of the Nitrogen plant and logged the kW for the entire plant, wherein the key components of the overall plant kW is the compressor and aftercooler kW.

The following heat map shows the operating profile of the compressor during the metering period:

Figure 2-19 Post case operating profile of the compressor

	Sun	Mon	Tue	Wed	Thu	Fri	Sat
0	352.9	351.9	350.5	351.5	355.7	354.9	354.8
1	353.5	355.6	353.9	351.3	351.6	351.8	355.0
2	351.3	353.5	354.8	355.3	354.1	352.9	349.0
3	353.1	351.8	350.6	353.9	355.4	356.3	352.9
4	356.2	354.6	352.4	348.9	352.1	355.3	353.9
5	354.2	356.3	355.5	352.9	351.8	350.6	349.6
6	350.6	352.0	353.2	355.5	353.9	354.9	351.9
7	353.3	352.8	351.1	351.8	355.0	357.5	353.6
8	355.0	355.1	351.6	351.8	351.7	352.0	354.6
9	351.3	353.5	355.2	355.3	352.2	353.3	350.2
10	351.6	350.2	350.9	354.9	355.6	357.2	354.5
11	354.5	352.1	349.7	350.2	352.6	356.0	353.7
12	352.9	354.1	352.0	354.0	351.8	351.1	351.4
13	347.9	348.8	352.2	356.5	353.9	353.7	350.5
14	351.8	349.4	348.7	354.3	353.2	354.3	353.0
15	353.7	354.1	350.9	353.7	351.0	352.0	353.1
16	350.8	352.7	352.9	357.0	352.7	352.6	349.7
17	351.9	350.1	351.9	357.1	355.1	355.3	353.0
18	354.7	353.6	350.8	353.2	352.3	355.9	353.8
19	353.8	355.2	354.2	356.2	351.7	351.7	350.8
20	352.1	351.3	354.3	358.4	356.2	355.2	351.6
21	355.0	352.2	349.7	352.6	355.1	355.4	355.2
22	355.9	355.2	351.2	351.8	350.4	351.8	355.9
23	351.9	353.2	355.1	355.7	352.8	350.3	350.0

The heat map shown above reveals that the nitrogen plant operates at a relatively uniform load during the metering period. Therefore, the average plant kW was estimated to be 353 kW.

The evaluators also re-adjusted the nitrogen loads at the plant after obtaining the production data of the HPN15 nitrogen plant and the nitrogen delivery data for a period of one year from the site. The evaluators obtained the nitrogen production data for HPN15 and the liquid nitrogen purchase delivery data from October 2021 to September 2022. The amount of purchased liquid N2 purchased by the site to balance the overall plant loads was used to adjust the nitrogen used by the site and was used to determine the average hourly nitrogen usage. Using the average hourly nitrogen usage, the applicant estimated the new nitrogen loads for the HPN15 plant. The new nitrogen loads for the plant was estimated to be 29,910

SCFH (498.5 CFM). The evaluators used the same methodology as the applicant to calculate the nitrogen loads for the site using the nitrogen production and delivery data obtained from the site as shown in the Figures below: .

Figure 2-20 Screenshot of Evaluation Load Analysis

Month	HPN15 (SCF)**	Purchased Liquid N2 (SCF)
January	33,058,382	465,829
February	35,155,062	1,295,439
March	39,154,608	624,396
April	37,778,562	744,694
May	39,024,156	1,138,363
June	37,453,976	1,266,855
July	38,205,481	652,049
August	38,572,330	1,137,525
September	36,763,150	1,191,994
October	38,947,752	1,303,447
November	37,571,282	908,381
December	39,348,300	1,024,024

The average hourly nitrogen demand based on 8760 hours was estimated to be 51,488 SCFH[8].

Therefore, using the same analysis methodology described in the applicant analysis section (Section 2.1.3), the evaluators calculated the savings for this measure as shown below:

Annual Operating Hours= 8,760[9] hours
System Capacity= 55,000 SCFH
Nitrogen demand= 51,488 SCFH (858 CFM)

Therefore, in the base case, the Nitrogen demand would be met by the two systems where one system will be run at full capacity i.e., provide 27,500 CFH or 50% of the requirement and the other would provide the rest which is 23,988 SCFH. Therefore, from the system spec-sheet, we know:

Nitrogen Capacity (SCFH)= 27,500
Compressed Air Req'd/System (SCFH)= 138,600
Compressed Air Req'd/System (CFM)= 2,310
Air to Nitrogen Ratio= 5.04
Qty of Systems= 2
Total System Capacity (SCFH)= 55,000

Air Compressor data:
Supply Air (SCFM)= 1,571
Operating Pressure (psig)= 100
Qty Per System= 2

Table 2-18 Calculation of Total system kW for Base Case PSA system

	N_2 Demand (A)	CAIR Demand (A)x5.04/60 CFM (B)	Comp 1 CAIR Demand (C)	Comp 2 CAIR Demand (B)-(C) (D)	Comp 1 % Load (C)/1571 (E)	Comp 2 % Load (D)/1571 (F)	Comp 1 Demand (kW) (1.0417 x E^3) - (2.5625 x E^2) +	Comp 2 Demand (kW) (1.0417 x F^3) - (2.5625 x F^2) +

[8] Total annual HPN 15 production= 451,033,041 SCF per year. Average N2 usage= 451,033,041/8760= 51,488 SCFH.

[9] Updated to 8760 hours using data from the loggers which showed continuous operation during the metering period.

							(2.3233 x E) + 0.2025 x 241.2 (G)	(2.3233 x F) + 0.2025 x 241.2 (H)
PSA System 1	27,500	2,310	1,571	739	100%	47%	242	202
PSA System 2	23,988	2,015	1,571	444	100%	28%	242	164

Total Demand= 242 kW + 242 kW + 202 kW + 164 kW
Total Demand= 850 kW

Base Case kWh Consumption= 850 kW x 8,760 Hours/yr.
Base Case kWh Consumption= 7,447,477 kWh/Yr.

In the post case, there would be only one cryogenic system (with one compressor and aftercooler) that serves the Nitrogen load i.e., 29,910 SCFH (499 CFM).
From the system spec sheet, we know:
Qty of Systems= 1
Total System Capacity (SCFH)= 55,000
Compressed Air Req'd/System (SCFH)= 121,871
Compressed Air Req'd/System (SCFM)= 2,031
Air to Nitrogen Ratio= 2.22

Air Compressor data:
Supply Air (SCFM)= 2,031
Operating Pressure (psig)= 78
Qty Per System= 1
Total Plant kW= 353 kW

Post Case kWh Consumption= 353 kW x 8,760 Hrs./yr.
Post Case kWh Consumption = 3,092,280 kWh/yr.

Annual Energy Savings= Base Case kWh Consumption – Post Case kWh Consumption
Annual Energy Savings= 7,447,477kWh/Yr. –3,092,280kWh/Yr.
Annual Energy Savings= 4,355,197 kWh/yr.

Therefore, the measure saves 4,355,197 kWh/yr.

EEM-3: Installing New 50HP Condenser Water Booster Pump

The evaluators used metered data obtained from the loggers to analyze the operating profile of the three 250HP condenser water pumps that are equipped with VFDs and pump tower water to the chillers. The following charts show the raw kW data obtained from the data loggers for each of the 250HP condenser water pumps:

Figure 2-22 CW Pump-13 Raw kW Data From logger

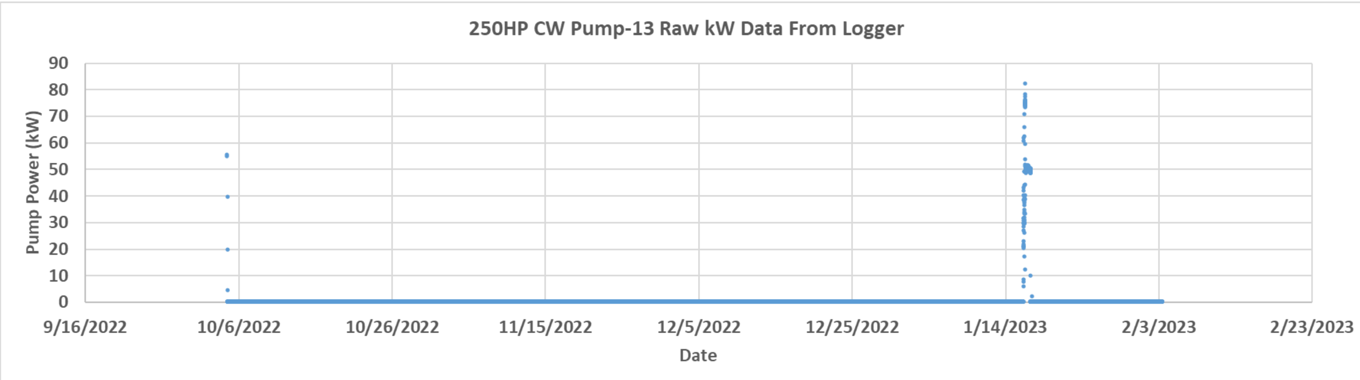


Figure 2-23 CW Pump-14 Raw kW Data from Logger

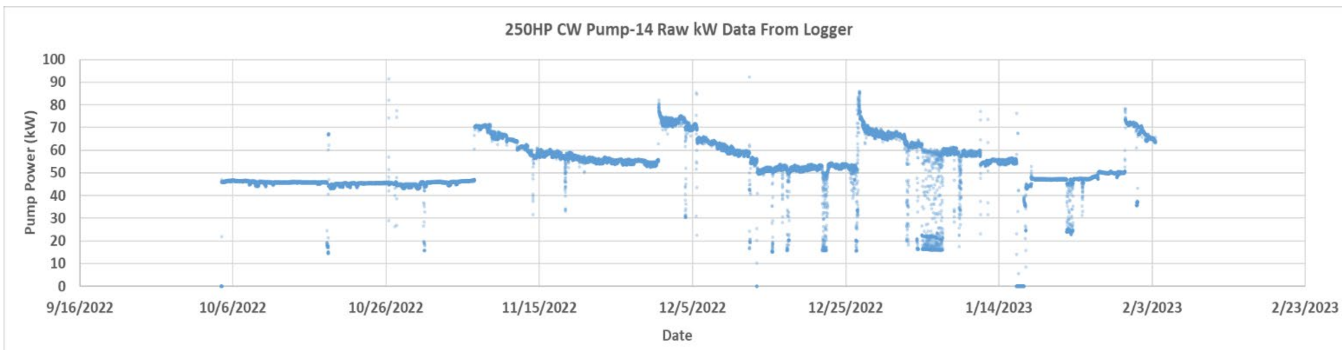
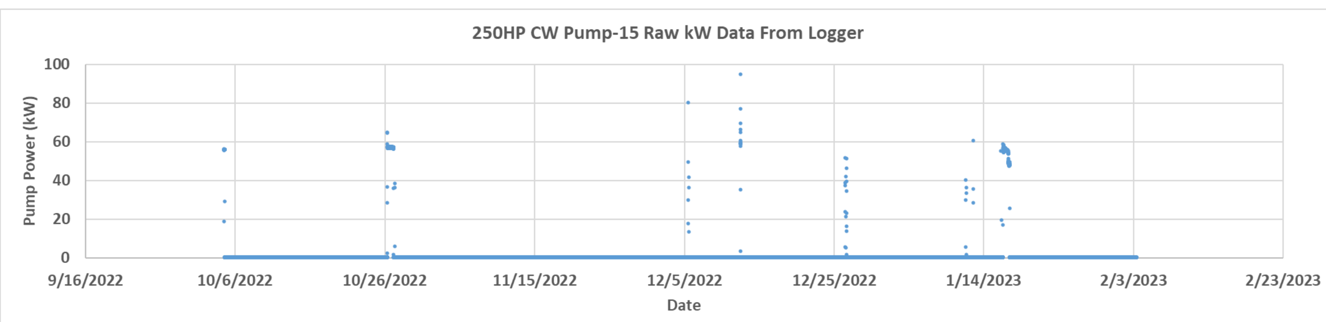


Figure 2-24 CW Pump-15 Raw kW Data from Logger



From the above Figures, we can observe that two of the three pumps show almost negligible operation during the metering period. The evaluators verified that the pressure differential between the suction and discharge side of the pumps is about 15 psi which is what was claimed in the applicant description. Therefore, the evaluators were able to confirm that the measure was installed as claimed in the application, wherein the pressure differential on the condenser water pumps was indeed reduced from 50 psi to 15 psi and the pressure of the water to the cooling unit was increased to 50 psi. The evaluators therefore give credit to the applicant for the savings for this measure installation. The savings for this measure basically comes from running the 250HP pumps at 50 psi vs running a 50HP pump at 50 psi. The evaluators modelled the typical weekly operating profile of the 250HP Condenser water pump (CW-14) as shown in the heatmap below:

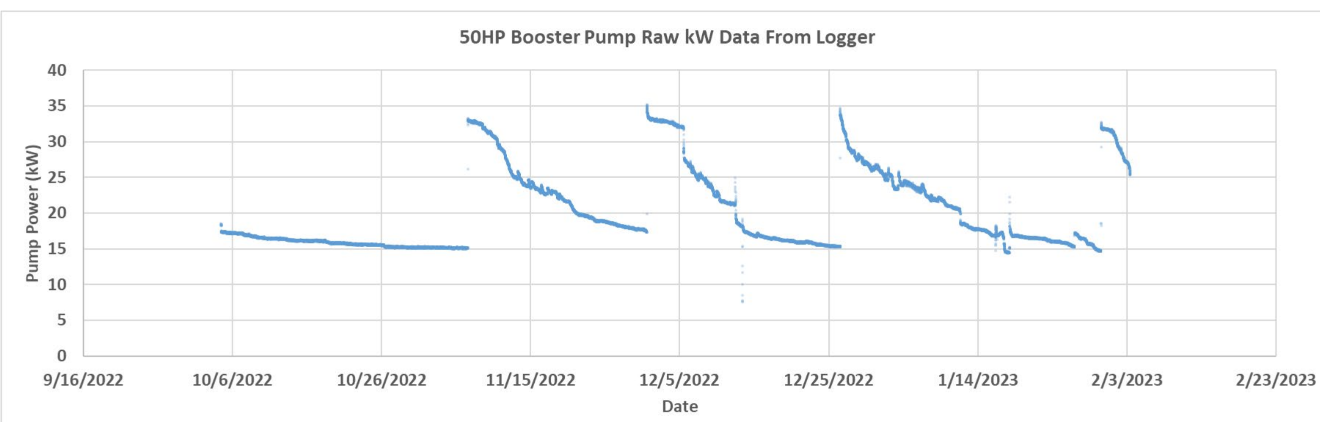
Figure 2-25 Heat Map showing typical operating profile of the 250HP Condenser Water Pump

Typical Weekly kW Profile of 250HP Condenser Water Pump							
	Sun	Mon	Tue	Wed	Thu	Fri	Sat
0	52.71	50.88	53.42	50.93	52.25	53.86	54.17
1	52.35	51.84	53.23	50.30	52.19	53.53	54.08
2	52.65	52.21	53.28	50.93	51.91	53.34	53.98
3	52.75	53.55	53.48	51.31	52.01	53.56	53.95
4	53.01	52.90	53.26	52.63	51.64	53.39	53.80
5	53.43	52.28	53.20	52.08	51.56	53.72	53.81
6	53.33	53.47	53.47	52.86	52.60	53.36	53.72
7	53.70	53.88	51.88	53.03	51.28	53.30	52.90
8	53.66	49.92	51.98	52.26	51.16	53.12	53.20
9	53.71	49.85	52.15	52.81	50.56	52.63	53.14
10	53.63	48.19	48.58	52.08	51.19	52.57	53.42
11	53.59	50.40	53.91	53.00	50.02	52.94	53.46
12	53.52	49.68	52.83	52.33	52.60	52.96	53.62
13	53.76	51.60	52.64	53.31	52.32	52.98	53.19
14	54.89	51.43	54.49	53.65	53.25	53.34	53.73
15	54.87	52.04	54.45	53.83	52.67	53.11	53.38
16	54.84	53.21	54.39	53.20	52.73	53.15	54.01
17	54.58	53.61	54.53	53.95	52.97	53.56	53.97
18	54.69	54.12	54.54	52.83	52.77	54.03	54.02
19	53.85	53.69	54.56	53.68	53.13	54.14	53.97
20	52.92	53.60	54.35	53.64	53.28	54.22	54.01
21	52.62	53.45	54.32	53.41	52.87	54.06	53.90
22	52.06	53.36	54.08	52.15	53.29	54.02	53.81
23	51.51	53.42	52.36	52.95	53.56	54.10	53.80

The above operating profile was annualized using an 8,760-spreadsheet to model the annual operating profile of the pump. The average pump kW was estimated to be 53 kW[10].

Additionally, the evaluators analysed the operation of the 50HP booster pump. The raw kW data from the pump is shown below:

Figure 2-26 50HP Booster Pump Raw kW Data from Logger



The evaluators modelled the typical weekly operating profile of the booster pump as shown in the heatmap below:

Figure 2-27 typical Weekly Operating Profile of 50HP Booster Pump

10 From Metered data

	Sun	Mon	Tue	Wed	Thu	Fri	Sat
0	19.2	20.0	21.1	20.4	20.9	20.5	19.7
1	19.0	19.9	21.1	20.4	20.8	20.5	19.6
2	19.1	19.9	21.1	20.3	20.8	20.5	19.6
3	19.2	19.8	21.1	20.3	20.7	20.4	19.6
4	19.2	19.9	21.1	20.3	20.7	20.4	19.6
5	19.2	19.9	21.1	20.3	20.8	20.4	19.5
6	19.1	19.8	21.1	20.5	20.8	20.4	19.4
7	19.2	19.8	21.1	20.4	20.8	20.4	19.5
8	19.2	19.8	21.2	20.4	20.8	20.3	19.5
9	19.1	19.8	21.1	20.4	20.8	20.3	19.3
10	19.0	19.9	20.9	20.4	20.7	20.0	19.4
11	19.1	20.0	20.8	20.3	20.6	19.9	19.4
12	19.0	21.3	20.7	20.3	20.6	19.9	19.4
13	19.0	21.5	20.6	20.2	20.6	19.9	19.2
14	19.7	21.5	20.6	20.8	20.6	19.8	19.3
15	20.1	21.4	20.5	21.1	20.5	19.8	19.3
16	20.0	21.3	20.4	21.0	20.5	19.8	19.2
17	20.0	21.3	20.4	20.9	20.5	19.7	19.2
18	20.0	21.3	20.4	20.8	20.4	19.7	19.3
19	19.9	21.3	20.4	20.9	20.3	19.6	19.3
20	19.9	21.2	20.3	20.9	20.4	19.7	19.3
21	19.9	21.2	20.4	20.9	20.4	19.7	19.3
22	19.9	21.2	20.4	20.9	20.4	19.6	19.3
23	20.0	21.2	20.4	20.8	20.5	19.6	19.3

The above operating profile was annualized using an 8,760-spreadsheet to model the annual operating profile of the pump. The average pump kW was estimated to be 20.2 kW[11].

The evaluators then created a bin analysis profile similar to the tracking calculations and used the metered kW obtained from the loggers to model the post case condenser water pump and the booster pump kW for the bin hours. Based on the metered data, the evaluators modelled the bin hours for 8,760 hours. The evaluation found that the free cooling system was not operational as claimed in the application. The site contact confirmed this, and the reason was that the free cooling system caused issues with the chiller controls and the heat exchanger and was therefore not used.

The evaluators re-adjusted the kW for the base-case 1 chiller operation because, the applicant ran a test operating condition at the time of the project installation wherein the pumps ran at 100% speed and not at the required pressure which resulted in a higher kW during the operating period where the applicant used one week's trend data. The evaluators thought that this was higher than normal operation and therefore de-rated the kW based on the pump flow rates for one chiller and two chiller operation[12]. Therefore, the base case kW was re-adjusted to 82% of 224 kW= 184 kW.

The following parameters (obtained from the metered data) were used in the bin analysis to estimate the savings:

Booster Pump Electric Usage= 20.2 kW
Base Case 1 Chiller Condenser Water Pump Electric Usage= 184 kW
Proposed Case 1 Chiller Condenser Water Pump Usage[13]= 53 kW

Base Case 2 Chiller Condenser Water Pump Electric Usage= 220.1 kW

Proposed Case 2 Chillers Condenser Water Pump Usage[14]= 106 kW

[11] From Metered data
[12] Pump flow rate for 1 chiller operation= 2,012 GPM
Pump flow rate for 2 chiller operation= 2,441 GPM. Therefore, 2012/2441= 82%.
[13] From metered data
[14] 53 kW x 2 = 106 kW

The following Figure shows the evaluation bin analysis used to estimate the savings:

Figure 2-28 Evaluation Bin Analysis

WEATHER DATA *from Peak Savings Tab (5)				ESTIMATED PUMP LOADS						EXISTING CASE CHILLER POWER AND ENERGY CONSUMPTION		PROPOSED CASE CHILLER POWER AND ENERGY CONSUMPTION	
Mid-pts	Dry Bulb (°F)	WB °F	Hrs	Total Chilled Water Load (Tons)	Number of Chiller Running	Free Cooling?	Existing Cond Pump kW	Proposed Cond Pump kW	Proposed Booster Pump kW	Pump Power (kW)	Total Pump Energy (kWh)	Pump Power (kW)	Total Pump Energy (kWh)
97.5	95 to 100	70.0	3	2,001.5	2.0	No	220	106.0	20.2	220.1	660	126.2	379
92.5	90 to 95	73.3	55	2,209.1	2.0	No	220	106.0	20.2	220.1	12,105	126.2	6,941
87.5	85 to 90	71.7	94	2,120.1	2.0	No	220	106.0	20.2	220.1	20,688	126.2	11,863
82.5	80 to 85	69.2	266	1,938.4	2.0	No	220	106.0	20.2	220.1	58,542	126.2	33,570
77.5	75 to 80	67.5	475	1,788.8	2.0	No	220	106.0	20.2	220.1	104,540	126.2	59,947
72.5	70 to 75	65.3	723	1,678.6	2.0	No	220	106.0	20.2	220.1	159,121	126.2	91,246
67.5	65 to 70	61.5	789	1,388.9	2.0	No	220	106.0	20.2	220.1	173,647	126.2	99,575
62.5	60 to 65	56.5	765	942.3	1.0	No	184	53.0	20.2	183.6	140,438	73.2	56,003
57.5	55 to 60	6.3	24	654.0	1.0	No	184	53.0	20.2	183.6	4,406	73.2	1,757
52.5	50 to 55	51.7	646	654.0	1.0	No	184	53.0	20.2	183.6	118,592	73.2	47,292
47.5	45 to 50	47.1	759	654.0	1.0	No	184	53.0	20.2	183.6	139,337	73.2	55,564
42.5	40 to 45	42.5	759	654.0	1.0	No	184	53.0	20.2	183.6	139,337	73.2	55,564
37.5	35 to 40	38.2	738	654.0	1.0	No	184	53.0	20.2	183.6	135,482	73.2	54,027
32.5	30 to 35	33.3	783	654.0	1.0	No	184	53.0	20.2	183.6	143,743	73.2	57,321
27.5	25 to 30	28.8	804	654.0	1.0	No	184	53.0	20.2	183.6	147,598	73.2	58,858
22.5	20 to 25	23.7	461	654.0	1.0	No	184	53.0	20.2	183.6	84,630	73.2	33,748
17.5	15 to 20	19.1	372	654.0	1.0	No	184	53.0	20.2	183.6	68,292	73.2	27,233
12.5	10 to 15	14.7	147	654.0	1.0	No	184	53.0	20.2	183.6	26,986	73.2	10,761
7.5	5 to 10	9.4	96	654.0	1.0	No	184	53.0	20.2	183.6	17,624	73.2	7,028
2.5	0 to 5	3.0	1	654.0	1.0	No	184	53.0	20.2	183.6	184	73.2	73
		Annual Hours:	8,760							Annual Energy Consumption	1,695,952	Annual Energy Consumption	768,751

Free-Cooling Range

The measure generated 927,201 kWh in savings.

3 Final Results

The project consisted of installing a new 100HP air compressor for the new production line A6, installing a new cryogenic nitrogen generation system, and installing a 50HP booster pump for the chilled water system. The evaluator's analysis indicated that the compressor operated at a higher capacity in the post case compared to the base case and the operating pressure of the chilled water pumps was not derated as claimed in the project. Table 0-4 provides a comparison of the key parameters.

Table 3-1. Summary of key parameters

Parameter	BASELINE		PROPOSED / INSTALLED	
	Tracking Value(s)	Evaluation Value(s)	Tracking Value(s)	Evaluation Value(s)
Compressor capacity (CFM)	235 CFM	300 CFM	323 CFM	225 CFM
Base Case Compressor Pressure (psig)	105 psig	100 psig	105 psig	100 psig
Nitrogen Loads (SCFH)	38,649 SCFH	51,488 SCFH	38,649 SCFH	51,488 SCFH
N2 Production (Annual)	557,641,016	N/A	N/A	451,033,041
N2 System Total kW	710 kW	850 kW	316 kW	353 kW
Booster Pump kW	N/A	N/A	31.1 kW	20.1 kW
Base Case Total Pump Power (kW)- 2 chillers running	220.1 kW	220.1 kW	220.1 kW	220.1 kW
Base Case Total Pump Power- 1 Chiller Running	224 kW	184 kW	224 kW	184 kW

Proposed Case Total Pump Power (kW)- 2 Chillers Running	124 kW	106 kW	124 kW	106 kW
Proposed Case Total Pump Power (kW)- 1 Chillers Running	62 kW	53 kW	62 kW	53 kW

3.1 Explanation of Differences

The evaluated savings are 31% more than the applicant reported savings primarily because: For EEM-1, the base case kW was found to be higher than the applicant reported value, because the evaluators used the appropriate compressed air storage curve based on the storage ratio of 3 Gallons/CFM. For EEM-2: The evaluators used updated N2 production data for the new HPN 15 system to estimate the new N2 loads, which was found to be higher than in the tracking analysis and resulted in higher base case kW. For EEM-3 the post case kW of the booster pump was found to be lower than the applicant reported value and the baseline kW for 1 chiller operation was re-adjusted based on the ratio of pump flow rates for one and two chiller operation. Table 3-2 provides a summary of savings deviations.

Table 3-2. Summary of deviations

Measure	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
12018706 Nitrogen system	Operation	Average hourly N2 use is higher	+15%	Increased savings – Based on data provided by the site, the average hourly N2 use in the post case was found to be higher than what was estimated by the applicant
11955499 Compressed air system	Baseline	Baseline Power Draw	+15%	Increased savings -The evaluation used a storage curve of 3 Gal/CFM to model the base case kW. The applicant analysis used 1 gal/CFM. The applicant used kW and CFM at rated full flow and zero flow conditions and created a regression that was used to estimate kW.
12886490 Booster pump	Baseline	Lower Baseline Pump kW	+1%	Increased Savings- The evaluation estimated a lower pump kW for 1 chiller operation in the post case. The applicant reported value was 224 kW, the evaluation estimated it to be 184 kW.
	Final RR			**131%**

3.2 Lifetime Savings

The measures have been classified as new construction and retrofit respectively. In each case, the baseline is ISP or the pre-existing condition.

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

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

where:

LAGI = lifetime adjusted gross impact (kWh)

FYS = first year savings (kWh)

EUL = measure life (years)

Table 3-3 provides a summary of key factors that influence the lifetime savings.

Table 3-3. Measure 11955499 - lifetime savings summary

Factor	Tracking	Application	Evaluator
Lifetime savings	2,469,105	2,469,105	3,450,120
First year savings	164,607	164,607	230,008
Measure lifetime	15	15	15
Baseline classification	New Construction	New Construction	New Construction

Table 3-4. Measure 12018706 - lifetime savings summary

Factor	Tracking	Application	Evaluator
Lifetime savings	47,224,860	47,224,860	65,327,955
First year savings	3,148,324	3,148,324	4,355,197
Measure lifetime	15	15	15
Baseline classification	New Construction	New Construction	New Construction

Table 3-5. Measure 12886490 - lifetime savings summary

Factor	Tracking	Application	Evaluator
Lifetime savings	13,625,120	13,635,120	13,908,015
First year savings	909,008	909,008	927,201
Measure lifetime	15	15	15
Baseline classification	Retrofit	Retrofit	Retrofit

3.2.1 Ancillary impacts

There were no ancillary impacts associated with the evaluated measure.

RICE21N069

Report Date: 7/17/2023

Program Administrator	Rhode Island Electric
Application ID(s)	11761473 10874645 10476007 10902885 11063124 10874646 7999525 11759401
Project Type	New Construction / ROF
Evaluation Type	Ops
Program Year	2021
Evaluation Firm	DNV
Evaluation Engineer	Matt Piana
Senior Engineer	Joe St. John

1 Evaluated Site Summary and Results

This project includes (8) applications completed at one manufacturing facility where welding is performed. Five of the eight applications involve new construction dust-collection measures, where the welding dust is removed from the air in new buildings where manufacturing occurs. The other remaining three measures are compressed air projects which are replace on failure measures.

Table 1 shows a summary of each of the (8) measures. This report provides the results as well as outlines the M&V process for the (3) measures that are being sub-sampled for data collection. The (3) measures were sub-selected based on wanting to capture a large portion of the savings, and having some of the sample come from the dust collection portion of the project, and some of the sample come from the compressed air portion of the project. The largest (2) dust collection measures were selected, and the largest compressed air measure was selected. Note that although the (5) dust collection measures are essentially identical, (3) were categorized as Process, and (2) were categorized as HVAC. Additional measures were not selected because it would be unlikely that there would be enough time during the site visit to collect the necessary data on those measures. Even with sub-sampling, the initial site work took two full days as the facility is very large and metering installation was complex.

Table 1. Measure List

PA Application ID	Project Type	Gross Energy kWh	% of kWh	Sub-Sampled ?	Measure Description
10109441/ 11761473 PROC	Dust Collection	3,581,569	32%	Yes	New construction dust collector project Building 9B. Baseline is (32) 60 HP baseline vendor fans, post-case is (83) 9 HP, and (66) 3 HP post-case vendor fans.
10109441/ 10874645 HVAC	Dust Collection	2,286,489	21%	Yes	New construction dust collector project Building 9A. Baseline is (21) 60 HP baseline vendor fans, post-case is (53) 9 HP, and (40) 3 HP post-case vendor fans.
7331289/ 10476007 PROC	Dust Collection	1,723,559	15%	No	New construction dust collector project Building 2019. Baseline is (20) 60 HP baseline vendor fans, post-case is (16) 9 HP, (39) 6 HP, and (26) 3 HP post-case vendor fans.
7944858/ 10902885 HVAC	Dust Collection	1,494,745	13%	No	New construction dust collector project Building 2014-Bay 4. Baseline is (18) 60 HP baseline vendor fans, post-case is (24) 9 HP, (29) 6 HP, and (26) 3 HP post-case vendor fans.
11063124 PROC	Dust Collection	892,476	8%	No	New construction dust collector project Building 2019 AFC Phase 2. Baseline is (11) 60 HP baseline vendor fans, post-case is (12) 9 HP, (24) 6 HP, and (13) 3 HP fans.
10454519/ 10874646 CAIR	Compressed Air	886,913	8%	Yes	Replace (5) 300 HP load/no-load compressors w/ (5) 300 HP VFD air compressors in Building 2003 and Building 2005.
7999525 CAIR	Compressed Air	149,781	1%	No	B60 Machine Room air compressor. New 125 HP VFD air compressor replacing (1) of (4) 150 HP water-cooled 2-stage reciprocating compressors operating in a step control manner. The existing compressors are 20 years old, so baseline as selected as a 125 HP fixed speed, load/no-load compressor.
11759401 CAIR	Compressed Air	113,820	1%	No	Replace (2) 930 CFM desiccant air dryer with (2) new 930 CFM desiccant air dryers equipped with demand dew point control.
Total		**11,129,352**			

The site contact indicated that the evaluated systems were not impact by Covid-19 and that metering collected during the evaluation monitoring period would be representative of the rest of the year. Therefore, the evaluators conducted a full M&V with metered data informing updates to operational parameters. The metered profile was extrapolated to all hours of the year to calculate evaluated savings. Table 2 provides a summary of the evaluation results. The dust collection measures had a realization rate of 90%, while the compressed air measure had a realization rate of 131%, resulting in an overall project evaluation realization rate of 94%.

Table 2. Evaluation Results Summary

PA Application ID	Measure Name	Parameter	Energy Savings (kWh/yr)	Energy Savings on Peak (%)	SP Demand Reduction (kW)	WP Demand Reduction (kW)	Lifetime Energy Savings (kWh)
10107675/ 11761473	Dust Collection 9B	Tracked	3,581,569	89%	446.3	446.3	53,723,535
		Evaluated	3,235,266	53%	387.2	449.9	48,528,996
		RR	90%	60%	87%	101%	90%
10109441/ 10874645	Dust Collection 9A	Tracked	2,286,489	89%	309.6	309.6	34,297,335
		Evaluated	2,065,408	53%	268.6	312.1	30,981,119
		RR	90%	60%	87%	101%	90%
7331289/ 10476007	Dust Collection 2019	Tracked	1,723,559	89%	208.9	208.9	25,853,385
		Evaluated	1,556,908	53%	181.2	210.6	23,353,616
		RR	90%	60%	87%	101%	90%
7944858/ 10902885	Dust Collection 2014 Bay 4	Tracked	1,494,745	89%	193.9	193.9	22,421,175
		Evaluated	1,350,218	53%	168.2	195.4	20,253,267
		RR	90%	60%	87%	101%	90%
11063124	Dust Collection 2019 AFC Phase 2	Tracked	892,476	89%	157.0	157.0	13,387,140
		Evaluated	806,182	53%	136.2	158.3	12,092,735
		RR	90%	60%	87%	101%	90%
10454519/ 10874646	(5) 300 HP VFD Compressors	Tracked	886,913	48%	113.0	105.9	13,303,695
		Evaluated	1,158,389	52%	153.9	156.6	17,375,833
		RR	131%	109%	136%	148%	131%
7999525	(1) 125 HP VFD Compressor	Tracked	149,781	48%	12.5	12.5	2,246,715
		Evaluated	195,628	52%	17.0	18.5	2,934,413
		RR	131%	109%	136%	148%	131%
11759401	(2) 930 CFM Desiccant Dryers with Demand Dewpoint Control	Tracked	113,820	43%	11.5	12.1	1,707,300
		Evaluated	148,659	47%	15.7	17.9	2,229,888
		RR	131%	109%	136%	148%	131%
Totals		**Tracked**	**11,129,352**	**85%**	**1,452.7**	**1,446.1**	**166,940,280**
		Evaluated	**10,516,658**	**53%**	**1,328.0**	**1519.1**	**157,749,868**
		RR	**94%**	**63%**	**91%**	**105%**	**94%**

RR = Realization rate
SP = Summer peak
WP = Winter peak

1.1 Explanation of Deviations from Tracking

The dust collection measure resulted in a realization rate of 90%. The evaluated savings for the dust collection measures were lower than the tracking savings primarily due to the evaluation finding that the post-case motor load factors were found to be higher than the values used in the tracking savings estimates. The tracking calculations showed motor load factors of 28% and 24% for the General Ventilation (GV) units and assist fan units respectively, whereas the evaluator showed motor load factors of 37% and 43%. The tracking estimates were based on data collected from 17 motors over 2 weeks, while the evaluator incorporated that data, as well as data from 54 motors collected over a period of 38 days.

The compressed air measures resulted in a realization rate of 131%. The evaluated savings for the compressed air measure were higher than the tracking savings in part because of higher compressed air loads which lead to higher savings, and in part because the evaluators found that the baseline average kW/CFM to be higher than the value used in the tracking calculations. This is due to the evaluator finding that the compressors were operating at a higher pressure (105 psi instead of 97 psi), but also because the evaluators found the baseline compressors to be operating at 52% load on average, whereas the tracking analysis had the baseline compressors operating at 59% on average. Baseline load/no-load compressors operate less efficiently at lower loads.

Overall, the somewhat lower realization rate from the dust collection measure (90%), cancelled out with the higher realization rate from the compressed air measure (131%), resulting in an overall project realization rate of 94%.

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

1.2 Recommendations for Program Designers & Implementers

Evaluators recommend that on future dust collection measures program implementers request vendors to provide data showing normalized energy use per quantity of dust removed from the filters. The evaluators are concerned that both the tracking and evaluated analysis for this measure are not being performed on an equal dust removal or air purification level basis but evaluation measurements on the quantity of dust collected were not available and extrapolation to the baseline performance was also problematic.

Three of the 5 dust collection measures were categorized as Process and the other 2 as HVAC. Evaluators recommend that implementers give guidance on whether dust collection systems should be categorized as Process or HVAC.

1.3 Customer Alert

There is no relevant customer alert.

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. Table 3 shows the three measures that were evaluated. Note that application 11761473 and application 10874645 are both dust collection measures located in the same building, so these measures were evaluated together. The evaluation team evaluated 6,754,971 kWh of the 11,129,352 kWh of tracking savings, representing 61% of the tracking savings.

Table 3. Evaluated Measures

PA Application ID	Project Type	Gross Energy kWh	Percentage of kWh	Sub-Sampled?	Measure Description
10107675/ 11761473	Dust Collection	3,581,569	32%	Yes	New construction dust collector project Building 9B. Baseline is (32) 60 HP baseline vendor fans, post-case is (83) 9 HP, and (66) 3 HP post-case vendor fans.
10109441/ 10874645	Dust Collection	2,286,489	21%	Yes	New construction dust collector project Building 9A. Baseline is (21) 60 HP baseline vendor fans, post-case is (53) 9 HP, and (40) 3 HP post-case vendor fans.
10454519/ 10874646	Compressed Air	886,913	8%	Yes	Replace (5) 300 HP load/no-load compressors w/ (5) 300 HP VFD air compressors in Building 2003 and Building 2005.
Total		**6,754,971**			

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.

2.1.1 Applicant Description of Baseline

Application 10107675/11761473– Dust collection project in Building 9B - 3,581,569 claimed kWh

This application was a new construction application where the applicant baseline is (32) 60 HP fans.

The baseline vendor system is selected as the baseline because it was a proposed system considered by the customer that was not selected to be installed. The measure is a lost opportunity with a site-specific unique baseline.

Application 10109441/10874645 – Dust collection project in Building 9A - 2,286,489 claimed

This application was a new construction application where the applicant is (21) 60 HP baseline vendor fans.

The baseline vendor system is selected as the baseline because it was a proposed system considered by the customer that was not selected to be installed. The measure is a lost opportunity with a site-specific unique baseline

Application 10454519/10874646 – (5) 300 HP VFD air compressor project in Buildings 2003 and 2005 - 886,913 claimed kWh

The applicant measure description says that the baseline for this project to be (5) 300 HP load/no-load compressors. However, the calculations base the savings from (3) compressors. The site visit confirmed that there are (5) new 300 HP compressors. The load/no-load baseline was used in the tracking calculations, referencing the Massachusetts baseline document, and uses 4 gal/cfm. The pressure is assumed to be 100 psig. This baseline is lost opportunity replace on failure because of the age of the existing compressors.

The applicant calculations shows that the baseline consists of:

- (3) 300 HP load/no-load compressors
- 5 kW associated with not having zero-loss drains in the baseline.

The tracking calculations did not provide details about the justification for using 5 kW in the baseline for installing zero-loss drains in the post-case.

The pre-existing equipment was at end-of-life and consisted of the following:

Building 2003:

- 300 HP IR reciprocating compressor, manufactured in 1978
- Inoperable IR XLE compressor
- Kaeser 200 HP single-stage rotary screw compressor installed in 2000
- Kaeser 200 HP single-stage rotary screw compressor

Building 2005:

- 200 HP rental rotary screw air compressor (Rogers Machinery)

Building 2018:

- Kaeser single-stage 300 HP air-cooled rotary screw

Regarding including building 2018, the tracking calculations include the following sentence in the project description:

"It should also be noted that it is unknown what % of compressed air from B2018 travels to 2003 and 2005 therefore modelling the system is rather difficult. Based on calculations the % air from B2018 had little effect on the overall kWh savings."

The tracking calculations state in the name given to the measure that the project is an upgrade to the compressed air system serving Buildings 2003 and 2005 and the impact on Building 2018 was not included.

2.1.2 Applicant Description of Installed Equipment and Operation

Application 10107675/11761473– Dust collection project in Building 9B - 3,581,569 claimed kWh

The tracking calculations indicate that that the installed system consists of (89) 9 HP GV unit fans, and (66) 3 HP assist fans. The GV fans are the centrifugal fans that are coupled with air filters, whereas the assist fans are used to mix the air in the space, and have no filters, and are axial fans. The tracking calculations indicate that these fans operate 6,188 hours per year. The tracking documentation indicates that the lower total horsepower required in the post-case is caused by filters that have a lower pressure drop compared to the baseline equipment.

Application 10109441/10874645 – Dust collection project in Building 9A - 2,286,489 claimed The tracking calculations indicate that the installed system consists of (53) 9 HP GV unit fans and (40) 3 HP post-case vendor fans. The tracking calculations indicate that these fans operate 6,188 hours per year. The tracking documentation indicates that the lower total horsepower required in the post-case is caused by filters that have a lower pressure drop compared to the baseline equipment.

Application 10454519/10874646 – (5) 300 HP VFD air compressor project in Buildings 2003 and 2005 - 886,913 claimed kWh

The tracking calculation description indicate that the installed equipment consists of (5) 300 HP VFD compressors. The tracking calculations themselves show that only (3) of these (5) compressors are ever operating at any given time. The tracking calculations indicate that the compressors operate for 8,736 hours per year.

2.1.3 Applicant Energy Savings Algorithm

Application 10107675/11761473– Dust collection project in Building 9B - 3,581,569 claimed kWh

$$Electric\ Savings\ = Baseline\ Elec - Post\ Elec$$

where,

$$Baseline\ Elec = Hours \times\ Qty_{BL}\ \times \frac{HP_{BL} \times LF_{BL}}{\eta_{BL}} \times 0.746 \frac{kW}{HP}$$

$$Post\ Elec = Hours\ \times [9\ HP\ Fan\ kW +\ 3\ HP\ Fan\ kW]$$

$$9\ HP\ Fan\ kW\ = Qty_{9P} \times Avg.Measured\ kW_{9P}$$

$$3\ HP\ Fan\ kW\ = Qty_{3P} \times Avg.Measured\ kW_{3P}$$

Where the variables are explained in Table 4.

Table 4. Variable List for Applicant Energy Savings Algorithm

Variable Name	Units	Variable Value	Variable Source
$Hours$	Hours/year	6,188	Measured data from (11) circuits collected during a two-week period.
Qty_{BL} Baseline Motor Quantity	-	32	Commissioning document.
HP_{BL} Baseline Motor Horsepower	HP	60	Baseline vendor proposal.
LF_{BL} Baseline Motor Load Factor	-	0.51	The spreadsheet shows that the 0.51 comes from 0.51 $=0.80^3$. The 0.80 is “the minimum possible airflow to achieve adequate air mixing, based on conversation with baseline equipment manufacturer”.
η_{BL} Baseline Motor Efficiency	-	94.1%	Hard-coded value for 30 HP motor. The 60 HP baseline means that there are (2) 30 HP motors per dust collector module.
Qty_{9P} Post-case 9 HP Motor Quantity	-	83	The quantity is based on the number of motors installed. The 9 HP installed here actually consists of a module made up of (3) 3 HP motors.
$Avg.Measured\ kW_{9P}$	kW	1.96	This kW value of 1.96 is the measured average value of (6) GV units, which are made up of (3) 3 HP dust collector fans collected in Buildings 9B, 9A, and 2014 for 14.8 days

Variable Name	Units	Variable Value	Variable Source
Average Measured Post-Case 9 HP Motor kW			
Qty_{3P} Post-case 3HP Motor Quantity	-	66	The quantity is based on the number of motors installed.
$Avg. Measured\ kW_{3P}$ Average Measured Post-case 3 HP Motor kW	kW	0.57	This kW value of 0.57 is the measured average value of (5) dust collector fans collected in Buildings 9B, 9A, and 2014 for 14.8 days.

The commissioning document stated that the baseline and post-case system designs (motor quantity, sizes, etc.) for buildings 2014, 9A, and 9B, were scaled to the 2019 Building baseline and post-case designs based on CFM. There were (4) phases of the project between 2017 and 2019.

- Phase 1 – Building 2019
- Phase 2 – Building 2014
- Phase 3 – Building 9A

Phase 4 – Building 9B In addition to those (4) phases, there is an additional phase (2019 AFC Phase 2), which was completed after the commissioning documents were created, but which followed the same approach as scaling to the Building 2019 baseline and proposed designs. The post-case kW was based on measurements of 17 dust collectors spread across the different buildings over the course of 2 weeks.

A write-up describing the tracking calculations for Phases 1-4 are found in the document called "1788916-11761473-Electric Boat - Fume Mitigation Cx v3.pdf".

Figure 1 below shows the data collected on the (17) measurements made over 2 weeks on the installed fans.

Figure 1. Measured data summary for GV units and Assist Fans

This page contains the Cx metering data and calculation of fan cfm at the measured input power

Average values across all buildings

	Total kW	kW/motor	bhp/motor	est cfm
Average GV Fan (3 motors)	1.96	0.65	0.79	2,900
Average Assist Fan (1 motor)	0.57	0.57	0.84	6,800

Average values for only 9B

	Total kW	kW/motor	bhp/motor	est cfm
Average GV Fan (3 motors)	1.52	0.51	0.61	2,500
Average Assist Fan (1 motor)	0.21	0.21	0.31	3,700

parameter	value	unit	note
Building volume	25,690,745	cubic feet	reported by Hastings
ACH	6	air change	*from customer
9B Length	588	ft	
9B Width	340	ft	
9B Height	119	ft	
9B Volume	23,790,480	ft^3	
9B Area	199,920	ft2	
Conversion	60	min/hr	
CFM Required	2,379,048	CFM	
Proposed Case Design	1,245,000	CFM	
Design ACH	3.14		
Actual CFM	809,250	CFM	*65% of design based on data logging
Actual ACH	2.0		

Building	Fan ID	Recorded Days	Average Power When ON (kW)	Average HP	Estiamted Annual Run Hours	Motors	Avg per Unit
9A	Assist Fan 1	14.8	0.44	0.59	6,472	1	0.44
9A	Assist Fan 2	14.8	1.12	1.50	6,483	1	1.12
9A	GV-42	14.8	2.69	3.60	6,483	1	2.69
9B	GV-1	14.8	2.09	2.80	6,812	1	2.09
9B	GV-3	14.8	0.68	0.91	6,454	1	0.68
9B	GV-14	14.8	1.79	2.40	6,468	1	1.79
9B	Assist Fans 4,8,12	14.8	0.88	1.17	6,470	3	0.29
9B	Assist Fans 22,23,24	14.8	0.37	0.50	6,454	3	0.12
2014	Assist Fans 7,8,9	11.8	2.56	3.43	5,370	3	0.85
2014	FM-30	11.2	2.27	3.04	5,443	1	2.27
2014	FM-29	11.3	2.26	3.02	5,471	1	2.26
						17	

Application 10109441/10874645 – Dust collection project in Building 9A - 2,286,489 claimed

The same approach described above for Application 10107675/11761473 in Building 9B, was used for Application 10109441/10874645, Building 9A, but with updates to the baseline and post case quantities, shown in bold italics. All the other input variables remain the same.

Variable Name	Units	Variable Value	Variable Source
$Hours$	Hours/year	6,188	See previous table
Qty_{BL}	-	***21***	"
HP_{BL}	HP	60	"
LF_{BL}	-	0.51	"
η_{BL}	-	94.1%	"
Qty_{9P}	-	***53***	"
$Avg.Measured\ kW_{9P}$	kW	1.96	"
Qty_{3P}	-	40	"
$Avg.Measured\ kW_{3P}$	kW	0.57	"

Application 10454519/10874646 – (5) 300 HP VFD air compressor project in Buildings 2003 and 2005 - 886,913 claimed kWh

The tracking calculations for this measure relied on post-case metered compressor data to develop a CFM profile based on day of week, and hour of day. The original raw data that was used to develop this profile is not immediately apparent in the project folder, but hard-coded values of a pivot table of these values were available.

Table 5 below shows the post-case CFM profile that was used as the basis for the tracking calculation. This data is hard-coded and seems to have been based on measured kW data, based on a description in the tracking calculations. Each 300 HP compressor has a capacity of 1,500 CFM.

Table 5. Post-case CFM profile used in tracking calculation

Hour	Average CFM Mon	Tue	Wed	Thu	Fri	Sat	Sun
0	2,856	2,741	2,851	2,945	2,721	2,504	2,577
1	2,536	2,605	2,752	2,855	2,620	2,522	2,589
2	2,833	2,877	2,897	2,989	2,614	2,539	2,599
3	2,790	2,803	3,054	2,987	2,747	2,563	2,541
4	2,614	2,469	2,802	2,871	2,639	2,620	2,587
5	3,017	3,315	3,298	3,484	3,058	2,476	2,561
6	3,131	3,069	3,403	3,320	3,489	2,547	2,613
7	3,268	3,874	4,029	3,997	4,279	3,121	2,774
8	3,501	4,414	4,237	4,144	5,161	2,916	2,561
9	3,396	3,406	3,292	3,514	3,808	2,662	2,651
10	4,256	4,632	4,956	4,489	4,852	2,965	2,689
11	4,082	4,260	4,405	4,396	4,486	2,685	2,498
12	3,150	3,145	2,905	3,454	3,405	2,618	2,433
13	4,348	4,456	4,790	4,479	3,963	2,792	2,484
14	3,114	3,388	3,524	3,306	3,441	2,757	2,460
15	2,960	2,793	3,072	3,034	3,251	2,721	2,468
16	3,597	3,327	3,721	3,797	3,285	2,623	2,451
17	3,854	3,708	3,666	3,787	3,218	2,544	2,416
18	3,199	3,162	2,811	2,997	2,995	2,495	2,399
19	3,915	4,012	3,096	4,037	4,114	2,556	2,395
20	3,641	3,435	2,923	3,759	3,632	2,420	2,398
21	3,085	2,985	3,166	2,862	3,025	2,533	2,405
22	4,206	4,007	4,123	3,875	3,163	2,538	2,359
23	3,023	3,165	3,449	3,151	2,462	2,543	2,406

This CFM was then used to develop kW estimates for (3) baseline load/no-load compressors, and (3) post-case VFD compressors for 1-year.

The equations used for converting CFM to kW for the baseline and post-case compressors are:

$$kW_{Baseline} = A \times CFM^3 + B \times CFM^2 + C \times CFM + D$$

Where the baseline constants are:

Variable	Value
A	-0.0177
B	-0.3783
C	1.1897
D	0.2070
CFM_{min}	0
CFM_{max}	1,500

The curve that the coefficients are based on come from the Compressed Air Challenge Handbook for generic load/no-load machines.

The tracking calculations cite Figure 2.5 from the book “Best Practices for Compressed Air Systems” by the Compressed Air Challenge.

The equation above accepts CFM values between CFM_{min} and CFM_{max}. So, one compressor serves as base compressor, and the remaining two compressors serve as trim compressors. Either two baseline compressors operate at full load, with one trim, or one compressor runs at full load, and another runs as trim, with the third one off.

The baseline also includes 5.0 kW for each hour of the year to account for not having zero-loss condensate drains in the baseline, and this is not included in the post-case. Documentation for this 5 kW load was not available.

The post kW is calculated using the following equation:

$$kW_{Post} = A \times CFM^3 + B \times CFM^2 + C \times CFM + D$$

Where the post-case constants are:

Variable	Value
A	0
B	0
C	0.0615
D	50.7887
CFM_{min}	416
CFM_{max}	1,585

The coefficients were developed from a regression from the specifications for a Kaeser SFC250 compressor, adjusted to a 97 psi operating pressure.

The tracking savings for the full year are thus calculated using the following equation:

$$Electric\ Savings\ = Baseline\ Elec - Post\ Elec$$

$$Baseline\ Elec\ = \sum_{0}^{8,760} (Compr1kW_{BL} + Comp\ 2kW_{BL} + Comp3_{BL} + Zero\ Loss\ Drain\ kW)$$

$$Post\ Elec\ = \sum_{0}^{8,760} (Compr1kW_{P} + Comp\ 2kW_{P} + Comp3_{P})$$

2.1.4 Evaluation Assessment of Applicant Methodology

The evaluators found the applicant's overall analysis methodology appropriate at the time of the project development.

2.2 On-Site Inspection and Metering

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

Evaluators visited the site April 4, 2023, to see the measures that were installed, as well as to install loggers as part of the measurement and verification plan. An evaluator returned to the site on May 12, 2023, to retrieve the loggers.

Table 6 provides a summary of the on-site verification.

Table 6. Measure Verification

Measure Name	Verification Method	Verification Result
Dust collection measures in Building 9A and 9B	On-site inspection and metering	Verified quantity of dust collection GV unts and assist fan units in Building 9A/9B. Also learned that there are (3) 25 horsepower house fans that are used to pull the dust from the ductwork and put it into (3) 55-gallon barrels located outside the building. These house fans operate a handful of hours per day. Installed kW loggers on (3) electrical panels that were dedicated panels for the post-case vendor dust collection system.
(5) 300 HP VFD air compressors	On-site inspection and metering	Visually verified (5) 300 HP VFD air compressors and installed kW loggers on each machine.

Application 10107675/11761473– Dust collection project in Building 9B - 3,581,569 claimed kWh kWh AND

Application 10109441/10874645 – Dust collection project in Building 9A - 2,286,489 claimed

During the site visit, the demarcation of where Building 9A ended and 9B started was not entirely clear. For this reason, we decided to calculate evaluated savings for both buildings together rather than separately.

For Building 9A/9B a comparison of the quantity of motors in the tracking calculations, and what was observed onsite is shown in the table below. Note that as of right now, the evaluators have not visually confirmed that he GVSC fans and assist fans are 3 HP. During the site visit, the evaluators were shown three screens next to each 25-horsepower house fan, which listed the quantity of GVSC fans and assist fans. The quantities on those screens matched what was in the tracking calculations. However, the tracking calculations did not include the (3) 25 horsepower house fans which pull the dust from the ventilation ducts and deposit the dust into barrels outside. Those house fans would run for 8 minutes, then shut off for several hours, so they do not operate continuously like the GVSC and assist fans. While the quantities matched between the user-interface screen the tracking calcs, and the evaluator's visual count for the GVSC fans (136, 136, 125, respectively), the difference was significant for the assist fans. The evaluator only visually counted 27 assist fans, even though the user-interface screen, and the tracking calculations both indicate that there are 106 of these assist fans at Building 9A/9B. For the evaluator analysis, the evaluator ended up using the 106 quantity since the count on-site was conducted in a limited amount of time and in many cases line of sites may have been blocked.

Table 7. Evaluation Results of Motor Quantity Verification

Unit	Tracking 9A Quantity	Tracking 9B Quantity	Tracking 9A & 9B	**Tracking Total HP**	Evaluated Quantity from Screen	**Evaluated HP from Screen**	Evaluated - Visually Counted	**Evaluated - Visually Counted HP**
Quantity of GVSC (3) 3 HP Fans	53	83	136	408	136	408	125	375
Quantity of 3 HP Assist Fans	40	66	106	318	106	318	27	81
Quantity of 25 HP House Fans	0	0	0	0	3	75	3	75
				726		801		531

DNV and facility staff installed 13 primary loggers, and 8 back-up loggers in Building 9A/9B comprising 20% of the installed horsepower associated with this project. The list of loggers installed, and their locations are shown in Table 8.

Table 8. List of Loggers Installed at Building 9A/9B

Equipment Logged	Logger 1	Logger 2	Estimated HP
Whole Panel D4N1A3	**Dent kW XC611002**	**Hobo Microstation Amp 2002707**	**133**
25 HP 'House Unit'	Dent kW SP1212063	Hobo Microstation Amp 2003819	25
GV47	Dent kW XC 1211091	Hobo 10574121	9
AF29, AF30, AF31	Dent kW SP1202140	Hobo Microstation Amp 10590840	9
Whole Panel P4N2E2	**Dent kW SP1211092**	**Hobo Microstation Amp 2002832**	**90**
GV27.1	Hobo Microstation Amp 10669462		9
GV29.1	Dent kW XC1803125	Hobo Microstation Amp ####3977	9
AF28.2, AF29.2, AF30.2	Hobo Microstation Amp 10669471		9
AF37.2, AF38.2, AF39.2	Hobo Microstation Amp 2002794		9
Whole Panel P4N2E1	**Dent kW XC1405010**	**Hobo Microstation 2002826**	**99**
GV3.1	Hobo Microstation Amp 10590061		9
GV15.1	Hobo Microstation Amp 10590031		9
GV4.1	Dent kW SP1210118	Hobo Microstation Amp 10590076	9
		Total HP measured in 9A & 9B	**322**
		Total HP in 9A & 9B per evaluator count	1,617
		Percent of HP measured in 9B	**20%**

Panel D4N1A3 has the following equipment served from it. The whole panel was logged, and (3) individual circuits were logged as indicated. Each bullet is one circuit breaker on the panel.

- 25 HP “House fan” **(LOGGED)**
- AF39, AF40
- AF32, AF33, AF34
- GV49
- GV51
- GV48
- GV44
- AF37, AF38
- AF29, AF30, AF31 **(LOGGED)**
- AF35, AF36
- GV50
- GV47 **(LOGGED)**
- GV45
- GV46

Panel P4N2E2 has the following equipment served from it. The whole panel was logged, and (4) individual circuits were logged as indicated. Each bullet is one circuit breaker on the panel.

- GV16.1
- GV27.1**(LOGGED)**
- GV18.1
- AF 25.2, AF26.2, AF27.2
- AF31.2, AF32.2, AF33.2
- AF37.2, AF38.2, AF35.2 **(LOGGED)**
- GV17.1
- GV28.1
- GV29.1 **(LOGGED)**
- AF 29.2, AF 29.2, AF 30.2 **(LOGGED)**
- AF 32.2, AF 35.2, AF 36.2
- AF 40.2, AF 41.2, AF 42.2

Panel P4N2E1 has the following equipment served from it. The whole panel was logged, and (3) individual circuits were logged as indicated. Each bullet is one circuit breaker on the panel.

- GV1.1
- GV3.1 **(LOGGED)**
- GV14.1
- GV25.1
- GV26.1
- GV4.1 **(LOGGED)**
- GV12.1
- GV13.1
- GV24.1
- GV15.1 **(LOGGED)**
- GV5.1
- GV6.1

A sample of the data collected from Table 7 on the whole panels, assist fans, and GVSC fans is shown in Figure 2 through

- Figure 4 shows the kW measured at the breaker serving (1) GV unit. The data shows that there was approximately 2.25 kW going through this breaker.

Figure 4.

In Figure 2, when the kW is around 50 kW, that means that the GV units are on, but the house fan is not on. When the kW is around 80 kW, that's when the house unit fan turns on to expel the dust from the ductwork and into the dust collection drum outside

Figure 2. Whole Panel D4N1A3 kW Data Collected

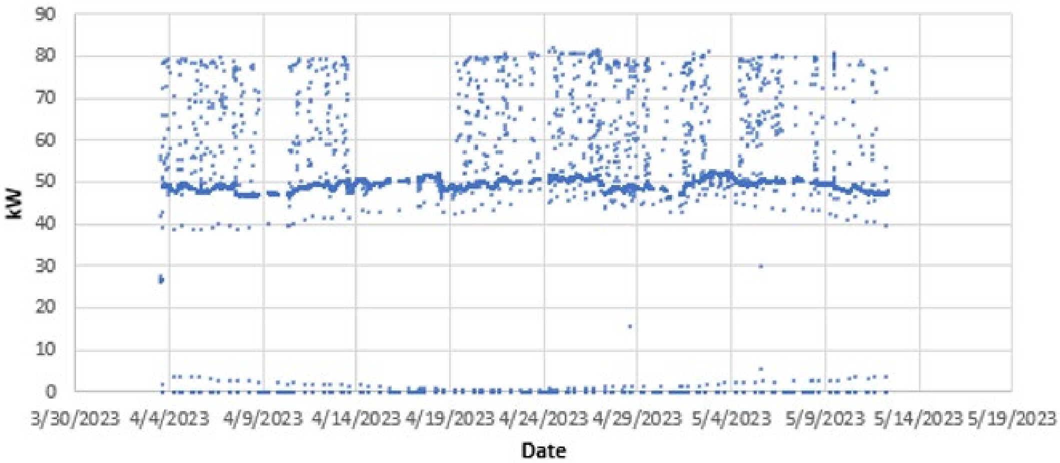


Figure 3 shows the kW measured at the breaker serving (3) assist fans. The data shows that there was approximately 6 kW going through this breaker.

Figure 3. Assist Fans 29, 30, and 31 kW

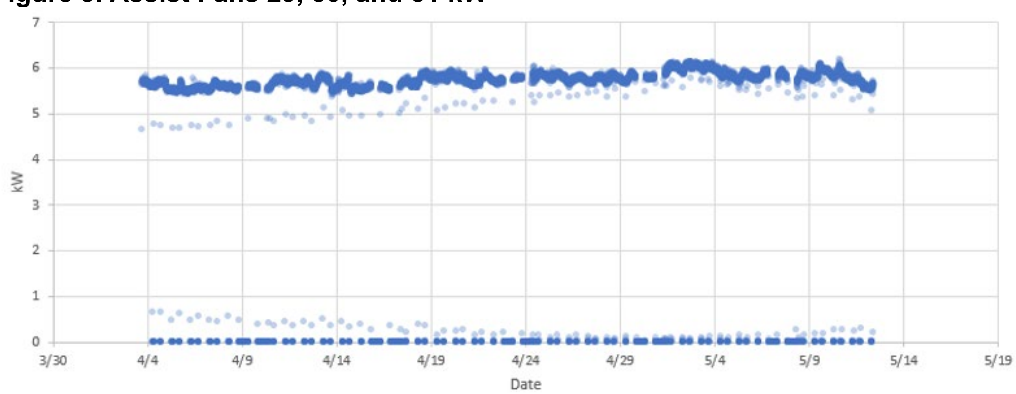
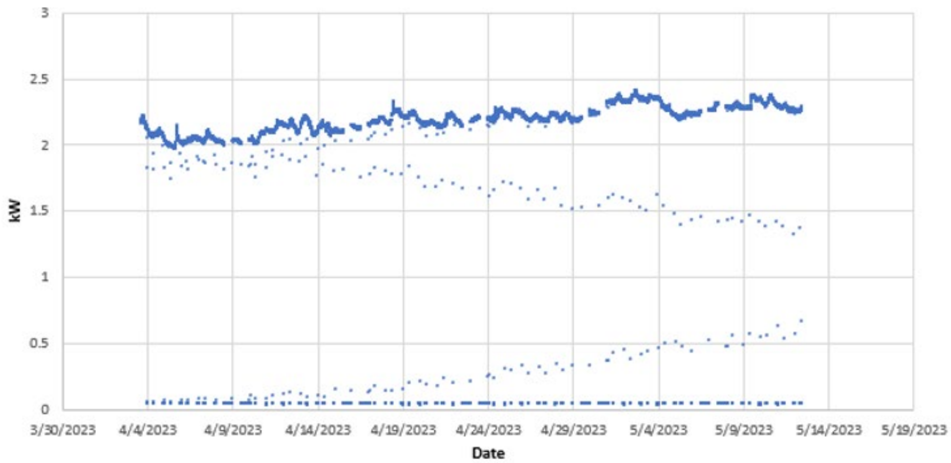


Figure 4 shows the kW measured at the breaker serving (1) GV unit. The data shows that there was approximately 2.25 kW going through this breaker.

Figure 4. GV29.1 kW



Also, there is a new building called the AMP Building that recently had new baseline vendor dust collectors installed. The baseline vendor is the vendor that provided a bid and estimate for the less efficient baseline system for Building 2019 that was not selected. The baseline vendor system is the system that was used as the basis for calculating the baseline energy use. The evaluators took this opportunity to install loggers on three of these baseline vendor units. The loggers that were installed are shown in the table below:

Table 9. List of Loggers Installed at AMP Building on Baseline Vendor Units

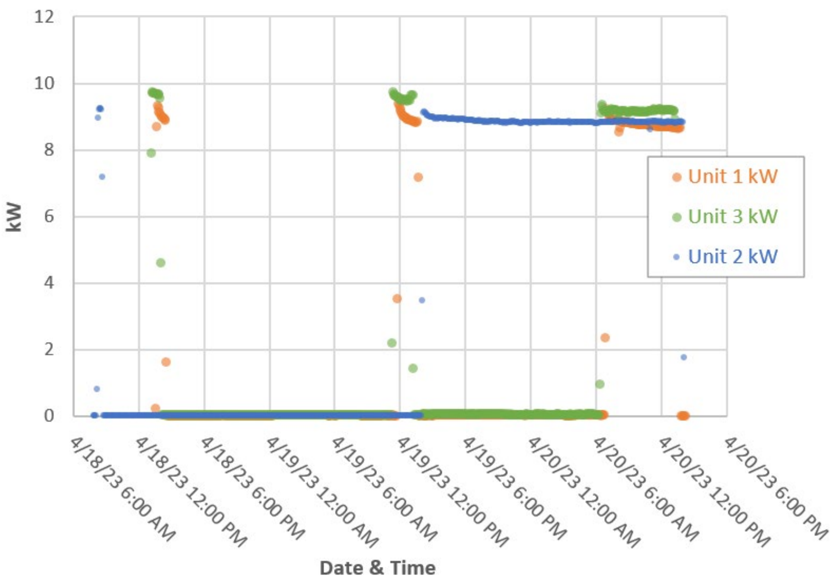
Location	Metering Equipment
FM431- 135, FM-04B - 30 HP Unit	Dent kW SP1212062
FM431-2,4,6, FM-03B	Dent kW XC 130707123
FM431-19,21,23 FM-01A	Dent kW XC1611236

Production has not started at this building yet. The following information was collected on the baseline vendor nameplates:

Series: Fusion
Model: DT4-7500-5-R
Mfg: 6/2022
30 Horsepower
480 Volts

Data from these loggers is shown in Figure 5. These units only came on for a few hours between 4/18 and 4/20 and were off for the remaining evaluation period. During this time, the filters were completely clean. The average measured kW for these units when they were on was 9.0 kW, which corresponds to a 37.12% motor load factor.

Figure 5. Data Collected on (3) 30 HP Baseline Vendor Units in AMP Building



Application 10454519/10874646 – (5) 300 HP VFD air compressor project in Buildings 2003 and 2005 - 886,913 claimed kWh

Loggers were installed on the (5) 300 HP compressors installed as part of this project. The names of the loggers are listed below:

Table 10. List of Loggers Installed on the Compressors at Building 2003 and 2005

Equipment Logged	Logger 1	Logger 2	Notes
Compressor 1 - 300 HP	DENT kW 1211088	Hobo Microstation Amp 2003869	
Compressor 2 - 300 HP	Dent kW 1803061	Hobo Microstation Amp 2002654	
Compressor 3 - 300 HP	Dent kW SP1210103	Hobo Microstation Amp 2003831	
Compressor 4 - 300 HP	Dent kW SP1210078	Hobo Microstation Amp 2002791	Only measuring half the amperage - Each Phase has two conductor wires but CTs only fit around 1 wire
Compressor 5 - 300 HP	Dent kW SP12120060		

The operating pressures (psi) at each compressor were as follows:

1. 107
2. 107
3. 104
4. 103
5. 103

Each compressor is a 300 HP, Kaeser, SFC compressor, rated at 1439 CFM at 125 psi. Each compressor had its own dedicated desiccant dryers (Kaeser KADP5-1550) that were operating at -40° F dew point during the

day of the site-visit (April 4, 2023). In the winter, they are set at -4° F, and in the summer, they are set at -94°F. Since the evaluation period occurred when the dew-point was set at a point between these two extremes, the evaluators believe that the data collected during the evaluation monitoring period is representative with respect to air dew-point (which has an effect on the CFM demand, since the lower the dewpoint setpoint, the more compressed air would be needed to dry and cycle the desiccant tanks).
Each compressor also had an oil filter, and (1) KAESER ANEC00RAW14 Eco Drain 14 no-loss condensate drain. In the room that housed compressors 1-3, there were (3) 5' diameter, 16' tall storage tanks. In the room that housed compressor 4-5, there were (4) storage tanks. (1) is 4' in diameter, and 15' tall, and the other (3) are 5' in diameter, and 20' tall (approximately). The site contact did not know what kind of drains existed prior to this project.

Figure 6 shows the total kW data collected on the (5) 300 HP VFD compressors. Figure 7 shows the data for each of the (5) compressors separately. Figure 7 shows that the compressors modulate their speeds together for the most part, rather than have one trim compressor, with the others operating at full load. Figure 8 shows the percentage of time that 2, 3, 4 and 5 compressors are on simultaneously.

Figure 6. Data Collected on (5) 300 HP VFD Air Compressors

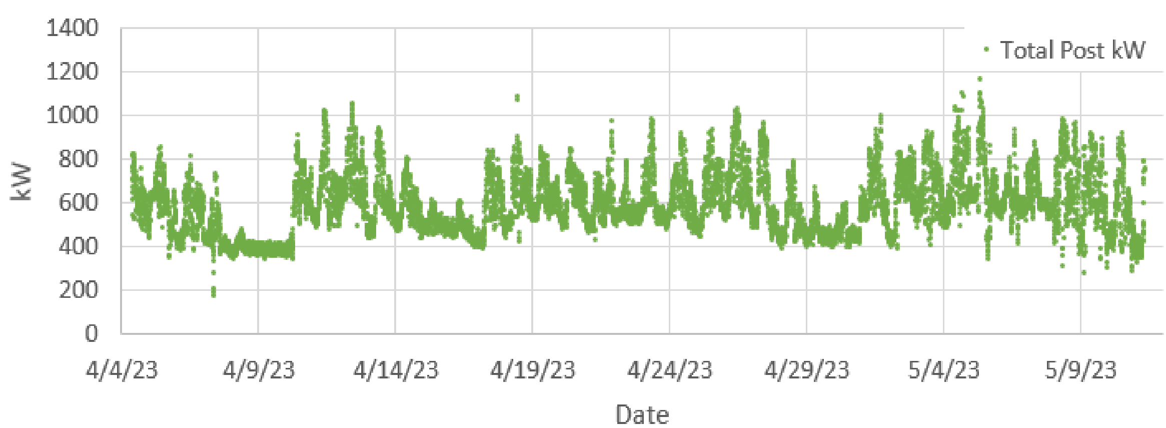


Figure 7. Data Collected on (5) 300 HP VFD Air Compressors – Disaggregated by Compressor

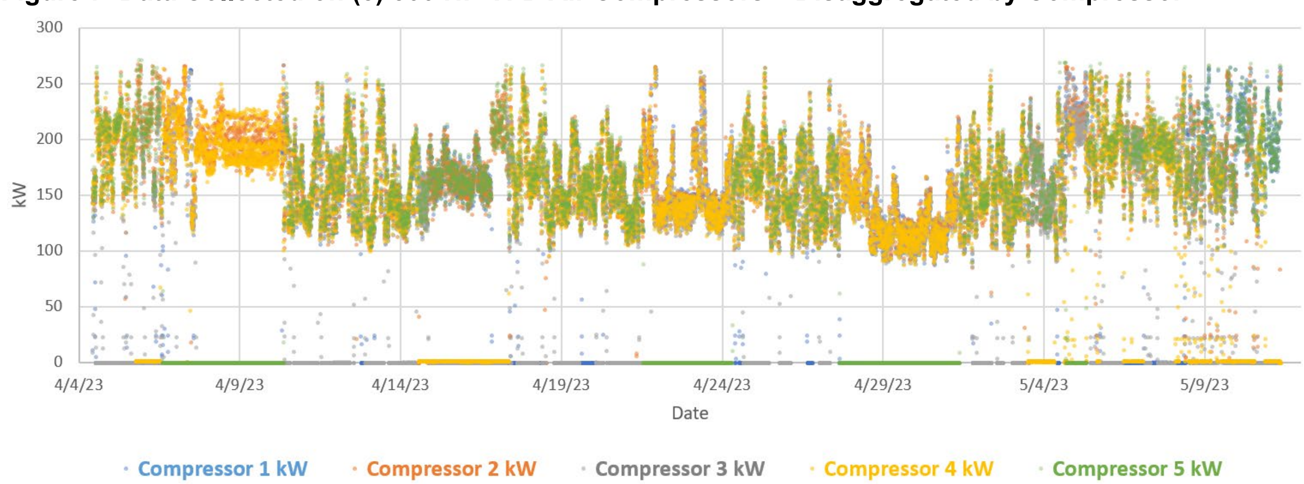
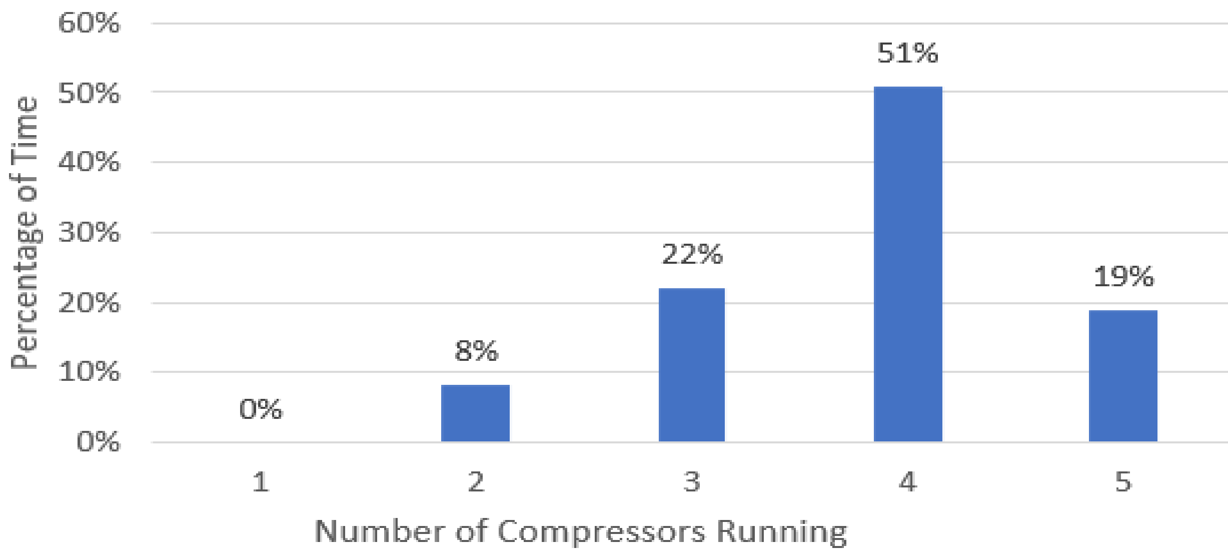


Figure 8 shows the percentage of time that 2, 3, 4, and 5 compressors are running simultaneously, and shows that for most of the time (51%), 4 compressors are running.

Figure 8. Percentage of Time that 2, 3, 4, and 5 Compressors are Running Simultaneously



2.3 Evaluation Methods and Findings

This section describes the evaluator methods and findings.

2.3.1 Evaluation Description of Baseline

Application 10107675/11761473– Dust collection project in Building 9B - 3,581,569 claimed kWh

AND **Application 10109441/10874645 – Dust collection project in Building 9A -** 2,286,489 claimed

For the dust collection projects in Buildings 9A and 9B, the evaluator agrees that this is a new construction project and agrees that it is appropriate to use an alternative vendor's proposal as the baseline for this measure, as this represents what the customer would have installed had the customer not chosen to go with the installed system.

Application 10454519/10874646 – (5) 300 HP VFD air compressor project in Buildings 2003 and 2005 - 886,913 claimed kWh

For the compressed air measure, new compressors replaced compressors that were at the end of their useful life. For this reason, the baseline is industry standard practice. The evaluator referred to the MA Compressed Air ISP Memo[1]. This memo indicates that the baseline is an oil-flooded, air-cooled single-stage rotary screw compressor with load/no-load control, and 1 ga/CFM of storage. However, the MA baseline framework document indicates[2] that the ISP baseline cannot be less efficient than the in-situ baseline unless the pre-existing system was incentivized. Given the age of the replaced system it could not be determined if it was funded through the program. In this case, the previous system had a storage capacity of 1.8 gal/CFM, which is more efficient that 1 gal/CFM. For this reason, the evaluator used a storage capacity of 1.8 gal/CFM rather than 1.0 gal/CFM referenced in the MA Compressed Air ISP Memo.

2.3.2 Evaluation Calculation Method

Application 10107675/11761473– Dust collection project in Building 9B - 3,581,569 claimed kWh

AND **Application 10109441/10874645 – Dust collection project in Building 9A -** 2,286,489 claimed

For the dust collection measure, the evaluator calculation used the following algorithms:

$$Electric\ Savings\ = Baseline\ Elec - Post\ Elec$$

where,

$$Baseline\ Elec = Hours_{BL} \times\ Qty_{BL}\ \times \frac{HP_{BL} \times LF_{BL}}{\eta_{BL}} \times 0.746\frac{kW}{HP}$$

$$Post\ Elec = 9\ HP\ Fan\ kW\ \ \times Hours_{9HP}\ +\ 3\ HP\ Fan\ kW \times Hours_{3HP} + 25HP\ Fan\ kW \times Hours_{25HP}$$

$$9\ HP\ Fan\ kW\ = Qty_{9P} \times Avg.Measured\ kW_{9P} \times Lifetime\ Filter\ Adjustment\ Factor$$

$$3\ HP\ Fan\ kW\ = Qty_{3P} \times Avg.Measured\ kW_{3P}$$

$$25HP\ Fan\ kW\ = Qty_{25P} \times Avg.Measured\ kW_{25P}$$

Where the variables are described in Table 11.

Table 11. Variable List for Evaluator Energy Savings Algorithms

Variable Name	Units	Variable Value	Variable Source
$Hours_{BL}$	Hours/year	6,783	This data is based on the evaluation post-case measurements collected on (26) GVSC fans collected over 38 days, and the commissioning data collected on (6) GVSC fans collected over 14 days. A weighted average was taken from the (26) units measured during evaluation, and the (6) units measured during the commissioning period, weighted by the quantity of units.
$Hours_{9HP}$	Hours/year	6,783	This data is based on the evaluation post-case measurements collected on (26) GVSC fans collected over 38 days, and the

[1]Boyd, K. and Maxwell, J. "ISP Study Findings – Air Compressors and Compressed air Dryers". Massachusetts Energy Efficiency Advisory Council. 2018. https://ma-eeac.org/wp-content/uploads/AirCompressors_ISP_Memo_final.pdf

[2]DNV and ERS. Massachusetts Commercial/Industrial Baseline Framework. Massachusetts Energy Efficiency Advisory Council. 2017. https://ma-eeac.org/wp-content/uploads/MA-Commercial-and-Industrial-Baseline-Framework-1.pdf

Variable Name	Units	Variable Value	Variable Source
			commissioning data collected on (6) GVSC fans collected over 14 days.
$Hours_{3HP}$	Hours/year	6,250	This data is based on the evaluation post-case measurements collected on (27) assist fans collected over 38 days, and the commissioning data collected on (11) assist fans collected over 14 days.
$Hours_{25HP}$	Hours/year	434	This data is based on the evaluation post-case measurements collected on (1) house fan collected over 38 days.
Qty_{BL} Baseline Module Quantity	-	53	This is the quantity of dust collection modules for Buildings 9A and 9B. Each module consists of (2) 30 HP motors and filters. This is based on the original baseline quotes from the baseline vendor.
Qty_{9P} Post-case 9 HP Module Quantity (GVSC units)	-	136	This is the quantity of post-case 9 HP dust collection modules for Buildings 9A and 9B. These are also referred to as GV units, and GVSC units. Each module consists of (3) 3 HP motors, and filters. This is based on what the evaluators observed on-site through the user-interface screen and matches the quantities on the tracking calculations.
Qty_{3P} Post-case 3 HP Assist Fan Quantity	-	106	This is the quantity of post-case 3 HP assist fans for Buildings 9A and 9B. These fans do not have a filter and are used to mix air in the space so that the GVSC units can be sure to capture and filter all the air in the space, and not leaving some portions of the space unfiltered.
Qty_{25P} Post-case 25 HP House Fan Quantity	-	3	This is the quantity of post-case 25 HP house fans for Buildings 9A and 9B. These motors operate for 1-2 hours per day and are used to remove the dust from the ductwork inside and put the dust into 55-gallon drums located outside the building. This quantity was observed during the site visit.
HP_{BL} Baseline Motor Horsepower per Module	HP	60	This is based on the original baseline quotes from the baseline vendor. There are (2) 30 HP motors per module.
LF_{BL} Baseline Motor Load Factor	-	0.49	This is based on the measured data on the baseline equipment at the AMP Building (see Figure 5), combined with information collected from the baseline vendor to account for how the load on that motor will change as the filters become loaded. The analysis included incorporating data from the fan curves. The baseline motor power draw is lowest when the equipment is brand new because dust has not accumulated on the filters yet. As dust accumulates on the filter, jets of compressed air pulse the filters periodically to clean them, which return the filters to almost new. According to the baseline vendor, after cleaning there is about 10% more pressure drop across the filter than the initial, brand-new condition. This cycle repeats throughout the rest of the life of the filter, until a point at which the pulse jet is no longer able to clean the

Variable Name	Units	Variable Value	Variable Source
			filter. At this point, the pressure drop continues to increase, and the filter is beyond its useful life, but the fan is still able to achieve the required airflow. The baseline vendor estimated that the filter is in this condition for 20% of the time that the filters are installed, but it can vary depending on how proactive a facility is about replacing the filters when they reach this point.
$Avg. Measured\ kW_{9P}$ Post-case 9 HP Module kW	kW	2.42	This value of 2.42 kW is based on the evaluation post-case measurements collected on (26) GVSC fans collected over 38 days, and the commissioning data collected on (6) GVSC fans collected over 14 days. Each GVSC unit consists of (3) 3HP motors and filters.
$Lifetime\ Filter\ Adjustment\ Factor$		1.10	The lifetime filter adjustment factor accounts for the fact that the proposed/installed motor kW was measured over a short period of time when the filters were relatively new. Similarly, the baseline load factor represents the average kW of the baseline motor over the life of its filter. This lifetime adjustment factor is the ratio of the calculated average lifetime power between a model that includes 15% of "extended" filter pressure drop life, to a model that does not include this 15%. The idea is that both the baseline and post-case would have a period where the filters operate at increased pressure drop operation. The increased pressure drop baseline scenario was found to use 10% more power compared to the baseline scenario that did not include this period with the increased pressure drop. So, because the baseline load factor does include this period that includes this increased pressure drop operation, that factor is applied to the post-case also to make the comparison more on an apples-to-apples basis. .
$Avg. Measured\ kW_{3P}$ Average Measured post-case 3 HP Assist Fan kW	kW	1.01	This value of 1.01 kW is based on the evaluation post-case measurements collected on (27) assist fans collected over 38 days, and the commissioning data collected on (11) assist fans collected over 14 days. A weighted average was taken from the (27) units measured during evaluation, and the (11) units measured during the commissioning period, weighted by the quantity of units.
$Avg. Measured\ kW_{25P}$ Average measured post-case 25 HP House Fan kW	kW	28.7	This value of 28.7 kW is based on the evaluation post-case measurements collected on (1) of the (3) house fans at Buildings 9A/9B collected over 38 days.
η_{BL} Baseline Motor Efficiency	-	93.0%	This value is estimated from an iteration process, and referring to a motor efficiency curve from the MotorMaster database. Using the measured kW data from the AMP building on the baseline system, a motor efficiency is guessed, and using the measured kW and assumed efficiency to calculate motor load, the efficiency is looked

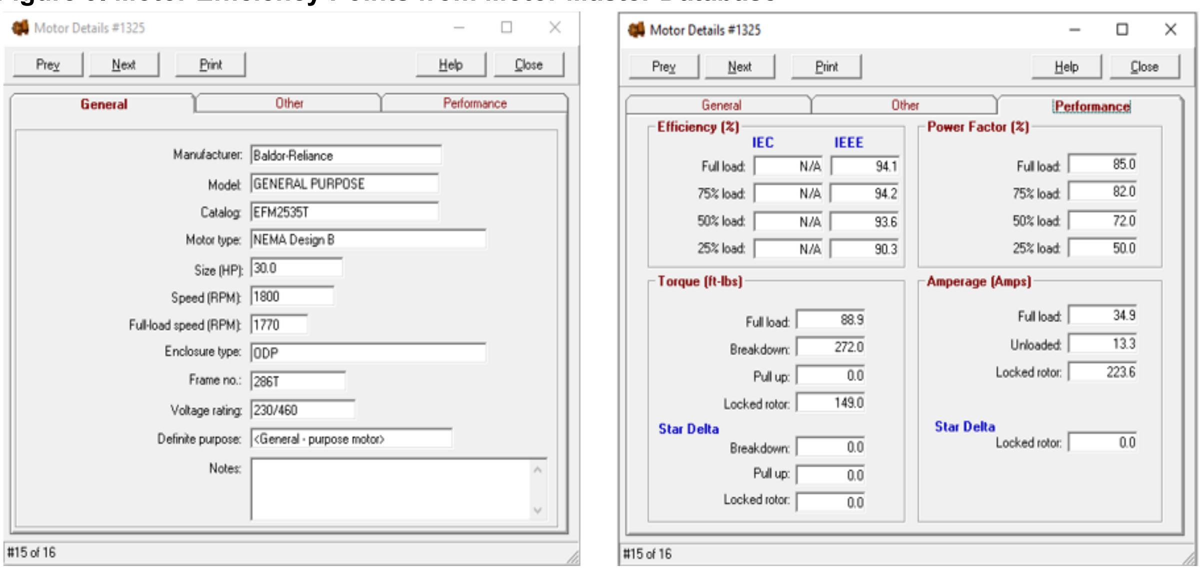
Variable Name	Units	Variable Value	Variable Source
			up at that load, and that process is repeated and iterated until the efficiencies match.

The following section describes the steps for estimating the baseline motor load factor.

1.) The measured kW of the (3) 30 HP motors on the baseline system that was installed at the AMP Building, from Figure 5 is 9.02 kW. This kW was for a new fan with no dust build-up or pressure drop across the fan

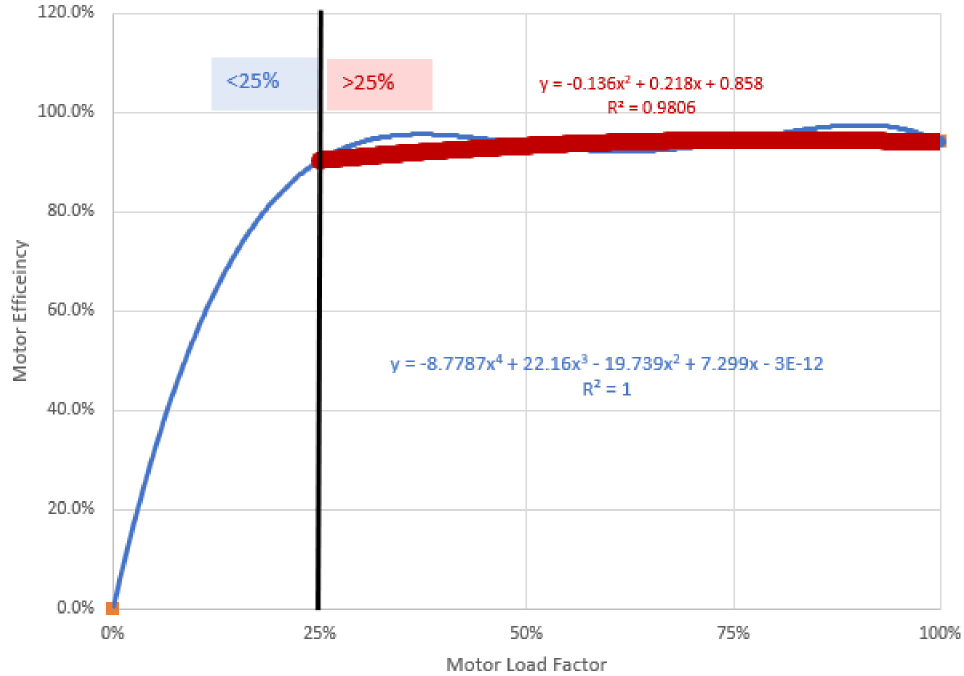
2.) Using the MotorMaster database, the motor shown in Figure 9 was selected, to get a motor efficiency curve.

Figure 9. Motor Efficiency Points from Motor Master Database



The motor efficiency curve was developed from the (5) motor loadings (0%, 25%, 50%, 75%, 100%). Polynomial equations were developed for the potion of the curve below 25% motor load factor, and the portion of the curve greater than 25% as shown in Figure 10.

Figure 10. Motor Efficiency Curve from Selected Motor from Motor Master Database



3.) Through iteration and using the motor curve in Figure 10, at 9.02 kW, the motor was estimated to have an operating efficiency of 92.02%, and a motor load factor of 37.1%. This represents the load factor at the point in time before any dust has accumulated on the filters, and so without any additional pressure drop from filters which have accumulated dust. Additionally, ductwork had not yet been added to these units. The baseline vendor indicated that 30 feet of 26" diameter duct would also need to be installed. From friction loss chart[3] in the ASHRAE Fundamentals book, at 13,000 CFM, the design airflow rate for this unit, there would be 0.169 in. of H_2O of pressure drop for 30' of duct. Accounting for an additional 25% of pressure drop for louvers, the total additional pressure drops from the ductwork and louvers would be 0.21 in. of H_2O.

4.) The baseline vendor provided fan curves for fans that would be used in their dust collection modules on these 30 HP motors. The important data from those fan curves is shown in Table 12.

Table 12. Nameplate data from fan curves – showing total pressure drop, power, fan efficiency at 13,000 CFM and various speeds and filter pressure drops

Nameplate HP	30	30	30	30
Nameplate CFM	13,000	13,000	13,000	13,000
Total Pressure (in. wg)	9.51	8.71	5.21	4.01
Static Pressure (in. wg)	9.00	8.20	4.70	3.50
Fan Power (HP)	19.5	17.8	10.7	8.2
BHP - Calculated	25.4	23.32	15.1	12.5
BHP - from Chart	25.4	23.4	15.1	12.6
Fan Efficiency	0.767	0.764	0.706	0.654

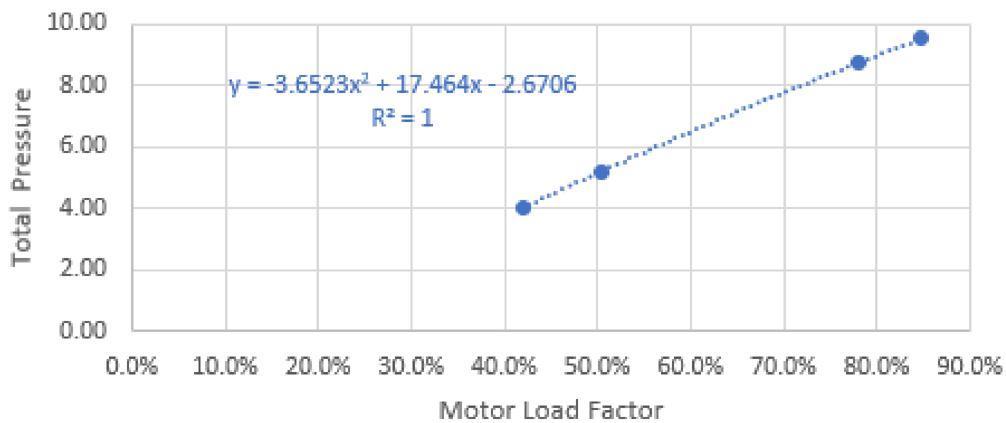
[3] See Fig. 10, page 21.9, in ASHRAE Fundamentals 2017

Motor Load Factor	84.7%	78.0%	50.3%	42.0%
Motor Efficiency	95%	95%	93%	93%
Measured kW Input	20.0	18.5	12.1	10.2

* This is the net power required to deliver the stated pressure and air flow at perfect fan efficiency

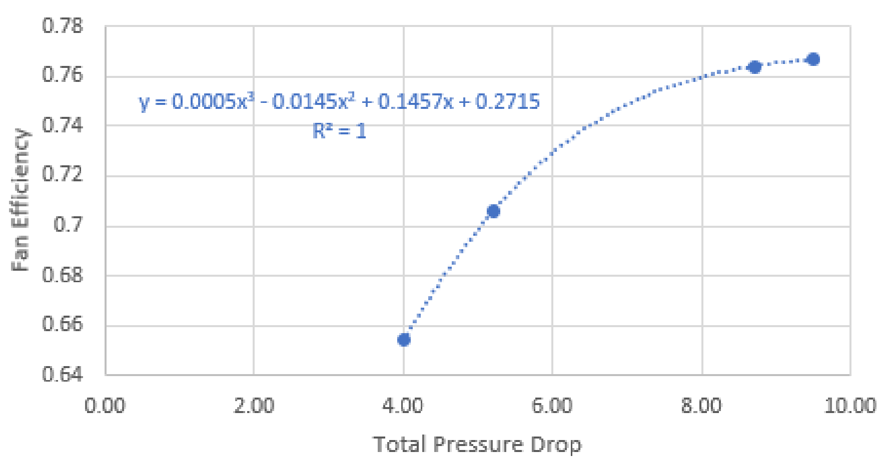
5.) From the table of data from the fan curve data in Table 12, a relationship between total pressure drop, and motor load factor can be developed, as shown in Figure 11. From this curve and knowing that the baseline motor load factor is 37.12% (before any dust has accumulated, and not accounting for duct or louver losses), the total pressure drop is 3.31”. Accounting for the additional 0.21” of pressure drop from the ductwork and louvers, the beginning of life pressure drop is 3.52 inches of water gauge.

Figure 11. Total Fan Pressure Drop vs. Motor Load Factor Curve



6.) In addition to Figure 11, the data in Table 12 was used to create the chart and curve shown in Figure 12, which shows the fan efficiency as a function of total pressure drop when the fan is producing 13,000 CFM.

Figure 12. Fan Efficiency vs. Total Fan Pressure Drop at Constant 13,000 CFM and Variable Speeds



7.) Assuming that the initial pressure drop with the equipment is 3.52 inches, that the airflow is meant to be maintained at 13,000 CFM and using the fan and motor efficiency curves in Figure 10 and Figure 12, the initial kW input (before the filters start accumulating dust and increasing the pressure drop), the initial kW input is estimated at 9.23 kW.

8.) The baseline vendor stated that the fan would continue operating in this low pressure drop realm for an extended period, while dust slowly accumulates on the filters. Over time, as dust accumulates, the filters are periodically pulsed with compressed air to clean the filters. The baseline vendor stated that this would return the filters to a state that has a pressure drop that is about 10% higher than the pressure drop that existed across the filters when they were brand new. This cycle would repeat, over and over, where the pressure drop across the filters increases to the setpoint, and then the compressed air jets clean the filters and reduce the pressure again. According to the vendor, eventually, after numerous cycles, the jets of compressed air will no longer be able to be able to bring the filters back to near their initial pressure drop, and the pressure would increase by about 4”. The baseline vendor estimated that the filters would remain in their initial state (3.52”, 9.23 kW), for approximately 5% of their life, and spend about 80% of their life going back and forth between 10% higher than the initial pressure drop, and 1.5” higher than 10% higher than the initial pressure drop. The baseline vendor estimated that the filter would spend about 15% of it’s life, at the end of the filter life, where the pressure drop is 4” higher than the point at which the pulses of compressed air get activated. A summary of the different filter conditions, and the associated input kW (based on the pressure drop, fan efficiency, and motor efficiency) is shown in Table 13.

Table 13. Pressure Drop, kW Input, and % of Time Spent at Various Stages of Filter Life (5%, 80% 15%)

Filter Condition and Filter Pressure Drop Status	Pressure Drop (in. wg)	% Time Spent at Condition	Fan Efficiency	Brake HP	Motor Load Factor	Motor Efficiency	kW Input
Beginning of life pressure drop	3.52	5%	63%	11.40	38%	92%	9.2
Initiation of pulsing pressure drop (1.5" higher than beginning of life pressure drop, per baseline vendor)	5.02						
After pulsing, regenerated pressure drop (10% higher than beginning of life pressure drop, per baseline vendor)	3.87						
Average of initiation of pulsing and after pulsing/regenerated pressure drop	4.45	80%	67%	13.48	45%	93%	10.8
End of life pressure drop - filter needs replacement since pulsing no longer dislodges particles	8.45	15%	77%	22.54	75%	95%	17.8
Weighted Average					**49%**	93%	11.8

9.) If no time were spent in the condition at the end of the filter life, where there is 8.45" of pressure drop, the motor load factor would be 45% rather than 49% shown in Table 13. In this case, the third column, the % time column, in Table 13 would be 5%, 95%, rather than 5%, 80%, 15%. The ratio of 49% to 45% is 1.10. This value is the lifetime filter adjustment factor and is applied to the measured kW data for the post-case GVSC filters, in an attempt to make the comparison between the post-case measured data more of an apples-to-apples comparison to the baseline motor load factor estimate – which is an estimate for the entire life of the baseline filter.

Application 10454519/10874646 – (5) 300 HP VFD air compressor project in Buildings 2003 and 2005 - 886,913 claimed kWh

The evaluator calculations for the compressed air measure followed the following steps:

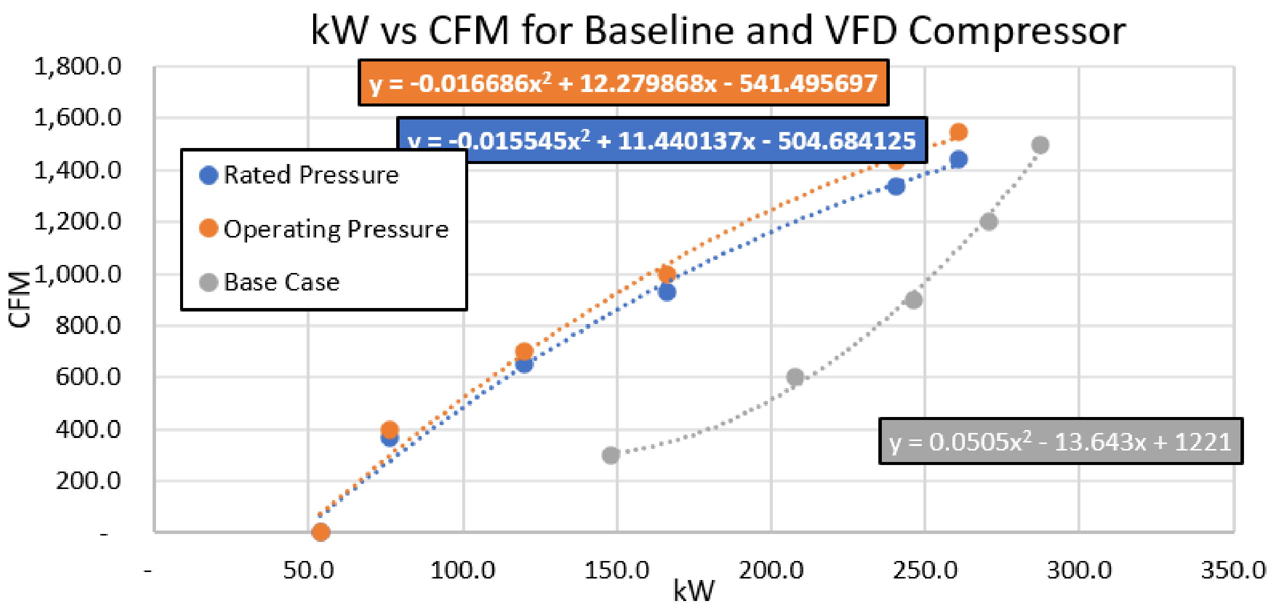
1.) The post-case kW data which was collected over the 38 days of the evaluation monitoring period was converted into an average weekly schedule, as shown in Figure 13, and then applied to an 8760 annual schedule.

Figure 13. Post-case measured kW – sum of (5) 300 HP VFD compressors

Hour	Sun	Mon	Tue	Wed	Thu	Fri	Sat
0	488	507	475	543	490	513	476
1	524	499	471	542	477	497	473
2	527	536	509	578	485	505	484
3	526	524	511	595	489	505	480
4	571	535	507	579	480	504	497
5	530	554	568	628	504	517	493
6	514	587	628	674	554	595	524
7	607	708	716	760	693	635	576
8	602	729	702	749	723	676	563
9	591	670	694	726	684	648	554
10	615	824	804	870	817	716	601
11	528	722	776	728	773	693	511
12	495	603	676	633	680	642	491
13	492	772	766	819	792	630	498
14	485	682	596	639	625	519	516
15	490	619	597	587	585	473	531
16	491	674	681	679	643	507	501
17	491	680	664	643	625	549	479
18	486	619	644	589	601	544	497
19	478	708	718	667	662	593	487
20	469	625	610	588	587	527	491
21	463	573	597	560	624	547	487
22	466	637	673	634	603	566	488
23	488	506	548	537	543	482	485

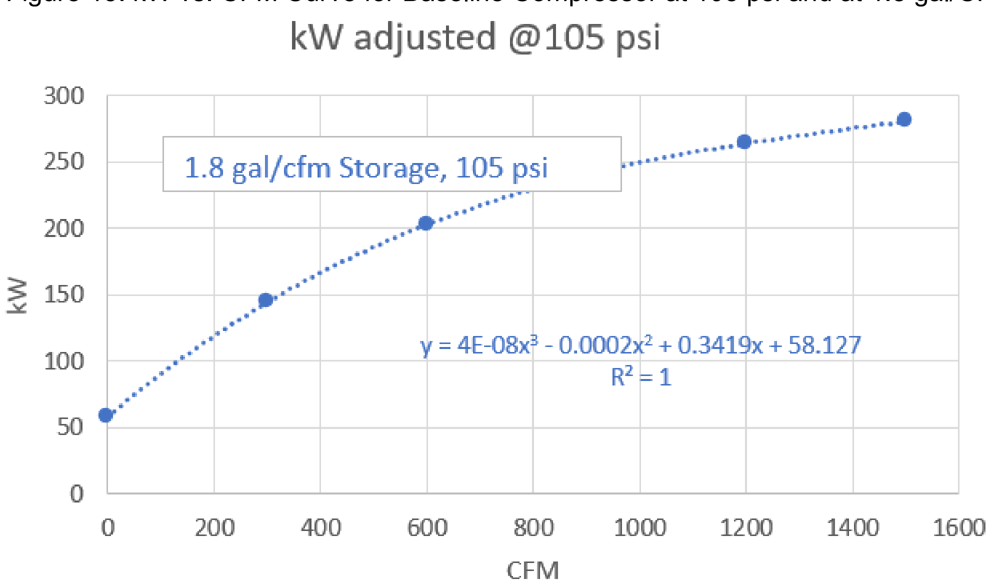
2.) The post-case kW data in the 8760 file for each compressor was converted to CFM data using the compressor's CAGI sheets, adjusted to 104 psi, which is the psi observed during the site visit. The kW vs. CFM curve is shown in Figure 14.

Figure 14. CFM vs. kW Curve for Baseline and VFD Compressor



3.) The total CFM data calculated in the previous step was then disaggregated to model the operation of (5) 300 HP, 1500 CFM, constant speed compressors operating in load/no-load mode. So, if the total Load was 5,000 CFM, the Compressor 1, 2, and 3 would be modelled to run at 1,500 CFM, while compressor 4 would be modelled to run at 500 CFM, and compressor 5 would be modelled to run at 0 CFM. The baseline CFM vs. kW curve was then applied to the disaggregated CFM data for each compressor, to estimate the baseline kW for each of the 5 compressors. The baseline kW vs. CFM curve is shown in Figure 15. This curve is based on the Compressed Air Challenge Handbook.

Figure 15. kW vs. CFM Curve for Baseline Compressor at 105 psi and at 1.8 gal/CFM.



4.) The tracking calculations indicated that the post-case included no-loss drains, whereas the baseline did not. The evaluator asked the site contact if they recall if the baseline did or did not have no-loss drains, and the site-contact did not know, since he was not around at that time. The evaluator was not able to verify if the baseline indeed did not have no-loss drains, but the evaluator did verify that the post-case did include no-loss condensate drains. The tracking calculations estimate that the baseline would have used an additional 5 kW for each hour of operation that the baseline compressors operated compared to the post-case, because of the no-loss condensate drains in the post-case. The evaluator accepted this estimate, as it had an insignificant impact on the overall results. As a result, the evaluator added an additional 5 kW for each hour of baseline operation to account for the post-case no-loss condensate drains. The energy savings were computed in the 8,760 file by taking the difference between the calculated baseline kW, and the post-case kW.

3 Final Results

The scope of this evaluation consisted of dust collection projects completed across (5) project numbers, and compressed air projects completed across (3) project numbers – all at the same manufacturing facility. The two largest dust collection projects, and the largest compressed air projects were sampled, and data was collected and used to develop realization rates for those similar measures not studied. The realization rate developed from the dust collection analysis was used for the remaining, un-sampled dust-collection measures, and the evaluation results from the sampled compressed air measure were applied to the non-sampled compressed air measures.

The final results for all the measures are shown in Table 14. The two dust collection measures evaluated had a realization rate of 90%, and the compressed air measure had a realization rate of 131%.

Table 14. Evaluation Results Summary

PA Application ID	Measure Name	Parameter	Energy Savings (kWh/yr)	Energy Savings on Peak (%)	SP Demand Reduction (kW)	WP Demand Reduction (kW)	Lifetime Energy Savings (kWh)
10107675/ 11761473	Dust Collection 9B	Tracked	3,581,569	89%	446.3	446.3	53,723,535
		Evaluated	3,235,266	53%	387.2	449.9	48,528,996
		RR	90%	60%	87%	101%	90%
10109441/ 10874645	Dust Collection 9A	Tracked	2,286,489	89%	309.6	309.6	34,297,335
		Evaluated	2,065,408	53%	268.6	312.1	30,981,119
		RR	90%	60%	87%	101%	90%
7331289/ 10476007	Dust Collection 2019	Tracked	1,723,559	89%	208.9	208.9	25,853,385
		Evaluated	1,556,908	53%	181.2	210.6	23,353,616
		RR	90%	60%	87%	101%	90%
7944858/ 10902885	Dust Collection 2014 Bay 4	Tracked	1,494,745	89%	193.9	193.9	22,421,175
		Evaluated	1,350,218	53%	168.2	195.4	20,253,267
		RR	90%	60%	87%	101%	90%
11063124	Dust Collection 2019 AFC Phase 2	Tracked	892,476	89%	157.0	157.0	13,387,140
		Evaluated	806,182	53%	136.2	158.3	12,092,735
		RR	90%	60%	87%	101%	90%

PA Application ID	Measure Name	Parameter	Energy Savings (kWh/yr)	Energy Savings on Peak (%)	SP Demand Reduction (kW)	WP Demand Reduction (kW)	Lifetime Energy Savings (kWh)
10454519/ 10874646	(5) 300 HP VFD Compressors	Tracked	886,913	48%	113.0	105.9	13,303,695
		Evaluated	1,158,389	52%	153.9	156.6	17,375,833
		RR	131%	109%	136%	148%	131%
7999525	(1) 125 HP VFD Compressor	Tracked	149,781	48%	12.5	12.5	2,246,715
		Evaluated	195,628	52%	17.0	18.5	2,934,413
		RR	131%	109%	136%	148%	131%
11759401	(2) 930 CFM Desiccant Dryers with Demand Dewpoint Control	Tracked	113,820	43%	11.5	12.1	1,707,300
		Evaluated	148,659	47%	15.7	17.9	2,229,888
		RR	131%	109%	136%	148%	131%
Totals		**Tracked**	**11,129,352**	**85%**	**1,452.7**	**1,446.1**	**166,940,280**
		Evaluated	**10,516,658**	**53%**	**1,328.0**	**1519.1**	**157,749,868**
		RR	**94%**	**63%**	**91%**	**105%**	**94%**

RR = Realization rate
SP = Summer peak
WP = Winter peak

Application 10107675/11761473– Dust collection project in Building 9B - 3,581,569 claimed kWh

AND

Application 10109441/10874645 – Dust collection project in Building 9A - 2,286,489 claimed

Table 15 provides a comparison of the key parameters for the dust collection measure. The main reason that is causing the realization rate that is lower than 100%, (88%), is the evaluation finding that the post-case fan motor load factors were higher than the load factors measured at the time that the tracking calculations were developed. The tracking calculations show post-case motor load factors of 28% and 24% for the GV units and AF units respectively, whereas the evaluator measured values that were 37% and 43%. The tracking calculations used measurements on (6) GV units, and (11) AF units. The evaluator calculations used incorporated these measurements, as well as data from an additional (26) GV units, and (27) AF units. The evaluator data was collected over 38 days, whereas the data used in the tracking calculations were based on data collected over 14 days.

Table 15. Summary of Key Parameters for Dust Collection Measure in Building 9A/9B

Condition		Variable	Tracking	Evaluator
Baseline	Baseline Vendor Units	Qty	53	53
		HP	60	60
		Load Factor	51%	49%
		Hours	6188	6,783
		Motor Efficiency	94.1%	93.1%
		kW to HP	0.746	0.746
		Total kWh	7,890,682	8,494,209
Post Case	Post Vendor GV Units	Qty	136	136
		HP	9	9
		Load Factor	28%	37%
		Hours	6188	6,783
		Motor Efficiency	94.1%	94.1%
		kW to HP	0.746	0.746
		Total kWh	1,651,759	2,455,689
	Post Vendor AF Units	Qty	106	106
		HP	3	3
		Load Factor	24%	43%
		Hours	6188	6,519
		Motor Efficiency	94.1%	94.1%
		kW to HP	0.746	0.746
		Total kWh	370,864	700,443
	Post Vendor House Fans	Qty	0	3
		HP	0	25
		Load Factor	0	145%
		Hours	0	434
		Motor Efficiency	0.0%	94.1%
		kW to HP	0	0.746
		Total kWh	0	37,403

Table 16 shows a comparison of the overall baseline, post-case, and energy savings estimates for the tracking and evaluator analyses.

Table 16. Overall Tracking and Evaluator Savings for Building 9A/9B

Condition	Tracking	Evaluator	Realization Rate for 9A/9B
Baseline Total	7,890,682	8,494,209	
Post Total	2,022,624	3,193,535	
Savings	5,868,058	5,300,674	90%

Application 10454519/10874646 – (5) 300 HP VFD air compressor project in Buildings 2003 and 2005 - 886,913 claimed kWh

Table 17 shows a summary of the key baseline and post-case parameters in the tracking analysis and the evaluation analysis. The parameter which has the most significant impact is the difference in the efficiencies of the baseline and installed compressors. The tracking calculations estimate that the proposed compressors use 0.032 kW/CFM less than the baseline, whereas the evaluator found the difference to be 0.040 kW/CFM. Most of this (90%) of this is due to the higher baseline average kW/CFM. The tracking analysis estimated a baseline kW/CFM of 0.196, whereas the evaluator estimated this to be 0.203. This is due to a difference in what part of the kW/CFM curve that the compressed air plant operated at between the tracking analysis and the evaluator analysis. The tracking analysis found that for 63% of the time that the compressors were not at 0% load, they were running at full load. So, they were at part load for 37% of the time. When they were in this part load operation, their average CFM was 59%, which corresponds with a kW/CFM of 0.23 kW/CFM.

In the evaluator analysis, 32% of the time the baseline compressors are operating at a part load condition which is not 0 CFM, or the maximum CFM of 1500 CFM. When it is operating at part load, the average part load is 53%, which has an average kW/CFM of 0.266 kW/CFM. This difference in the where the load falls is what is causing the higher baseline energy in the evaluator analysis compared to the tracking analysis.

The other main reason the evaluator analysis resulted in higher savings compared with the tracking analysis is due to the evaluator finding that the plant is generating more CFM on average during the evaluation monitoring period compared with the tracking monitoring period. The evaluation monitoring period observed an average CFM demand of 3,590 CFM, with all (5) compressors operating, whereas the tracking analysis resulted in an average CFM demand of 3,191 CFM, with only a maximum of (3) compressors ever running. The tracking analysis only used (3) compressors in the analysis, because at the time, there was uncertainty about how many compressors would run simultaneously, but the evaluator analysis found that (5) compressors did run simultaneously in the post case for a good portion of the time.

Table 17. Summary of Key Parameters for Compressed Air Measure in Buildings 2003 and 2005

Parameter	Baseline		Post	
	Tracking	Evaluator	Tracking	Evaluator
	Value(s)	Value(s)	Value(s)	Value(s)
Number of Compressors	3	5	3	5
Compressor HP	300	300	300	300
Operating Pressure	97	105	97	105
Compressor CFM	3,191	3,525	3,191	3,525
Compressor kW/CFM	0.197	0.203	0.166	0.167
Compressor kW/CFM Reduction			0.032	0.036
Compressor kW	630	715	529	587
Annual Hours	8736	8,760	8736	8,760
Compressor kWh	5,463,853	6,261,952	4,619,156	5,145,894
Drain kW	4.8	4.8	0	0
Drain Hours	8760	8,760	0	0
Drain kWh	42,216	42,332	0	0
Total kWh	5,506,069	6,304,283	4,619,156	5,145,894
Total Savings			886,913	1,158,389

3.1 Explanation of Differences

Application 10107675/11761473– Dust collection project in Building 9B - 3,581,569 claimed kWh

AND

Application 10109441/10874645 – Dust collection project in Building 9A - 2,286,489 claimed

The evaluated savings are lower than the applicant-reported values (90%) predominantly because of discrepancies in operations. Table 18 provides a summary of savings deviations for the dust collection measure.

Table 18. Summary of deviations for Dust Collection Measure

Measure	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
11761473 and 10874645	Operation	Post-case Motor Load Factors	-11%	**Decreased savings -** evaluation findings indicate that post-case GV fans operated at 37% rather than 28%, and AF fans operated at 43% rather than 24%.
11761473 and 10874645	Operation	Operating Hours	2%	**Increased savings –** evaluation findings indicate that the average operating hours were about 8% higher compared to the tracking estimate.
11761473 and 10874645	Operation	Baseline Motor Load Factor	-1%	**Decreased savings –** evaluation findings indicate that baseline fans would have operated at 49% (based on analysis of measured data and fan curves), whereas tracking indicates the baseline fans would have operated at 51% motor load factor.
11761473 and 10874645	Operation	Incorporation of House Fans	-0.2%	**Decreased savings –** evaluation findings indicate that the incorporation of the (3) 25 HP house fans that operate <500 hours/year reduced the savings by about 1%.
Final RR				**90%**

Application 10454519/10874646 – (5) 300 HP VFD air compressor project in Buildings 2003 and 2005 - 886,913 claimed kWh

The evaluated savings are higher than the applicant-reported values (131%) primarily because of discrepancies in operation. Table 19 provides a summary of savings deviation for the compressed air measure.

Table 19. Summary of Deviations for the Compressed Air Measure

Measure	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
10874646	Operation	Change in kW/CFM between baseline and post-case	18%	**Increased savings –** Evaluator change in kW/CFM from pre to post is 0.036, whereas tracking was 0.032. This is driven by evaluator finding that the operating pressure is 105 psi rather than 97 psi, and due to the evaluation finding that the baseline CFM demand percent when not fully loaded or off is 53% rather than 59% as was the case in the tracking calculations. At 53%, kW/CFM is 0.289, whereas at 59%, kW/CFM is 0.270.
10874646	Operation	CFM Demand	13%	**Increased savings –** evaluation findings that average CFM demand was 3,590, whereas tracking savings estimated 3,191 CFM.
Final RR				**131%**

3.2 Lifetime Savings

The dust collection measures have been classified as new construction, and the compressed air measures have been classified as replace on burnout.

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

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

where:

LAGI =	lifetime adjusted gross impact (kWh)
FYS =	first year savings (kWh)
EUL =	measure life (years)

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

Table 20. Lifetime Savings Summary

Factor	Tracking	Evaluator
Lifetime Savings	166,940,280	157,749,868
First Year Savings	11,129,352	10,516,658
Measure Lifetime	15 years	15 years
Baseline Classification	Dust-collection: NC Compressed Air: ROF	Dust-collection: NC Compressed Air: ROF

3.2.1 Ancillary impacts

There were no ancillary impacts associated with the evaluated measure.

RICE21N043_S

Report Date: 5/16/2023

Program Administrator	RI Energy	
Application ID(s)	12590113	
Project Type	New Construction	
Evaluation Type	Ops	
Program Year	2021	
Evaluation Firm	DNV	
Evaluation Engineer	Matthew Piana	
Senior Engineer	Max Ma	

1 EVALUATED SITE SUMMARY AND RESULTS

The evaluated project consists of the installation of one coffin case freezer and one vertical reach-in cooler in a grocery store. The as-built units are located in customer-facing areas of the grocery store and are used by customers. The measure saves energy because the as-built units use less energy than standard open commercial refrigerated cases. The first year tracked savings for this measure were 7,723 kWh.

The applicant used a vendor-provided spreadsheet-based analysis to calculate the measure savings. The applicant calculated the energy savings associated with the cooler based on the difference in the energy consumptions between the baseline refrigerated case with industry standard practice (ISP) performance and the as-built high-performance refrigeration unit as defined by its daily energy consumption (DEC) listed on its specification sheet. The applicant calculated the energy savings associated with the freezer based on the difference in the energy consumptions between the baseline freezer with code performance and the as-built high-performance refrigeration unit as defined by its DEC listed on its specification sheet.

The applicant determined the baseline ISP energy consumption (DEC) of the cooler based on a modified calculated daily energy consumption value (MCDEC). The applicant determined the baseline daily energy consumption of the freezer based on the performance of a horizontal open freezer as defined by code, DEC_{code}.

During the meter installation visit, evaluators located two freezers next to each other of the model listed in the application. Evaluators metered the operation of both the freezers and used the average of their performance to evaluate the savings associated with the freezer. Evaluators were unable to locate the cooler listed in the application during the meter install visit. Because of this uncertainty and indication it may have been moved to another location in the same grocery chain, it was assumed the as-built cooler would have operated at its DEC value listed on its spec sheet (2.04 kWh/day) with an in-service factor of 50% applied to its evaluated savings along with a load factor from recently evaluated similar coolers.

Evaluators calculated the measure savings for this application using an 8,760 spreadsheet-based analysis. For the freezer, evaluators used metered data to calculate an hourly load factor to account for the variation in the refrigeration load between the rated load and the actual load of the freezer. In this case the term load factor is not an annual percent runtime loading over the year but a percent of the metered hourly consumption over the average rated hourly consumption calculated from the DEC. The evaluators applied the calculated load factor from the as-built freezer to the baseline freezer energy consumption and calculated the savings based on the difference in consumption between the as-built and baseline freezers. For the cooler, evaluators assumed the as-built cooler operated at its DEC value as specified in its specification sheet. Evaluators calculated the savings associated with the cooler by calculating the difference in energy consumption between the as-built cooler and the baseline cooler. For both the freezer and the cooler, the evaluators used the same baseline as the applicant, however evaluators did apply a load factor to the freezer's baseline based on the as-built freezer's load factor observed through metering and the cooler's baseline based on evaluator experience.

The applicant classified the project as a new construction project and characterized the baseline as one freezer with ISP performance and one cooler with code performance. The evaluators classified the measure as a new construction with a lost opportunity site-specific unique baseline. Considering the applicant reported ISP uses a vendor defined ISP, the evaluators discussed the project with the Baseline Advisory Group (BAG) and determined the site baseline should be classified as unique and site specific until further direction is given from future ISP research. Therefore, the evaluated baseline technology is equivalent to the applicants.

The site contact indicated that the site's operations were not changed since the project's completion and will remain the same in the future, without any impacts from Covid-19. The site contact was also willing to participate in a site visit. Therefore, the evaluators adopted the full M&V approach. Table 1-1 provides a summary of the evaluation results.

Table 1-1. Evaluation results summary

PA Application ID	Measure Name		Annual Electric Energy (kWh)	% Of Energy Savings On-Peak	Summer On-Peak Demand (kW)	Winter On-Peak Demand (kW)
12590113	Refrigerated units	Tracked	7,723	47.3%	0.91	0.91
		Evaluated	3,663	53.7%	0.42	0.42
		Realization Rate	47%	113.5%	46%	46%

1.1 Explanation of Deviations from Tracking

The evaluated savings are less than the applicant-reported savings primarily due to the in-service factor applied to the as-built cooler. Further details regarding deviations from the tracked savings are presented in Section 3.1.

1.2 Recommendations for Program Designers & Implementers

The evaluators recommend that program implementers screen applicants for the intended persistence of the installed measures through interviews during the application process, to reduce the risk of low service factors.

1.3 Customer Alert

There is no relevant customer alert.

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 evaluated project consists of the installation of one cooler and one freezer in a grocery store.

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.

2.1.1 Applicant Description of Baseline

The applicant classified the project as new construction with an ISP baseline for the cooler and a code baseline for the freezer. Table 2-1 provides a summary of the applicant's baseline parameters.

Table 2-1. Applicant baseline summary

Measure/Application#	Parameter	Value(s)	Source of Parameter Value
12590113	Freezer DEC (kWh/day)	11.6	Applicant analysis - code
12590113	Freezer hours of operation	8760	Applicant analysis
12590113	Cooler MCDEC (kWh/day)	14.1	Applicant analysis - ISP
12590113	Cooler hours of operation	8760	Applicant analysis

2.1.2 Applicant Description of Installed Equipment and Operation

The applicant described the installed equipment as one coffin case freezer and one vertical reach-in cooler. Table 2-2 provides a summary of the applicant's installed equipment parameters.

Table 2-2. Application proposed case key parameters

Measure	Parameter	Value(s)	Source of Parameter Value
12590113	Freezer DEC (kWh/day)	2.6	Applicant analysis - spec. sheet
12590113	Freezer hours of operation	8760	Applicant analysis
12590113	Cooler DEC (kWh/day)	1.95	Applicant analysis - spec. sheet
12590113	Cooler hours of operation	8760	Applicant analysis

2.1.3 Applicant Energy Savings Algorithm

The applicant used a custom spreadsheet-based analysis to calculate energy savings for the measure. For the cooler, the applicant calculated an MCDEC (modified calculated daily energy consumption) value by considering the rated consumption from a sample of cases available in the market with similar capacity ratings. The applicant performed a linear regression between the daily energy consumptions and the TDA's (total display areas) of the sampled cases. The applicant then calculated the MCDEC value for the baseline cooler based on the TDA of the as-built cooler. The applicant used the following algorithm to calculate the energy savings associated with the cooler that is part of this measure:

$$\Delta kWh_c = Quantity \times Days \times (MCDEC - DEC)$$

where,

ΔkWh_c	= annual cooler electric energy savings, in kWh
$Quantity$	= the number of coolers (1 cooler)
$Days$	= annual days of operation, year-round (365 days)
$MCDEC$	= modified calculated daily energy consumption of the baseline cooler (14.1 kWh/day) based on the energy performance of a sample of refrigeration cases available in the market with comparable capacity ratings, as presented in Table 2-3
DEC	= daily energy consumption of the as-built cooler as specified in the specification sheets of the as-built refrigerated case (1.95 kWh/day), see Table 2-3 for values

The applicant calculated the MCDEC using the linear regression function "FORECAST" in Excel and the parameters listed in Table 2-3 as inputs into the following formula:

$$MCDEC = FORECAST(TDA_{installed}, array(DEC_1, DEC_2, DEC_3), array(TDA_1, TDA_2, TDA_3))$$

Table 2-3. Sampled cases model numbers and parameters for baseline cooler MCDEC calculation

Description	Model	TDA (ft^2)	MCDEC/DEC (kWh/day)
Sampled case #1	GSVM4060A	11.3	15.59
Sampled case #2	GSVM4072A	16.6	19.01
Sampled case #3	GSVM5272A	20.1	20.77
Baseline cooler	N/A	8.7	14.1
As-built cooler	BA MMR23HC	8.7	1.95

Figure 2-1 shows a screenshot from the applicant savings calculation file for the cooler.

Figure 2-1 Applicant savings calculation cooler

	HB-?	BA MMR23HC								
Quantity	0	1	0	0	0	0	0	0		
Length in		52.6							From Spec	
Width in		23.8							From Spec	
Height (Depth) in									not needed	
TDA	0.0	8.7							ft^2	
V		23.1							ft^3	
BTU/hr										
Code CDEC (kwh/da	4.7	19.4								
Modified CDEC (kw	9.0	14.1		9.0	9.0	9.0	9.0	9.0		
MDEC (kWh/Day)	15.6	1.95							From Spec	
Base kW	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0		
Eff kW	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0		
Base Btu	-	2,007	-	-	-	-	-	-		
Eff Btu	-	277	-	-	-	-	-	-		
									Total	
kWh savings	-	4,440	-	-	-	-	-	-		4,440
kW savings	-	0.51	-	-	-	-	-	-		0.51

The kW savings is the same for summer and winter consistent year round.

Kwh of cases are compared against code depending on case type.

Btu load within the space is then entered into the model as equipment load on the sales floor.

https://www.ecfr.gov/cgi-bin/text-idx?SID=b2ea2f49c7e152fd0517175378b94c68&mc=true&node=sp10.3.431.c&rgn=div6#se10.3.431_166

Code baseline modified with due to market availability of efficient cases.

https://www.regulations.doe.gov/certification-data/CCMS-4-Refrigeration_Equipment_-_Commercial__Single_Compartment.html#q=Product_Group_s%3A%22Refrigeration%20Equipment%20-%20Commercial%2C%20Single%20Compartment%22

Sample Baseline Data

Model	Refrigerant	BTU/Hr	MEC		TDA	
GSVM4060A	R-290	4410	15.59	kwh/day	11.3	Sqft
GSVM4072A	R-290	4410	19.01	kwh/day	16.6	Sqft
GSVM5272A	R-290	4610	20.77	kwh/day	20.1	Sqft

Self-Contained Commercial Refrigerators and Commercial Freezers Without Doors	Self-Contained (SC)	Vertical Open (VOP)	38 (M)	≥32	VOP.SC.M	1.69 × TDA + 4.71.
			0 (L)	<32	VOP.SC.L	4.25 × TDA + 11.82.
		Semivertical Open (SVO)	38 (M)	≥32	SVO.SC.M	1.7 × TDA + 4.59.
			0 (L)	<32	SVO.SC.L	4.26 × TDA + 11.51.
		Horizontal Open (HZO)	38 (M)	≥32	HZO.SC.M	0.72 × TDA + 5.55.
			0 (L)	<32	HZO.SC.L	1.9 × TDA + 7.08.

The applicant used the following algorithm to calculate the energy savings associated with the freezer that is part of this measure:

$$\Delta kWh_f = Quantity \times Days \times (DEC_{\ code} - DEC_{\ as-built})$$

where,

ΔkWh_f = annual freezer electric energy savings, in kWh

$Quantity$ = the number of freezers (1 freezer)

$Days$ = annual days of operation, year-round (365 days)

$DEC_{\ code}$ = daily energy consumption of the baseline freezer based on code (11.6 kWh/day)

$DEC_{\ as-built}$ = daily energy consumption of the as-built freezer (2.6 kWh/day) as specified in the specification sheet of the as-built refrigerated case

The applicant calculated $DEC_{\ code}$ of the baseline freezer based on the following algorithm from ASHRAE 90.1-2016:

$$DEC_{\ code} = 0.57 \times TDA + 6.88$$

where:

$$TDA = total\ display\ area\ of\ installed\ freezer\ unit$$

Figure 2-2 shows a screenshot from the applicant savings calculation file for the cooler.

Figure 2-2 Applicant savings calculation freezer

	HB-14HCD Freezer	HB-11HCD Freezer	Spec Sheets in project folder
Quantity	0	1	
Length in	51.8	43.5	From Spec
Width in	27.4	27.4	From Spec
Height (Depth) in			not needed
TDA	9.8	8.3	ft^2
V	13.8	11.1	ft^3
CDEC (kwh/day)	12.5	11.6	
MDEC (kWh/24 hr)	2.1	2.6	From Spec

kW For Model	kW	Btu
Base kW	0.5	1,648
Eff kW	0.1	370

kWh savings	-	3,283

eQuest Inputs	Baseline	Proposed	<< These are input into the model
Equipment-kW	0.5	0.1	kW
Sales Floor			0.4

The kW savings is the same for summer and winter consistent year round.

Kwh of cases are compared against code depending on case type.

Equipment category	Condensing unit configuration	Equipment family	Rating temp. (°F)	Operating temp. (°F)	Equipment class designation*	Maximum daily energy consumption (kWh/day)
Remote Condensing Commercial Refrigerators and Commercial Freezers	Remote (RC)	Vertical Open (VOP)	38 (M) 0 (L)	≥32±2 <32±2	VOP.RC.M VOP.RC.L	0.82 × TDA + 4.07 2.27 × TDA + 6.85
		Semivertical Open (SVO)	38 (M) 0 (L)	≥32±2 <32±2	SVO.RC.M SVO.RC.L	0.83 × TDA + 3.18 2.27 × TDA + 6.85
		Horizontal Open (HZO)	38 (M) 0 (L)	≥32±2 <32±2	HZO.RC.M HZO.RC.L	0.35 × TDA + 2.88 0.57 × TDA + 6.88
		Vertical Closed Transparent (VCT)	38 (M) 0 (L)	≥32±2 <32±2	VCT.RC.M VCT.RC.L	0.22 × TDA + 1.95 0.56 × TDA + 2.61
		Horizontal Closed Transparent (HCT)	38 (M) 0 (L)	≥32±2 <32±2	HCT.RC.M HCT.RC.L	0.16 × TDA + 0.13 0.34 × TDA + 0.26

2.1.4 Evaluation Assessment of Applicant Methodology

The evaluators determined that the overall applicant savings methodology is appropriate. However, the applicant's analysis considered the baseline and the as-built energy consumptions of the cooler in laboratory-rated conditions, not site-specific conditions. The applicant also considered the as-built energy consumption of the freezer in laboratory-rated conditions and not site-specific conditions, while using code to define the baseline energy consumption of the freezer. It is not clear to evaluators why the applicant used code as a baseline for the freezer and ISP as a baseline for the cooler, however evaluators deem the overall applicant savings methodology reasonable.

2.2 On-Site Inspection and Metering

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

Evaluators visited the site on October 27th, 2022 to inspect the installed refrigeration units, install power monitoring devices to determine their energy uses, and interview the site contact on the project details. Table 2-3 provides a summary of the on-site verification.

Table 2-4. Measure verification

Measure Name	Verification Method	Verification Result
12590113 (freezer)	Visual verification and metering	Two freezers of the model type listed in the project documentation were identified by evaluators while on site. Evaluators installed plug load loggers to both the identical coffin case freezers identified.
12590113 (cooler)	Visual verification	Evaluators were unable to locate the cooler model type listed in the project documentation. Evaluators searched the store floor multiple times and interviewed multiple site contacts; however, the cooler was unable to be located in the end. Evaluators were therefore unable to install any metering on the cooler listed in project documentation.

Figure 2-2 depicts the coffin case freezer listed in the project documentation that was located on site.

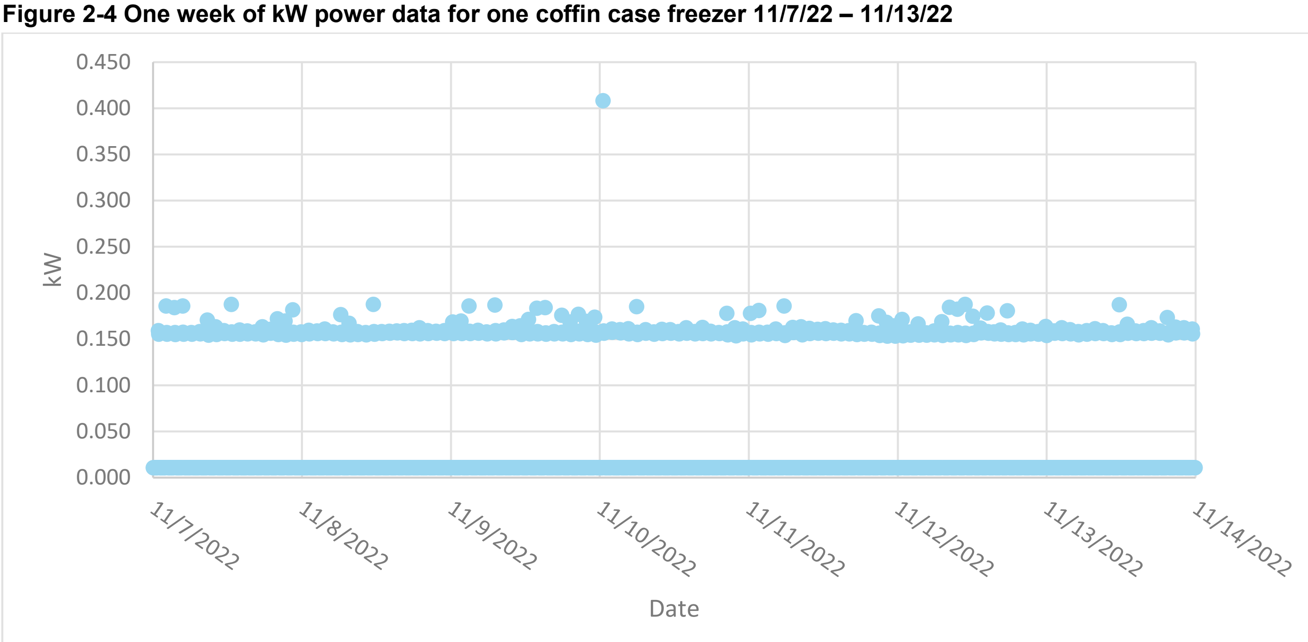
Figure 2-3 Coffin case freezer located on site

The evaluator's metering for this site included:

1. One plug load logger installed on each of the two coffin case freezers identified. The loggers measured active power data in 5-min intervals between October 27th and February 22nd, 2023, for a total of 10 weeks.
2. Evaluators could not locate the cooler listed in this application. No plug load logger installed on the cooler listed in the application.

The plug load loggers deployed to monitor the operation of the coffin case freezers recorded good data. Figure 2-3 provides an example of the kW power data measured for one of the coffin case freezers over a 1-week period.

Figure 2-4 One week of kW power data for one coffin case freezer 11/7/22 – 11/13/22



Evaluators averaged the metered data from both the coffin case freezers and developed a weekly, hourly operational profile. The evaluators also calculated a load factor defined as the ratio of the metered hourly average power to the average power calculated from the as-built rated DEC. The load factor represents the normalization from lab-rating conditions to actual site conditions (accounting for variables such as door openings, ambient conditions etc), Figure 2-5 below shows the weekly, hourly kW operational profile of the as-built coffin case freezer. Figure 2-6 shows the corresponding load factor operational profile for the as-built freezer.

Figure 2-5 Weekly, hourly kW operational profile of as-built freezer

DOW/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
Sunday	0.047	0.040	0.043	0.045	0.040	0.040	0.045	0.044	0.044	0.046	0.044	0.044	0.043	0.047	0.051	0.043	0.046	0.049	0.047	0.047	0.047	0.046	0.048	0.051
Monday	0.045	0.045	0.047	0.047	0.046	0.042	0.050	0.046	0.047	0.041	0.047	0.045	0.045	0.045	0.046	0.047	0.044	0.046	0.048	0.044	0.046	0.048	0.048	0.047
Tuesday	0.043	0.047	0.044	0.040	0.046	0.050	0.047	0.043	0.048	0.046	0.043	0.042	0.047	0.045	0.043	0.048	0.045	0.046	0.046	0.046	0.044	0.047	0.049	0.045
Wednesday	0.047	0.048	0.047	0.046	0.041	0.047	0.046	0.045	0.043	0.047	0.049	0.045	0.047	0.047	0.048	0.047	0.048	0.045	0.048	0.048	0.047	0.045	0.045	0.049
Thursday	0.048	0.042	0.044	0.049	0.043	0.046	0.044	0.046	0.049	0.046	0.046	0.042	0.047	0.046	0.044	0.041	0.041	0.046	0.044	0.041	0.042	0.042	0.043	0.041
Friday	0.046	0.044	0.036	0.044	0.048	0.044	0.036	0.046	0.046	0.041	0.043	0.047	0.043	0.042	0.041	0.046	0.046	0.048	0.041	0.042	0.043	0.046	0.042	0.046
Saturday	0.046	0.037	0.046	0.048	0.042	0.043	0.044	0.045	0.046	0.044	0.046	0.042	0.044	0.046	0.045	0.043	0.048	0.045	0.040	0.046	0.047	0.040	0.038	0.045

Figure 2-6 Weekly, hourly load factor operational profile of as-built freezer

DOW/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
Sunday	60%	51%	54%	56%	51%	51%	57%	56%	56%	59%	56%	55%	54%	59%	64%	54%	58%	62%	60%	59%	59%	58%	61%	64%
Monday	56%	56%	59%	59%	58%	54%	63%	59%	59%	52%	60%	57%	56%	57%	58%	59%	55%	58%	61%	56%	58%	61%	61%	59%
Tuesday	55%	59%	55%	50%	58%	64%	59%	55%	61%	59%	55%	53%	59%	57%	54%	60%	57%	59%	58%	59%	55%	59%	62%	57%
Wednesday	60%	61%	60%	58%	51%	59%	57%	57%	54%	59%	62%	57%	59%	59%	60%	60%	61%	56%	60%	60%	59%	57%	57%	61%
Thursday	61%	53%	56%	62%	54%	59%	56%	58%	61%	58%	58%	53%	60%	58%	56%	52%	52%	58%	55%	52%	54%	53%	54%	52%
Friday	59%	55%	45%	55%	61%	56%	46%	58%	58%	51%	54%	59%	55%	53%	51%	58%	58%	60%	52%	53%	54%	58%	54%	59%
Saturday	58%	47%	58%	60%	53%	55%	55%	56%	58%	56%	58%	54%	55%	58%	57%	55%	60%	56%	50%	58%	59%	50%	48%	57%

2.3 Evaluation Methods and Findings

This section describes the evaluator methods and findings.

2.3.1 Evaluation Description of Baseline

The evaluators classified the measure as a lost opportunity with an ISP baseline for the cooler and a code baseline for the freezer. The evaluated baseline is similar to the applicant baseline which is one cooler with an ISP baseline and one freezer with a code baseline; however, the evaluators applied load factors to the baseline freezer consumption in the 8760-analysis based on the load factors measured during the metering period. A load factor of 75% was assumed for the baseline cooler due to the fact that evaluators were unable to locate and meter the cooler while on site. Evaluators chose a load factor of 75% based on previous observations of similar refrigeration units evaluated. Considering the applicant baseline uses a mixture of a vendor defined ISP and code, the evaluators discussed the project with the Baseline Advisory Group (BAG) and determined the site baseline should be classified as unique and site specific until further direction is given from future ISP research. Therefore, the evaluated baseline technology is equivalent to the applicant's classification. Table 2-5 shows the key evaluator baseline parameters.

Table 2-5. Evaluator baseline key parameters

Parameter	Value(s)	Source of parameter value
Quantity of coolers	1	Application
Quantity of freezers	1	Application
Average hourly baseline power draw cooler	0.44 kW	ISP
Average hourly baseline power draw freezer	0.27 kW	Code and metered LF data
Annual cooler operation	8760 hours	Assumed based on use of freezer metered data
Annual freezer operation	8760 hours	Metered data

2.3.2 Evaluation Calculation Method

The evaluators calculated the measure savings using an 8,760 spreadsheet-based analysis. The evaluators used the metered data for the freezer to develop a weekly, hourly load factor profile for the freezer (presented in Figure 2-6) as well as a weekly, hourly kW profile for the freezer (presented in Figure 2-5). The kW profile from Figure 2-5 was used as the as-built freezer consumption and the load factor profile for the freezer from Figure 2-6 was used to scale the consumption of the baseline freezer (normalizing to site-specific operating loads and conditions). Because evaluators were not able to obtain any metered data on the cooler due to its removal from the site, a load factor of 75% was assumed for all hours of operation of the cooler in the 8760-analysis. Evaluators chose this load factor based on observations from previous sites. Figure 2-6 below shows the key values used by evaluators in the 8760-analysis.

Table 2-6. Evaluator baseline key parameters

Parameter	Value(s)	Source of parameter value
As-built cooler avg. hourly kW	0.06	Spec sheet
Baseline cooler avg. hourly kW	0.44	ISP
Average cooler load factor	75%	Previous evaluations*
As-built freezer avg. hourly kW	0.04	Metered data
Baseline freezer avg. hourly kW	0.27	Code and metered data
Average freezer load factor	57%	Metered data

*Based upon evaluator experience at other similar sites

Based on communications with the vendor, evaluators believe that the missing cooler was originally installed at the correct location and then moved prior to the evaluator on-site visit. For this reason, evaluators have applied an in-service factor of 50% to the relocated cooler savings because though it is likely in operation at another store location it is not certain, thus a compromise approach was taken. The evaluators also updated the DEC of the as-built cooler based on the specifications of the installed model.

Evaluators used the following algorithm to calculate the energy savings associated with the cooler for this measure:

$$\Delta kWh_c = ISF \times \sum_{1}^{8760} LF_c \times \left[\left(\frac{MCDEC}{24} - \frac{DEC}{24}\right)\right]$$

where,

ΔkWh_c	= cooler annual electric energy savings, in kWh.
ISF	= in service factor (50%)
LF_c	= load factor cooler (constant value of 75%)
$MCDEC$	= modified calculated energy consumption value of baseline cooler (14.1 kWh/day)
DEC	= daily energy consumption value of as-built cooler from spec sheet (2.04 kWh/day)

Evaluators used the following algorithm to calculate the energy savings associated with the freezer for this measure:

$$\Delta kWh_f = \sum_{1}^{8760} LF_f \times \left[\left(\frac{DEC_{code}}{24} - kW_f\right)\right]$$

where,

ΔkWh_f	= freezer annual electric energy savings, in kWh.

LF_c	= load factor freezer (varies, avg. value of 57%)
$DEC_{\ code}$	= daily energy consumption of the baseline freezer based on code (11.6 kWh/day)
kW_f	= power draw of as-built freezer based on weekly, hourly operational profile developed from metered data (varies, avg. value of 0.04 kW)

3 FINAL RESULTS

The evaluated project consisted of the installation of one coffin case freezer and one vertical reach-in cooler in a grocery store.

The applicant used a spreadsheet-based analysis to calculate the project savings. The evaluator used a spreadsheet-based analysis with a different methodology to calculate the savings, utilizing metered data in addition to spec sheets. The evaluated savings are less than the reported savings. The key parameters that impact the analysis are summarized in Table 3-1.

Table 3-1. Summary of key parameters

Parameter	BASELINE		PROPOSED / INSTALLED	
	Tracking Value(s)	Evaluation Value(s)	Tracking Value(s)	Evaluation Value(s)
Quantity of coolers	1	1	1	1
Quantity of freezers	1	1	1	1
Annual hours of operation cooler	8760	8760	8760	8760
Annual hours of operation freezer	8760	8760	8760	8760
Cooler daily energy consumption	14.1 kWh/day	14.1 kWh/day	1.95 kWh/day	2.04 kWh/day
Cooler load factor	100%	75%	100%	75%
Cooler in-service factor	100%	50%	100%	50%
Freezer daily energy consumption	11.6 kWh/day	11.6 kWh/day	2.6 kWh/day	1.08 kWh/day
Average freezer load factor	100%	57%	100%	57%
Freezer in-service factor	100%	100%	100%	100%

3.1 Explanation of Differences

The evaluated savings are lower than the applicant-reported values predominantly because of the in-service factor applied to the as-built cooler savings. Evaluators also observed lower levels of as-built freezer operation compared to the applicant as-built predictions, which resulted in lower savings. Table 3-2 provides a summary of savings deviations.

Table 3-2. Summary of deviations

Measure	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
12590113	Operational	In-service factor	-29%	**Decreased savings –** The in-service factor of 50% applied to the cooler savings reduced the lifetime savings of the cooler
12590113	Operational	Freezer load factor	-17%	**Decreased savings –** Freezer daily energy consumption
12590113	Operational	Cooler load factor	-7%	**Decreased savings –** Cooler daily energy consumption
Final RR				**47%**

3.2 Lifetime Savings

This measure has been classified as a lost opportunity. The baseline is ISP for the cooler and code for the freezer.

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

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

where:

LAGI = lifetime adjusted gross impact (kWh)

FYS = first year savings (kWh)

EUL = measure life (years)

Table 3-3 provides a summary of key factors that influence the lifetime savings.

Table 3-3. Measure 12590113 - lifetime savings summary

Factor	Tracking	Application	Evaluator
Lifetime savings	74,655	86,110	36,635
First year savings	7,723	7,723	3,663
Measure lifetime	10	11.1	10
Baseline classification	New construction	New construction	Lost opportunity

3.2.1 Ancillary impacts

There were no ancillary impacts associated with the evaluated measure.

DNV

RI CUSTOM ELECTRIC EVALUATION SITE-SPECIFIC REPORT

DNV SITE ID: RICE21N037

Report Date: 6/5/2023

Application ID(s)	8677807 / 9065754 (parent / child)	
Project Type	C&I End of Useful Life Replacement	
Program Year	2021	
Evaluation Firm	DMI	DMI
Evaluation Engineer	Bennett Rose	
Senior Engineer	Mickey Bush	

1 EVALUATED SITE SUMMARY AND RESULTS

This new construction project considers the end of useful life upgrade of a secondary crusher plant for the production of crushed stone and stone dust. The customer's pre-existing secondary crusher plant was installed in 1985 and required several repairs and upgrades in 2018. The customer had the option in 2018 to replace the pre-existing system with similar equipment (i.e., replace in kind) or purchase additional higher capacity equipment to increase their production rate from 120 tons/hour to 250 tons/hour. One of the major differences in system design is that the existing (and baseline) system includes a 300HP crusher and the proposed system includes a 400 HP crusher.

The secondary crusher plant consists of a large stone crusher that breaks large pieces of stone into smaller pieces. The smaller pieces are filtered with a series of screens and conveyors and sorted into different piles based on size.

The project, TA study, and post inspection were all completed in 2018. Parent and child applications were created for this project. The child application was cancelled in 2021 and the incentive retainage was not paid out. The child application was cancelled because the post installation data collected during commissioning indicated that the increase in production volume and increase in production rate that was expected did not occur. The tracking savings match the total applicant savings; therefore, it does not appear that the tracking savings made any adjustment to the child application to reflect diminished savings discovered during the post installation period when production data should have been used to update the child application savings. The tracking savings are 246,605 kWh (~8% of annual electric consumption)

The evaluator savings for this project for this project are -160,516 kWh.

In a follow-up conversation with the site contact, it was found that one of the product types produced by the evaluated crusher system, NOVA stone, requires that a large portion of the crushed aggregate is recycled back to the crusher which slows down the production rate for most other product types. The site is considering the installation of a smaller add-on crusher system that will handle the extra processing required for the Nova Stone product. It may be the case that this add-on project will allow the evaluated crusher system to increase production rate by eliminating the recycling process. More information is needed to determine if this add-on project will provide energy savings as it will include an increase in overall motor horsepower. Data was not provided to verify this assertion, however the site contact claimed that the NOVA stone production goal was met prior to the end of the production season and the site eliminated the re-crushing step which increased production rate by 90 tons/hour. The evaluator and the RI Energy staff tried multiple times to get the most up to date production, but the customer did not respond to requests.

Table 1-1. Evaluation Results Summary

PA Application ID	Measure Name		Annual Electric Energy (kWh)	% of Energy Savings On-Peak	Summer On-Peak Demand (kW)	Winter On-Peak Demand (kW)
8677807 / 9065754	**New Secondary Crusher Plant**	**Tracked**	246,605	71.0%	0	-81.3
		Evaluated - ops	**-160,516**	**78.1%**	**-61.0**	**0.0**
		Realization Rate	**-65.1%**	**110.0%**	**N/A**	**0.0%**

N/A = Not applicable

1.1 Explanation of Deviations from Tracking

The evaluated energy penalty is less than the applicant-reported savings primarily due to the production rate of the installed secondary crusher being lower than predicted by the applicant. The basis for energy savings is that the larger crusher will require fewer operating hours to crush the same amount of aggregate. There is a demand penalty associated with the proposed/installed equipment so there is a breakeven point to consider, if the run hour reduction is below that point the project will result in a penalty. Further details regarding deviations from the tracked savings are presented in Section 3-4.

1.2 Recommendations for Program Designers & Implementers

1. Reason for Production Rate Increase - The basis for energy savings associated with this project is overall production efficiency improvement. The applicant calculated savings for a system with 41.8% more motor HP (34% more motor kW) expecting an increase in production rate of 108%. A ~34% increase in production rate with the installed system is required to break even (i.e., no savings or penalty). The evaluator recommends clearly documenting the limiting factors of plant production rate and how those limitations or bottlenecks would be addressed by the new system because the secondary crusher plant is one component of a larger system.

   A parameter that was not documented in the applicant documentation or uncovered during this evaluation is the design production rate of the baseline system. If baseline system capacity was not a bottle neck for the production rate of the crusher plant there is no basis of savings for the project. This also could have been used to correlate system horsepower to design production rate for the baseline system and compared to the proposed system to determine if it is reasonable to assume a 108% increase in production rate for a 41.8% increase in system horsepower.

   The applicant analysis does not state what features of the proposed system will lead to a production rate increase that is greater than percent increase in motor horsepower.

2. The baseline considered by the applicant is based on the existing system. There may have been an opportunity to collected metered data to inform the load factor assumptions in the analysis. Data showing low load factor for existing equipment could also have been an indicator that the system was lightly loaded and may have been capable of operating at a higher production rate.

3. Basis for Proposed Case Production Rate - Particularly in the case of this project that involves a demand penalty, the assumption used to justify run hour reduction which is the basis for savings should be well documented. The documentation for the proposed case production rate of 250 tons/hour is a note in the excel file that says the assumption is from the site. If there was an email thread, corporate annual projects or some other document that supported this assumption it would have helped document the basis for energy savings.

4. Commissioning Update - The child application was closed for this project because the lack of increase in the production rate was identified during commissioning. In an email thread between the PA and TA vendor conducting the post inspection, data collected for the post inspection indicated the same finding as the evaluator that the secondary crusher tons/hour is much lower than the 250 tons/hour expected. Based on this finding the tracking savings should have been modified for this project.

1.3 Customer Alert

None.

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.

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.

2.2 Applicant Description of Baseline

The applicant measure event is New Construction. The baseline considered by the applicant is to replace the existing secondary crusher plant, that was originally installed in the 1980s, in kind. The baseline values used in the applicant savings analysis are presented in Table 2-1.

Table 2-1. Applicant baseline key parameters

		BASELINE		
Measure	**Parameter**	**Value(s)**	**Source of Parameter Value**	**Note**
M1	Combined Motor HP	505 HP	Vendor Quote (See Table 2-3)	
M1	Operating kW	318 kW	Calculated assuming 80% motor load	
M1	Production Rate	121 tons/hour	Calculated using annual operating hour and production trends	
M1	Annual Production Volume	265,000 tons	Site estimate for future production	
M1	Annual Operating Hours	2,197 hours	Annual Tons divided by production rate	
M1	Annual kWh	698,599 kWh	Calculated	

2.2.1 Applicant Description of Installed Equipment and Operation

The proposed system values used in the applicant savings analysis are presented in Table 2-2.

Table 2-2: Application proposed key parameters

		PROPOSED		
Measure	Parameter	Value(s)	Source of Parameter Value	Note
M1	Combined Motor HP	716.25 HP	Vendor Quote (See Table 2-4)	
M1	Operating kW	426.4 kW	Calculated assuming 80% motor load	
M1	Production Rate	250 tons/hour	Assumed based on design capacity of new crusher	
M1	Annual Production Volume	265,000 tons	Site estimate	
M1	Annual Operating Hours	1,060 hours	Annual Tons divided by production rate	
M1	Annual kWh	451,994 kWh	Calculated	

2.2.2 Applicant Energy Savings Algorithm

The applicant calculated the baseline and proposed crusher plant operating kW using a motor inventory for each case. The formula used to calculate the estimated operating kW for each motor is as follows.

Motor kW = Motor HP * 80% Load * 0.746 kW/HP / Motor Efficiency

Using this approach, the applicant calculates the baseline secondary crusher plant demand is 318.0 kW and the proposed secondary crusher plant demand is 426.4 kW.

The baseline motor summary is presented in Table 2-3.

Table 2-3: Baseline System Demand

Motor	Motor (hp)	Motor Eff	Load Factor	Motor kW
C18 Conveyor	15	93.0%	80%	9.6
C19 Conveyor	10	91.7%	80%	6.5
Secondary Crusher	300	95.8%	80%	186.9
Crusher Oil Pump	10	91.7%	80%	6.5
Crusher Hydraulic Pump	10	91.7%	80%	6.5
C20 Conveyor	15	93.0%	80%	9.6
Screen	60	95.0%	80%	37.7
C24A Conveyor	10	91.7%	80%	6.5
C24B Conveyor	15	93.0%	80%	9.6
C33 Conveyor	15	93.0%	80%	9.6
C21 Conveyor	15	93.0%	80%	9.6
C22 Conveyor	15	93.0%	80%	9.6
C23 Conveyor	15	93.0%	80%	9.6
TOTAL	505	Base Case kW		318.0

The proposed case motor summary is presented in Table 2-4 and assumes the same 80% load factor as the baseline calculation. The proposed case motor demand calculation also includes an assumed Run Factor which is applied as a percentage and may be intended to account for a runtime adjustment associated with motors expected to cycle on and off during operation. Most of the motors have a 100% run factor. The formula used to calculate the estimated operating kW for each motor is as follows.

Motor kW = Motor HP * Run Factor * 80% Load * 0.746 kW/HP / Motor Efficiency

Table 2-4: Proposed System Demand

Equipment Description	Motor HP	Run Factor	Avg. HP	Motor Eff	Motor kW
Sandvik CH660 Hydrocone Crusher	400	100%	400	95.8%	249.2
Hydroset	4.5	100%	4.5	89.5%	3.0
Oil Pump	4	100%	4	89.5%	2.7
Cooling Fan	4	50%	2	89.5%	1.3
Dust Seal Fan	0.75	100%	0.75	85.5%	0.5
Truss Extension and New Drive Components for C-20	25	100%	25	93.6%	15.9
Terex Triple Deck Horizontal Screen (40hp)	40	100%	40	94.1%	25.4
36" BW Underscreen Collecting Conveyor (C-45)	10	100%	10	91.7%	6.5
Terex Triple Deck Horizontal Screen (40hp)	40	100%	40	94.1%	25.4
36" BW Underscreen Collecting Conveyor (C-46)	10	100%	10	91.7%	6.5
24" BW x 71' Long Overs Collecting Conveyor (C-34)	7.5	100%	7.5	91.0%	4.9
24" BW x 137' Long Overs Transfer Conveyor (C-35)	10	100%	10	91.7%	6.5
24" BW x 35' Long Collecting Conveyor (C-36)	7.5	20%	1.5	91.0%	1.0
30" BW x 100' Radial Stacker - Manual Travel (C-37)	15	20%	3	93.0%	1.9
OPTION: Add Power Travel	2	1%	0.02	86.5%	0.0
24" BW x 31' Long Collecting Conveyor (C-39)	7.5	100%	7.5	91.0%	4.9
24"BW x 58' Long Transfer Conveyor (C-40)	7.5	100%	7.5	91.0%	4.9
30" BW x 100' Radial Stacker - Manual Travel (C-41)	15	100%	15	93.0%	9.6
OPTION: Add Power Travel	2	1%	0.02	86.5%	0.0
24" BW x 18' Long Collecting Conveyor (C-42)	7.5	50%	3.75	91.0%	2.5
24" BW x 80' Long Transfer Conveyor (C-43)	7.5	50%	3.75	91.0%	2.5
30" BW x 100" Radial Stacker - Manual Travel (C-44)	15	50%	7.5	93.0%	4.8
OPTION: Add Power Travel	2	100%	2	86.5%	1.4
24" BW x 75' Long Collecting Conveyor (Sand) (C-47)	10	100%	10	91.7%	6.5
24" BW x 356' Long Transfer Conveyor (Sand) (C-51)	30	100%	30	94.1%	19.0
Terex Simplicity 4' x 12' Single Deck Screen	7.5	100%	7.5	91.0%	4.9
24" BW x 38' Long Collecting Conveyor (C-52)	7.5	100%	7.5	91.0%	4.9
24" BW x 100' Radial Stacker - Manual Travel (C-53)	15	100%	15	93.0%	9.6
OPTION: Add Power Travel	2	5%	0.1	86.5%	0.1
Proposed Case kW					**426.4**

Energy savings for this measure compare baseline production rate with projected production rate.

The applicant used production data from the site to calculate existing system production rate in tons/hour and it is assumed baseline production rate will be equal to existing production rate.

The production data includes total product weight (tons) by each product type and plant operating time. The analysis considers annual production data provided by the site for 2015, 2016, 2017. It is assumed that the secondary crusher plant processes 50% of the washed dust produced by the site and all of the 3/8” ledge, ¼” ledge stone, stone dust ledge, and ½” ledge. The results from this analysis are that the secondary crusher plant processed 185,451 tons of product per year on average from 2015-2017 and operated 1,537 hours per year for an average existing (and baseline) production rate of 121 tons/hour.

The analysis assumed that the proposed system, which is designed for 325 tons/hour, will operate at an average rate of 250 tons/hour. The analysis file states this estimate is from the customer.

Savings are determined on an equal production basis. The site projected 265,000 tons of product in 2018 for the secondary crusher plant, which is used as the baseline and proposed annual production.

This represents a 43% increase in production volume. The proposed system is assumed to run fewer hours at this higher hourly production rate.

The analysis confirms that the existing equipment operating at the calculated production rate would be able to produce this volume of product within the runtime limitations of the site. The crusher plant operates for 37 weeks (April 1-December 15), 7AM-5PM, 7 days per week. Considering a realization factor of 89% (downtime/maintenance) the plant is able to operate a maximum 2,301 annual operating hours. The baseline system would need to operate 2,196 hours to produce the projected volume.

The formula used to calculate base and proposed energy consumption for this measure is as follows.

Annual Energy kWh=(Production Tons *Average Plant kW)/(Production Rate Tons/hour)

This methodology results in base annual electric use of 698,599 kWh, proposed annual electric use of 451,994 kWh, and annual savings of 246,605 kWh.

Table 2-5: Application proposed key parameters

Measure Case	Prod. Volume Tons	Prod. Rate Tons/hr	Prod. Hours	Avg. kW	Energy kWh
Baseline	265,000	121	2,196	318.0	698,599
Proposed	265,000	250	1,060	426.4	451,994
Demand Penalty			1,060	-108.4	-114,904
Savings from Reduced Hours			1,136	318.0	361,341
Net Savings					246,605

The applicant calculates on peak energy savings and peak demand savings assuming that savings are evenly distributed across plant operating hours and that the plant operates from 7AM-4PM 7-days per week, 18 out of 18 summer weeks and 15 out of 34 winter weeks. The average summer peak demand penalty (average from 1PM-5PM Monday-Friday) is 81.3 kW. The average winter peak demand penalty (average from 5PM-7PM Monday-Friday) is 0 kW. The annual on-peak energy percentage is 71.4% (average from 7AM-11PM Monday-Friday).

2.2.3 Evaluation Assessment of Applicant Methodology

The applicant uses the same methodology to estimate the baseline and proposed system operating demand. This results in a demand penalty across all proposed operating hours associated with the measure which accurately reflects the larger system in the proposed case.

The basis for energy savings is the proposed case annual production rate, which leads to lower run hours to provide equal production. The hourly baseline production rate is documented based on the operating hours for the site and the annual production volume of the site that is associated with the secondary crusher plant.

The proposed case system is designed for a production rate of 325 tons/hour. The applicant assumes that it will operate at 250 tons per hour (76.9% of design). It is not clear how modelled proposed system 77% of design production rate compares to the percent output of the pre-existing/baseline system because the design production rate of the existing system is not included in the applicant documentation. The assumption that the proposed case production rate will be 250 tons/hour is not well documented.

2.3 On-site Inspection and Metering

This section provides details on the tests performed during the on-site inspection. Evaluators were granted access to the site and conducted a full M&V evaluation.

2.3.1 Summary of Site Visit

This section summarizes the site visit.

- The evaluator visited the site on October 5, 2022.
- The plant shuts down for maintenance December 22 through March 23. Otherwise, there is no scheduled downtime. During the crushing season the plant operates Monday through Saturday and is off Sunday.
- The evaluator installed kW meters on five secondary crusher process motors including the 400 HP Crusher motor, a 10 HP collecting conveyor, a 30 HP transfer conveyor, a 40 HP terex screen, and a 15 HP radial stacker.
- The site contacts were unavailable at the time of the meter install site visit, the evaluator and electrician were escorted by a facility employee without detailed knowledge of the secondary crusher installation project.
- After the site visit, the site contact answered the site visit interview questions via email.
- The site contact provided annual production data; annual operating hours and production volume in tons for 2018, 2019, 2020, and 2021. This data includes breakdown by product type.
- The evaluator returned to the site on January 18, 2023 to retrieve the meters.
- During meter retrieval, the evaluator found that voltage clips for three out of four of the kW meters had been disconnected during the metering period. The 15 HP radial stacker kW meter disconnected almost immediately. The 10-HP conveyor and 30 HP conveyor voltage clips remained connected long enough to collect useful operating data. It is suspected that the intense vibrations from rock crushing jostled the voltage clips loose. The motor control room where the meters were installed is a shipping container that is located next to the crusher plant.
- The evaluator had a follow-up call with the site contact to discuss the unexpectedly low production rate calculated for the proposed case (as described in Section 1). The site contact indicated that the requirement for one of the product types to recycle aggregate after the first crushing (crush and crush again) slows down the overall production rate. A flow diagram for the pre-existing system indicates that there was a recycling stream associated with the that system as well so it is not clear if recycling has an impact on the energy impact of this project. The site contact was not an employee at the facility at the time of the project and was not familiar with the pre-existing system.

Table 2-6. Measure Verification

Measure Name	Verification Method	Verification Result
M1 – New Secondary Crusher Plant	Metered sample of motors, observed installed equipment, and used site production data to confirm plant production efficiency.	Production rate did not increase as expecting resulting in no savings for the measure, but installed equipment matches the proposed scope.

2.3.2 Measured and Logged Data

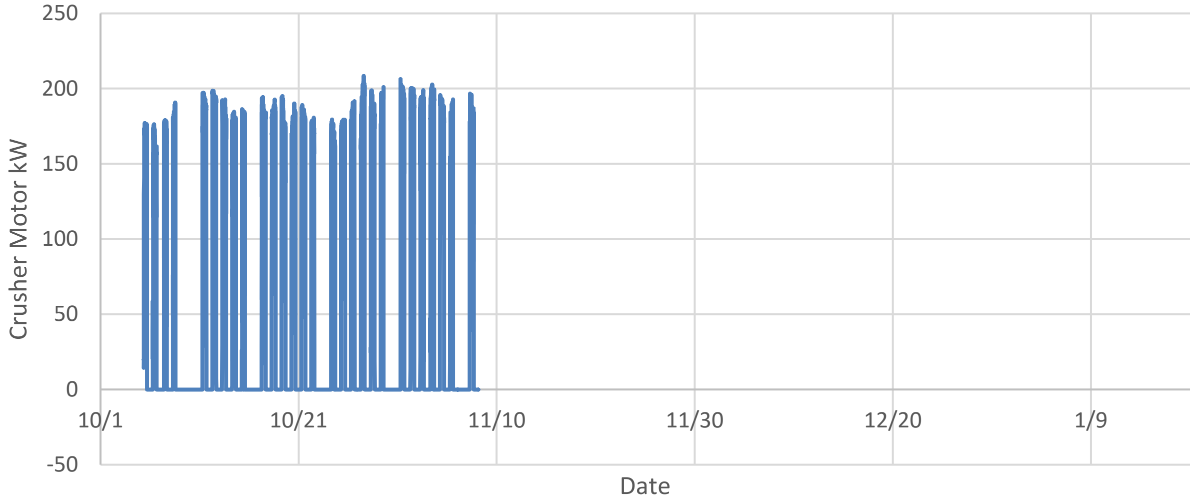
Table 2-7 summarizes the metered data collected and the period of useful data collected for each piece of equipment. The metered data from the useful data period is used in the evaluation savings analysis.

Table 2-7. Metered Data Summary

Motor	Useful Data Duration
400 HP Crusher kW (5-minute interval)	33 Days (10/5/2022-11/8/2022)
10 HP Collecting Conveyor kW (1-minute interval)	2 Days (10/5/2022-10/7/2022)
30 HP Transfer Conveyor kW (1-minute interval)	19 Days (10/5/2022-10/24/2022)
40 HP Terex Screen kW (1-minute interval)	105 Days (10/5/2022-1/18/2023)
15 HP Radial Stacker kW (1-minute interval)	0 Days (10/5/2022-12/31/2022)

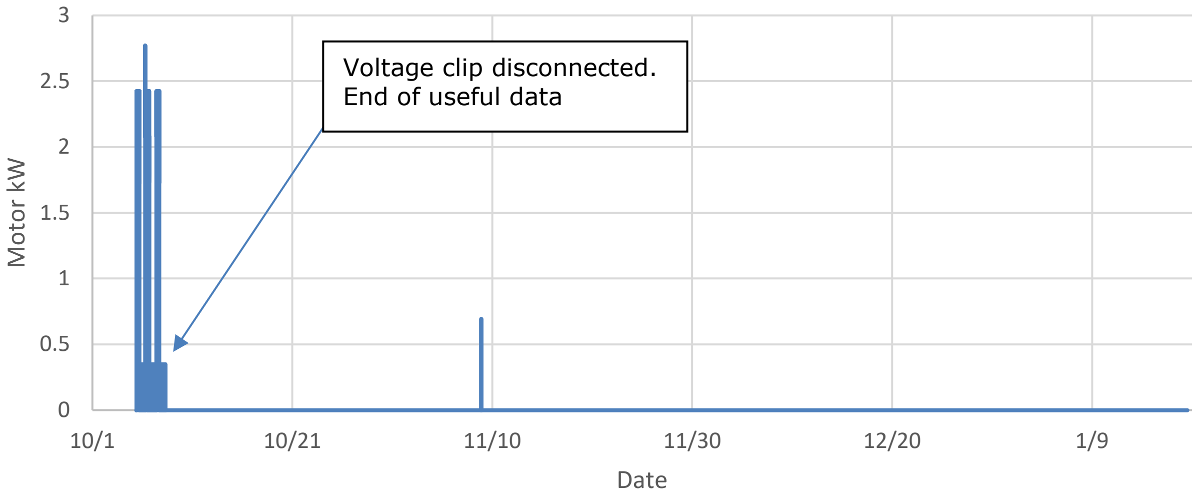
The raw kW data for the 400 HP crusher motor is presented in Figure 2-1. It is unclear why the data stopped logging in November. All of the voltage leads were connected and the disconnect serving the motor was switched off at the time of the meter retrieval because the plant was shut down for the season.

Figure 2-1. 400 HP Crusher Motor Raw kW Data



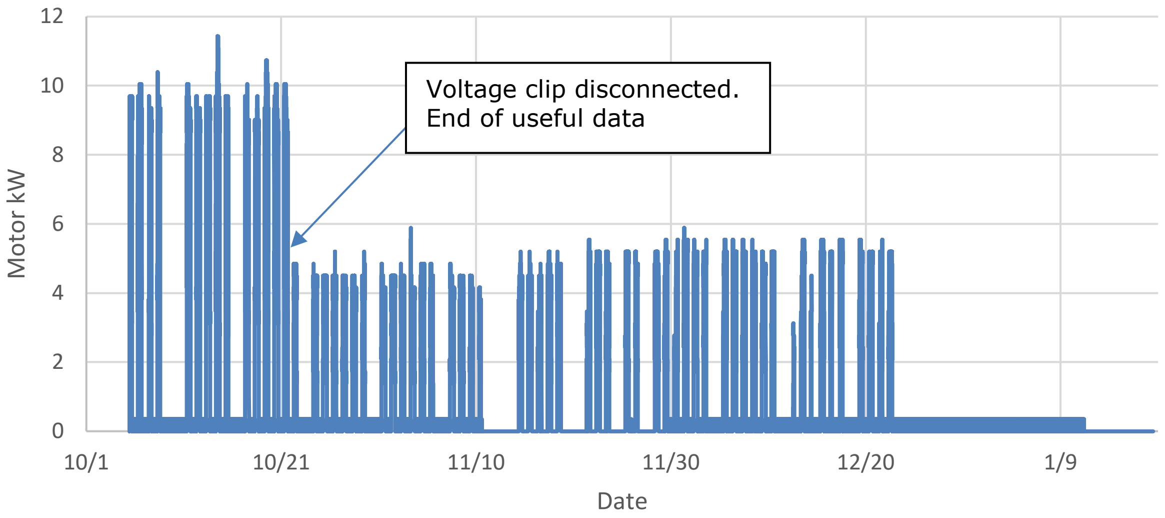
The raw kW data for the 10 HP collecting conveyor motor is presented in Figure 2-2. The voltage clip was disconnected on 10/7 (2 days of operating data).

Figure 2-2. 10 HP Collecting Conveyor Motor Raw kW Data



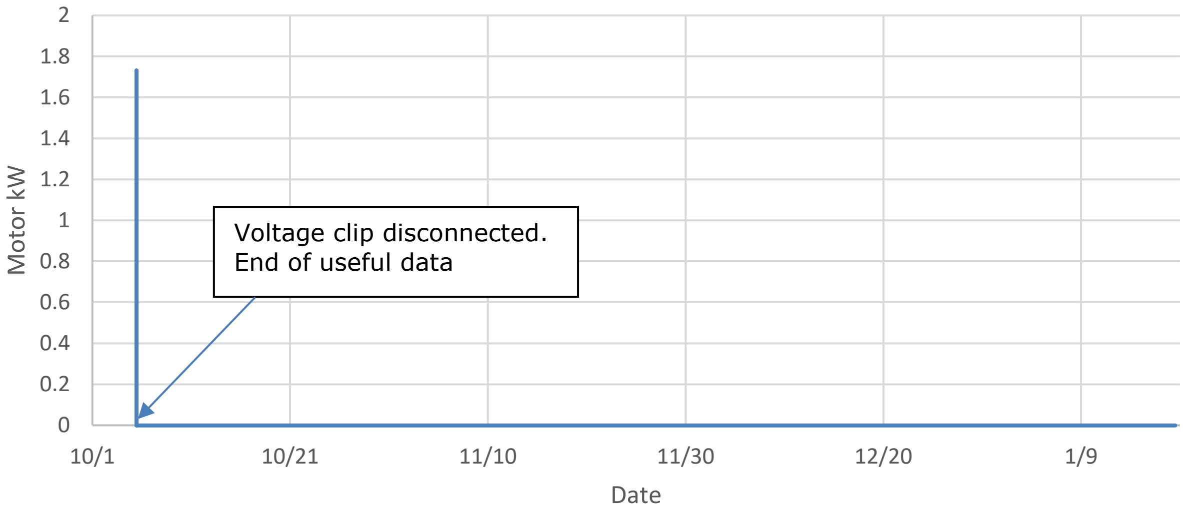
The raw kW data for the 30 HP transfer conveyor motor is presented in Figure 2-3. One of the voltage connectors disconnected on 10/22 (17 days of operating data).

Figure 2-3. 30 HP Transfer Conveyor Motor Raw kW Data



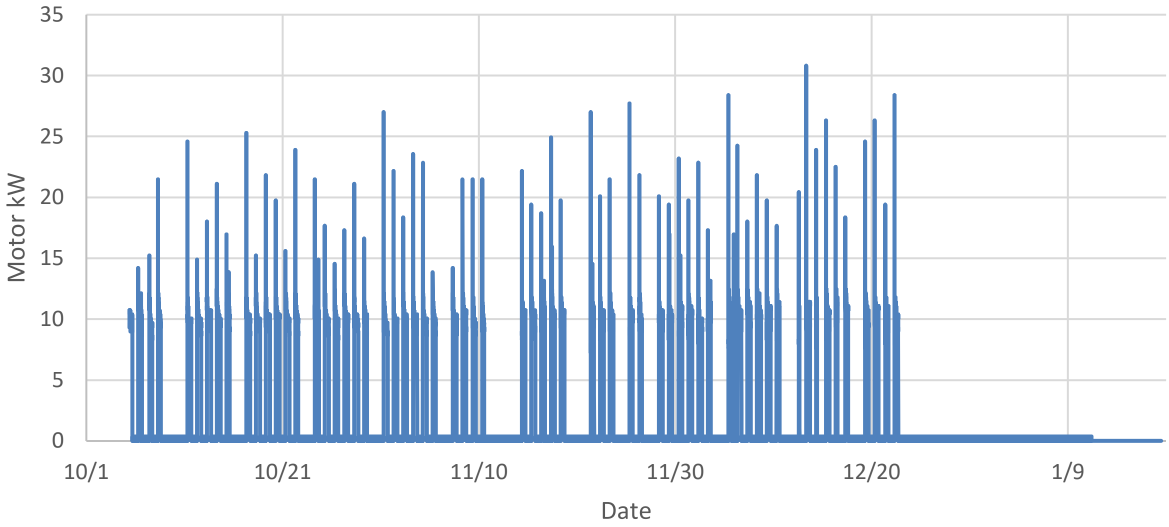
The raw kW data for the 15 HP radial stacker motor is presented in Figure 2-4. The voltage clip was disconnected on 10/5 (0 days of operating data).

Figure 2-4. 15 HP Radial Stacker Motor Raw kW Data



The raw kW data for the 40 HP terex screen motor is presented in Figure 2-5.

Figure 2-5. 40 HP Terex Screen Motor Raw kW Data



Production data provided by the site is summarized in Table 2-8.

Table 2-8. Site Production Data

Data Type	Time Period	Notes
Production Hours	2018, 2019, 2020, 2021	Provides total primary and finishing operating hours for the facility
Production Volume Tons	2018, 2019, 2020, 2021	Total production volume in tons. Includes breakdown by product type

2.4 Evaluation Methods and Findings

This section describes the evaluator methods and findings.

2.4.1 Evaluation Description of Baseline

The evaluator measure event type is new construction, and the baseline is a 'like for like' replacement of the existing secondary crusher system, which is the same as the applicant's measure event type and baseline. The site contact confirmed that the age of the pre-existing secondary crusher system was installed in the 1980s and had reached the end of useful life.

2.4.2 Evaluation Calculation Method

Baseline and Installed Operating Demand

The average motor load is calculated for each metered motor when it running during the identified period of useful data as indicated in section 2.3.2. To only consider time when the motor is running, the average only considers values greater than 0 kW to filter periods when the motor is off. Table 2-9 summarizes the metered average motor load.

Table 2-9. Average Motor Loads

Motor Type	Motor HP	Average kW	Load kW/HP	Load Factor
Crusher	400	165.6	0.41	53.2%
Collecting Conveyor	10	1.8	0.18	22.4%
Transfer Conveyor	30	7.4	0.25	31.1%
Terex screen	40	7.7	0.19	24.3%
Radial Stacker[1]	15	N/A	0.21	26.8%
Other[2]	N/A	N/A	0.21	N/A

[1]No useful metered data, average of Collecting Conveyor and Transfer Conveyor

[2]Average of Collecting Conveyor, Transfer Conveyor, Terex Screen

The use of metered data to calculate an average kW/HP for the different types of process motors is useful in that it uses empirical data to encapsulate analysis parameters such as load factor and motor efficiency. The applicant assumed that the load factor is the same for all process motors in the baseline and proposed case. The evaluator takes a similar approach and assumes that the average kW/HP for each motor type shown in Table 2-6 is characteristic of the other similar motor types included in the baseline and installed crusher systems. The metered data indicates that the motors are more lightly loaded than assumed by the applicant. This finding reduces the calculated motor demand in the base and installed cases reducing energy savings and the demand penalty proportionally.

Table 2-10 summarizes the calculated operating demand for the baseline system applying this motor load calculation approach.

Table 2-10: Evaluator Baseline System Demand

Motor	Motor (hp)	Motor Type	Load kW/HP	Motor kW
C18 Conveyor	15	Transfer Conveyor	0.25	3.7
C19 Conveyor	10	Transfer Conveyor	0.25	2.5
Secondary Crusher	300	Crusher	0.41	124.2
Crusher Oil Pump	10	Other	0.21	2.1
Crusher Hydraulic Pump	10	Other	0.21	2.1
C20 Conveyor	15	Transfer Conveyor	0.25	3.7
Screen	60	Terex screen	0.19	11.6
C24A Conveyor	10	Transfer Conveyor	0.25	2.5
C24B Conveyor	15	Transfer Conveyor	0.25	3.7
C33 Conveyor	15	Transfer Conveyor	0.25	3.7
C21 Conveyor	15	Transfer Conveyor	0.25	3.7
C22 Conveyor	15	Transfer Conveyor	0.25	3.7
C23 Conveyor	15	Transfer Conveyor	0.25	3.7
TOTAL	**505**	**Base Case kW**		**170.7**

Table 2-11 summarizes the calculated operating demand for the installed system applying this motor load calculation approach.

Table 2-11: Evaluator Installed System Demand

Equipment Description	Motor HP	Motor Type	Load kW/HP	Motor kW
Sandvik CH660 Hydrocone Crusher	400	Crusher	0.41	165.6
Hydroset	4.5	Other	0.21	0.9
Oil Pump	4	Other	0.21	0.8
Cooling Fan	4	Other	0.21	0.8
Dust Seal Fan	0.75	Other	0.21	0.2
Truss Extension / New Drive Components for C-20	25	Transfer Conveyor	0.25	6.2
Terex Triple Deck Horizontal Screen (40hp)	40	Terex screen	0.19	7.7
36" BW Underscreen Collecting Conveyor (C-45)	10	Collecting Conveyor	0.18	1.8
Terex Triple Deck Horizontal Screen (40hp)	40	Terex screen	0.19	7.7
36" BW Underscreen Collecting Conveyor (C-46)	10	Collecting Conveyor	0.18	1.8
24" BW x 71' Long Collecting Conveyor (C-34)	7.5	Collecting Conveyor	0.18	1.4
24" BW x 137' Long Transfer Conveyor (C-35)	10	Transfer Conveyor	0.25	2.5
24" BW x 35' Long Collecting Conveyor (C-36)	7.5	Collecting Conveyor	0.18	1.4
30" BW x 100' Radial Stacker (C-37)	15	Radial Stacker	0.21	3.2
OPTION: Add Power Travel	2	Other	0.21	0.4
24" BW x 31' Long Collecting Conveyor (C-39)	7.5	Collecting Conveyor	0.18	1.4
24"BW x 58' Long Transfer Conveyor (C-40)	7.5	Transfer Conveyor	0.25	1.9
30" BW x 100' Radial Stacker (C-41)	15	Radial Stacker	0.21	3.2
OPTION: Add Power Travel	2	Other	0.21	0.4
24" BW x 18' Long Collecting Conveyor (C-42)	7.5	Collecting Conveyor	0.18	1.4
24" BW x 80' Long Transfer Conveyor (C-43)	7.5	Transfer Conveyor	0.25	1.9
30" BW x 100" Radial Stacker (C-44)	15	Radial Stacker	0.21	3.2
OPTION: Add Power Travel	2	Other	0.21	0.4
24" BW x 75' Long Collecting Conveyor (C-47)	10	Collecting Conveyor	0.18	1.8
24" BW x 356' Long Transfer Conveyor (C-51)	30	Transfer Conveyor	0.25	7.4
Terex Simplicity 4' x 12' Single Deck Screen	7.5	Terex screen	0.19	1.4
24" BW x 38' Long Collecting Conveyor (C-52)	7.5	Collecting Conveyor	0.18	1.4
24" BW x 100' Radial Stacker (C-53)	15	Radial Stacker	0.21	3.2
OPTION: Add Power Travel	2	Other	0.21	0.4
TOTAL	**Proposed Case kW**			**231.8**

Baseline and Installed Production Rate

The evaluator uses the same approach as the applicant to calculate the baseline production rate.

Table 2-12 summarizes the baseline production data which is shown for illustrative purposes and not used for the calculations which were based on an assumed increase in production rate.

Table 2-12: Baseline Production Data

Year	Production Volume		Annual Operating Hours			Production Rate
	Total Tons	Secondary Tons	Primary	Finishing	Average	Tons/Hour
2015	718,642	170,578	1,343	1,703	1,523	112
2016	800,407	200,145	1,421	1,773	1,597	125
2017	767,717	185,630	1,398	1,586	1,492	124
Average	**762,255**	**185,451**	**1,388**	**1,687**	**1,537**	**121**

The evaluator uses the same approach to calculate installed production rate in tons per hour as the applicant used to calculate the baseline production rate. This approach is to use the site’s data for total annual production tons and operating hours.

The secondary crusher plant produces a fraction of the total production volume of the plant. The secondary plant produces the 3/8" ledge, 1/4" ledge, 1/2" ledge, stone dust ledge, and an estimate 50% of the washed dust produced by the site. This is the same assumption used by the applicant and the site provided feedback that this is accurate. Based on site feedback, the secondary crusher also produces Nova stone which was not produced prior to the project. Production data provided by the site shows the production volume broken down by product type so the secondary crusher production volume and the total production volume can be directly calculated.

The total operating hours are provided for these years as well. The evaluator takes the same approach as the applicant in assuming that annual secondary crusher plant operating hours are the average of the primary and finishing annual operating hours. The "finishing" and "primary" distinctions refer to two different labor divisions at the facility and it is assumed that the average represents actual run hours for the plant.

Table 2-13 summarizes the installed case production data. 2018 data is excluded because it includes both existing system and installed system operation.

Table 2-13: Installed Production Data

Year	Production Volume		Annual Operating Hours			Production Rate
	Total Tons	Secondary Tons	Primary	Finishing	Average	Tons/Hour
2019	805,560	170,283	1,584	1,726	1,655	103
2020	862,224	159,738	1,769	1,628	1,699	94
2021	814,058	127,141	1,444	1,560	1,502	85
Average	**827,281**	**152,387**	**1,599**	**1,638**	**1,619**	**94**

Unexpectedly, the secondary crusher plant production rate decreased after the installation of the new system. The site contact was not able to offer a definite explanation for the decrease in production rate.

The annual energy savings for this measure are calculated using a one-line equation shown below.

$$Energy\ Savings\ kWh = Annual\ Production\ Tons * \left(\frac{Baseline\ Demand\ kW}{Baseline\ Tons/hour} - \frac{Installed\ Demand\ kW}{Installed\ Tons/hour}\right)$$

Table 2-14 shows the energy savings calculated for this project.

Table 2-14: Evaluator Energy Savings

Parameter	Units	Value
Secondary Crusher Production Volume	Tons	152,387
Baseline Demand	kW	170.7
Baseline Production Rate	Tons/hour	120.6
Proposed Demand	kW	231.8
Proposed Production Rate	Tons/hour	94
Energy Savings	kWh	-160,516

Bill data was collected for the site. The bill data has significant data gaps. The monthly bill data set is missing data from January 2018 through January 2022. For this reason, bill data analysis was not performed for this evaluation site.

The on-peak energy and peak demand savings were calculated using a time of day, day of week runtime matrix to determine the operating hours of the site based on metered data. The metered data indicates the plant operates 6AM-5PM Monday through Friday and 6AM-3PM on Saturday. The average summer peak demand penalty (average from 1PM-5PM Monday-Friday) is 61.0 kW. The average winter peak demand penalty (average from 5PM-7PM Monday-Friday) is 0 kW. The annual on-peak energy percentage is 78.1% (average from 7AM-11PM Monday-Friday).

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.

Table 3-1. Summary of Key Parameters

Parameter	BASELINE		PROPOSED / INSTALLED	
	Tracking Value(s)	Evaluation Value(s)	Tracking Value(s)	Evaluation Value(s)
Total Production Tons	265,000	152,387	265,000	152,387
Production Efficiency Tons/hour	121	121	250	94
Annual Operating Hours	2,196	1,267	1,060	1,624
Operating Demand kW	318.0	170.7	426.4	231.8

3.4 Explanation of Differences

This section describes the key drivers behind any difference in the application and evaluation estimates, annual kWh savings. The following table summarizes 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 3-2. Summary of Deviations

Measure	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
M1	Operational – Load Shape	Baseline and Proposed kW/HP (Load Factor)	-19.9%	**Decreased savings –** Both the base and proposed demand decreased due to lower load factor than assumed by applicant which decreased savings.
M1	Operational – Operating Efficiency	Installed Tons/hour	-127.5%	**Decreased savings –** The installed system does not achieve a sufficient increase in production efficiency to achieve energy savings and in fact results in a penalty.
M1	Operational – Operating Load	Annual Production Volume	-17.8%	**Decreased savings –** The annual production volume associated with the secondary crusher is less than assumed by the applicant resulting in less savings.
Final RR				**-165.1%**

3.5 Lifetime Savings

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

$$\text{Lifetime Savings kWh} = \text{Annual Savings kWh} * \text{Measure Lifetime Years}$$

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

Table 3-3. Measure 5891377 - Lifetime Savings Summary

Factor	Tracking	Application	Evaluator
Lifetime savings	3,699,070 kWh	3,699,070 kWh	-2,407,739 kWh
First year savings	246,605 kWh	246,605 kWh	-160,516 kWh
Measure lifetime	15 years	15 years (project BCR)	15 years (TRM)
Baseline classification	New Construction	New Construction	End of Useful Life Replacement

3.5.1 Ancillary impacts

There are no ancillary impacts associated with this project.

RICE21N0001_S

Report Date: 7/26/2023

Program Administrator	Rhode Island Energy	
Application ID(s)	11996709/11259894	
Project Type	New Construction	
Evaluation Type	Ops, Full M&V	
Program Year	2021	
Evaluation Firm	DNV	DNV
Evaluation Engineer	Laeng Khoun, Joe St. John	
Senior Engineer	Rick Boswell	

1 Evaluated Site Summary and Results

This new construction (NC) project (child 11996709/parent 11259894) involved the replacement of an (1) electric infrared drying oven with a (1) new gas impingement oven. The gas oven burns natural gas but also uses some electricity. The oven is used to dry volatile organic compounds (VOC) in polymer film to make pressure sensitive tape. This is a fuel switching measure, which results in a significant decrease in electrical energy consumption using natural gas instead.

The site contact indicated that the evaluated system was not impacted by Covid. Therefore, the evaluators conducted a full M&V with metered data informing updates to operational parameters. A full 2.5 years of gas usage data for the new oven was provided by the site contact. This data, along with pre and post measured kW and pre-gas usage data was used to develop energy savings normalized to the average post-case year of gas usage data. Table 1 and Table 2 provide a summary of the evaluation results.

Table 1.Evaluation results summary

PA Application ID	Measure Name		Annual Electric Energy (kWh)	% Of Energy Savings On-Peak[1]	Summer On-Peak Demand (kW)[2]	Winter On-Peak Demand (kW)[3]
11996709/11259894	Natural Gas Hot Air Impingement Drying Oven	Tracked	206,052	66%	45.9	45.9
		Evaluated	238,895	47%	21.5	62.5
		Realization Rate	116%	72%	47%	36%

Table 2. Evaluation gas use increase results summary

PA Application ID	Measure Name		Annual Increase in Gas Use (Therms)
11996709/11259894	Natural Gas Hot Air Impingement Drying Oven	Tracked	21,983
		Evaluated	20,358
		Realization Rate	93%

1.1 Explanation of Deviations from Tracking

The evaluated electricity savings are higher than the applicant reported savings primarily because the evaluator incorporated an adjustment factor to account for the fact that the new oven produces approximately 25% more output per unit time compared to the old unit. Whereas the tracking calculation normalized the energy savings based on operating hours, the evaluators normalized the energy savings based on production, with the idea that the production demand would have been the same in the post-case whether or not the project was installed, and based on the post-case operation, the evaluators adjusted the baseline operation so that the same approximate production would have occurred in the counterfactual scenario of the new oven project not being completed.

[1] Sum of winter peak kWh savings and summer peak kWh savings divided by total kWh savings. Peak winter kWh savings occur during non-Holiday weekdays between October and May between 7 AM and 11 PM. Peak summer kWh occurs during non-Holiday weekdays between June and September between 7 AM and 11 PM.

[2] Average kW Savings during non-Holiday weekdays in June, July, and August between 1 PM and 5 PM

[3] Average kW savings during non-Holiday weekdays in December and January between 5 PM and 7 PM

Additionally, the tracking calculations estimated that the post-case oven when it is off would draw 0 kW, but the evaluator data found that the post case oven drew 1.4 kW in “off/stand-by” mode. As a result, this reduces the savings. This had a much smaller impact on the overall adjustment compared with the approach for normalizing the energy savings.

The evaluated increase in gas usage for the project were found to be less than the reported savings by 7% for a 93% realization rate. The decrease is due to a lower production. Further details regarding deviations from the tracked savings are presented in Section 3.1.

1.2 Recommendations for Program Designers & Implementers

For this project, an in-situ baseline was used for the energy savings calculation, indicating the measure event type is early retirement though the applicant classified it as a new construction project. For the incremental cost calculation, the difference in cost between the installed gas impingement over and an electric impingement oven, rather than the cost of a new electric infrared oven, is used. An electric impingement oven consumes significantly more energy than an electric infrared oven. The documentation indicates that the project was completed to achieve energy savings and that the existing oven had operated well since the 1980s and was in good working condition. For early retirement calculations, the incremental cost would be the full cost of the new equipment, rather than the cost of the new equipment minus the cost of a standard efficiency unit. The evaluators recommend that the cost and energy savings are consistent for cost effectiveness calculations. This is mentioned further in section 2.1.1.

1.3 Customer Alert

There is no relevant customer alert.

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.

This project involves the replacement of an electric infrared drying oven with a new gas impingement oven. The gas oven burns natural gas, but also uses some electricity for fans and controls.

2.1 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.

2.1.1 Applicant Description of Baseline

The tracking calculations state that this project was performed to achieve cost savings, since running a gas oven is less expensive than running an electric oven. The tracking documentation classified this project as new construction (NC).

The documentation indicates that a quote was obtained for a new electric impingement oven (as opposed to a new electric IR oven), but an impingement oven consumes significantly more electricity than the infrared oven that the customer replaced. For this reason, the vendor who developed the tracking calculations chose to use the existing IR oven electric use as the baseline, rather than an impingement oven that was used to estimate the baseline cost for the cost-effectiveness calculations.

The baseline energy use in the tracking calculations is the existing infrared oven’s energy use. The tracking calculations show that the baseline oven used 66.9 kW for 3,382 hours per year and used no gas.

2.1.2 Applicant Description of Installed Equipment and Operation

The applicant described the installed equipment as replacing the existing electric infrared drying oven with a new gas oven. The tracking calculations show that the new gas oven uses 6.5 therms/hour and 6.0 kW for 3,382 hours per year when the oven is on, and 0 kW and 0 therms when the oven is off.

2.1.3 Applicant Energy Savings Algorithm

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

$$Electric\ Savings\ = Baseline\ Elec - Post\ Elec$$

where,

$$Baseline\ Elec = Facility\ Production\ Hours\ \times Oven\ Utilization\ Rate_P\ \times Average\ Oven\ Power_{BL}$$

$$Post\ Elec = Facility\ Production\ Hours\ \times Oven\ Utilization\ Rate_P\ \times Average\ Oven\ Power_P$$

And,

$$Gas\ Savings\ = Baseline\ Gas - Post\ Gas$$

$$Baseline\ Gas = 0$$

$$Post\ Gas = Facility\ Production\ Hours\ \times Oven\ Utilization\ Rate_{BL} \times Oven\ Therms/Hr$$

where the variables are described in Table 3.

Table 3. Tracking calculations variable list

Variable Name	Units	Variable Value	Variable Source
Facility Production Hours	Hours/year	8,400	50 weeks/year x 7 days/week x 24 hours/day
$Oven\ Utilization\ Rate_{BL}$	-	63.7%	30-second interval baseline data collected between 8/20/2019 and 9/1/2019. Times when the kW is greater than 2. Note – this value was not used, the tracking savings were normalized to post-case operating hours. So the post-case utilization rate was used in the baseline.
$Oven\ Utilization\ Rate_P$	-	38.7%	30-second interval post-case data collected between 11/19/20 and 12/10/20. Times when kW is greater than 0.5.
$Average\ Oven\ Power_{BL}$	kW	66.9	30-second interval baseline data collected between

			8/20/2019 and 9/1/2019. Times when the kW is greater than 2.
$Average\ Oven\ Power_P$	kW	6.0	30-second interval post-case data collected between 11/19/20 and 12/10/20. Times when kW is greater than 0.5.
$Oven\ Therms/Hr$	Therms/Hr	6.5	Spec sheet found in calculation workbook.

2.1.4 Evaluation Assessment of Applicant Methodology

The evaluators found the applicant's overall analysis methodology appropriate, although while the tracking analysis normalized energy savings based on equivalent oven operating hours pre and post, the evaluators normalized energy savings based on equivalent production output from the oven pre and post. The site-contact stated that the new oven can produce 125% of the output compared to the baseline oven in 1 hour of operation. The evaluators therefore first estimated the post-case oven operation and then developed the baseline operation by multiplying the post-case operating hours by 1.25. In addition to the operating hours, the applicant's analysis contained other input parameters such as pre and post oven kW usage rate, and post-case gas usage rate, which the evaluator updated based on metered data.

2.2 On-Site Inspection and Metering

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

The evaluators conducted a site visit on April 25th, 2023 which included an interview with the engineering manager for the facility. The evaluators confirmed the installation of the gas oven and confirmed with the site contact that there are electrical loads on the oven from running fans. The evaluators installed metering equipment to collect post-case kW data for 44 days and inspected the gas meter for the oven.

Table 4 provides a summary of the on-site verification.

Table 4. Measure verification

Measure Name	Verification Method	Verification Result
Natural Gas Hot Air Impingement Drying Oven	On-site inspection and metering	Gas oven was confirmed to be installed and operational. A kW logger was installed on the gas oven. The electricity for the gas oven operates the gas oven's fans.

The evaluator's metering for this site included:

1. One (1) Dent ElitePro data logger. The logger measured kW data in 5-min intervals for 44 days.

Figure 1 and Figure 2 shows the post-case kW data collected during the evaluation metering period. Figure 1 is a scatter plot of the metered data during the logging period and Figure 2 is a heat map by date and hour of day.

Figure 1. Metered post-case oven kW data

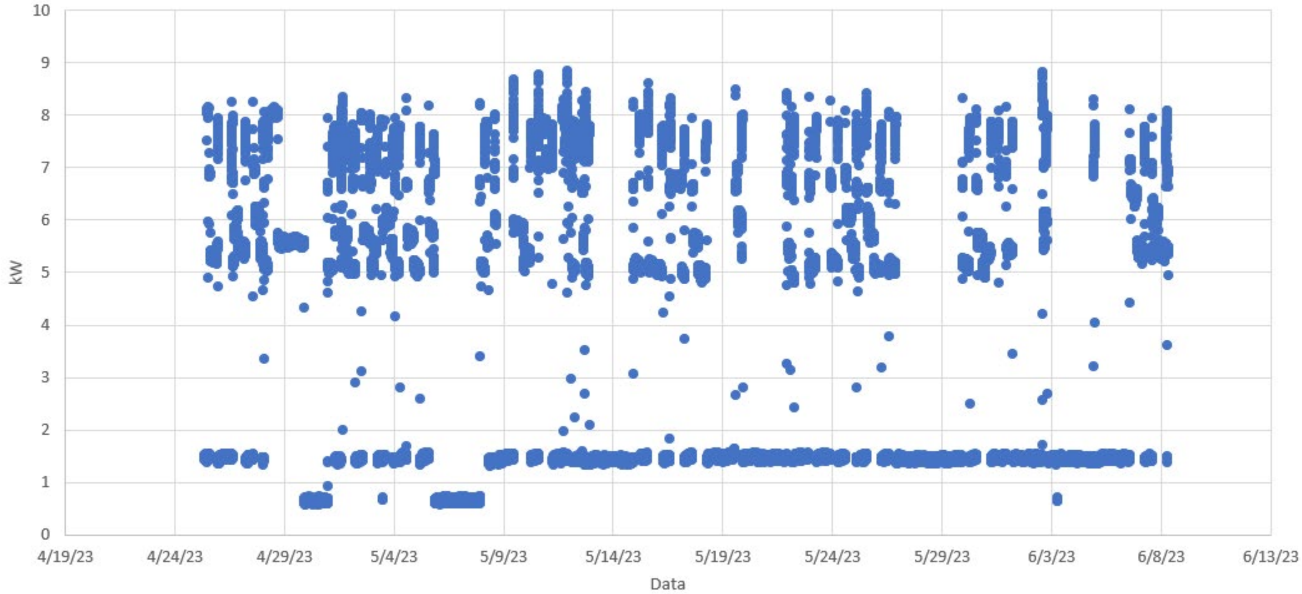


Figure 2. Metered post-case oven kW data – heat map

		Hour																							
Weekday	Date	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Thu	4/27/2023	5.5	5.5	5.5	5.5	5.5	5.8	4.8	1.4	1.5	1.5	1.5	1.5	1.5	1.5	3.0	7.0	6.4	6.2	6.1	6.2	6.1	6.1	5.5	5.5
Fri	4/28/2023	6.2	2.9	5.3	5.1	5.1	5.1	7.5	8.0	8.0	8.0	8.0	8.0	8.0	8.1	8.1	8.0	8.0	6.9	5.6	5.5	5.6	5.5	5.6	5.6
Sat	4/29/2023	5.6	5.6	5.6	5.6	5.5	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.5	5.5	5.6	5.5	3.2	0.6
Sun	4/30/2023	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.7
Mon	5/1/2023	5.6	5.1	5.1	5.1	5.1	6.0	7.6	7.5	2.0	1.4	1.4	1.4	1.4	1.4	4.1	6.9	6.7	5.7	5.7	5.7	5.7	5.7	5.1	5.1
Tue	5/2/2023	5.1	5.0	7.3	6.3	5.1	5.1	5.5	1.4	1.4	1.4	1.4	1.4	2.0	1.8	3.2	5.8	5.7	5.7	5.7	5.7	5.7	5.7	7.0	5.6
Wed	5/3/2023	5.1	5.1	5.2	5.5	5.5	6.0	4.1	1.4	1.5	1.5	4.5	7.8	2.5	1.5	3.2	6.9	6.1	6.1	6.1	6.0	6.0	5.6	5.5	6.2
Thu	5/4/2023	1.4	5.2	5.1	5.1	5.2	5.1	5.6	1.4	1.5	1.5	1.5	1.5	1.5	1.5	3.2	6.0	5.7	5.7	5.7	5.6	5.7	5.6	5.2	5.1
Fri	5/5/2023	5.1	5.1	5.1	5.1	6.0	2.8	1.4	1.5	1.5	1.5	1.5	1.5	1.5	1.5	2.1	6.7	6.0	5.8	5.8	5.7	6.1	2.2	0.6	0.6
Sat	5/6/2023	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.7	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.7
Sun	5/7/2023	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.6	0.7	0.7	0.7	0.7	0.7	0.7	1.8	5.8
Mon	5/8/2023	5.1	5.1	5.1	5.8	7.7	7.8	7.5	5.6	2.1	1.4	1.4	1.4	1.4	1.4	2.3	6.4	2.8	1.4	1.4	1.4	1.4	1.5	1.5	1.5
Tue	5/9/2023	1.4	1.4	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	7.3	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.3	5.3
Wed	5/10/2023	5.4	5.4	5.3	5.4	5.4	5.4	5.8	1.5	1.5	1.5	1.5	1.5	1.5	1.5	4.4	7.8	7.7	7.7	7.8	7.9	7.9	7.8	7.6	7.1
Thu	5/11/2023	7.2	7.2	7.1	7.2	7.2	7.2	4.6	1.4	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.4	3.4	8.0	3.2	7.9	7.9	6.6	4.5	7.4
Fri	5/12/2023	7.2	7.2	7.3	2.9	5.2	5.1	5.1	1.4	1.4	1.4	1.5	1.5	1.5	1.4	3.4	6.6	5.9	4.6	5.3	5.1	5.1	5.4	4.0	1.4
Sat	5/13/2023	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Sun	5/14/2023	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	2.9	5.3
Mon	5/15/2023	5.1	5.2	5.2	5.2	5.2	7.9	7.9	3.9	1.5	1.5	1.5	1.5	1.5	1.5	5.4	5.3	5.2	5.1	5.1	5.1	5.1	5.1	5.1	5.1
Tue	5/16/2023	5.1	5.1	5.1	5.1	5.1	5.1	7.0	1.4	1.5	1.5	1.5	1.5	1.4	1.4	3.2	7.2	6.7	6.7	6.8	6.8	6.7	6.7	6.7	6.8
Wed	5/17/2023	6.7	6.7	6.7	6.8	5.4	5.0	5.6	1.4	1.5	1.5	1.5	1.5	1.5	1.5	3.0	6.6	6.1	5.6	5.6	5.6	5.6	5.5	5.0	5.0
Thu	5/18/2023	5.0	5.0	5.0	5.0	5.0	5.0	6.5	1.4	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Fri	5/19/2023	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	3.3	6.6	6.9	6.0	6.1	6.1	6.1	6.7	2.7	1.4
Sat	5/20/2023	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Sun	5/21/2023	1.4	1.4	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.4	1.4	1.4	1.4	1.5	1.5	1.5	2.6	6.4
Mon	5/22/2023	5.5	5.4	5.8	3.3	5.5	4.9	6.1	2.6	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	2.8	6.2
Tue	5/23/2023	5.6	5.1	5.1	5.1	5.2	5.2	6.5	2.1	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	3.0	5.8
Wed	5/24/2023	5.3	5.2	5.2	5.2	5.2	5.2	6.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	4.6	6.7	6.1	6.1	6.1	6.0	6.1	6.1	5.5	5.4
Thu	5/25/2023	5.5	5.5	5.5	4.6	6.0	5.0	6.4	2.0	1.5	1.5	1.5	1.5	1.5	1.5	5.7	6.1	6.1	6.0	5.7	5.7	5.7	5.6	5.1	5.0
Fri	5/26/2023	5.1	5.1	5.1	5.0	5.0	6.9	4.7	1.4	1.5	1.5	1.5	1.5	1.5	1.5	4.5	5.1	5.2	5.2	5.1	5.1	5.1	6.4	2.4	1.4
Sat	5/27/2023	1.4	1.4	1.5	1.5	1.5	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Sun	5/28/2023	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Mon	5/29/2023	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	2.9	5.4
Tue	5/30/2023	5.2	5.2	5.2	5.2	5.2	5.2	6.7	2.0	1.5	1.5	1.5	1.5	1.5	1.5	4.3	6.2	5.7	5.7	5.6	5.6	5.4	5.1	5.1	5.1
Wed	5/31/2023	5.2	5.3	5.3	5.4	5.4	5.5	4.7	1.4	1.5	1.5	1.5	1.5	1.5	1.5	4.2	2.0	1.5	1.5	1.5	1.5	1.5	1.5	2.8	6.2
Thu	6/1/2023	5.4	5.5	5.4	5.4	5.4	6.1	3.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.4	1.4	1.4	1.4	1.4	1.4	1.5	1.5	1.5
Fri	6/2/2023	1.5	1.5	1.4	1.4	1.4	1.4	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.9	5.4	7.4	5.7	5.7	6.3	7.8	4.8	1.4	1.4	1.4
Sat	6/3/2023	1.4	1.5	1.4	1.4	1.4	1.4	1.4	1.4	1.5	1.5	1.5	1.5	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Sun	6/4/2023	1.4	1.4	1.4	1.5	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	2.9	5.1
Mon	6/5/2023	1.4	1.4	1.4	1.4	1.4	1.4	1.5	1.5	1.5	1.5	1.5	1.5	1.4	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Tue	6/6/2023	1.5	1.5	1.4	1.4	1.4	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	3.4	7.0	6.6	6.5	6.5	6.4	6.4	6.3	5.5	5.5
Wed	6/7/2023	5.4	5.4	5.4	5.3	5.4	5.4	6.8	1.4	1.4	1.5	1.5	1.5	1.5	1.5	3.3	5.9	6.0	6.1	6.1	6.2	6.1	6.1	5.5	5.4

In addition to the post-case kW data that was collected, the tracking calculation also included baseline kW data that was collected over a 2-week period. That data is shown in Figure 3 and Figure 4. Figure 4 has the same data as Figure 3, but presented as a heat map.

Figure 3. Metered baseline kW data

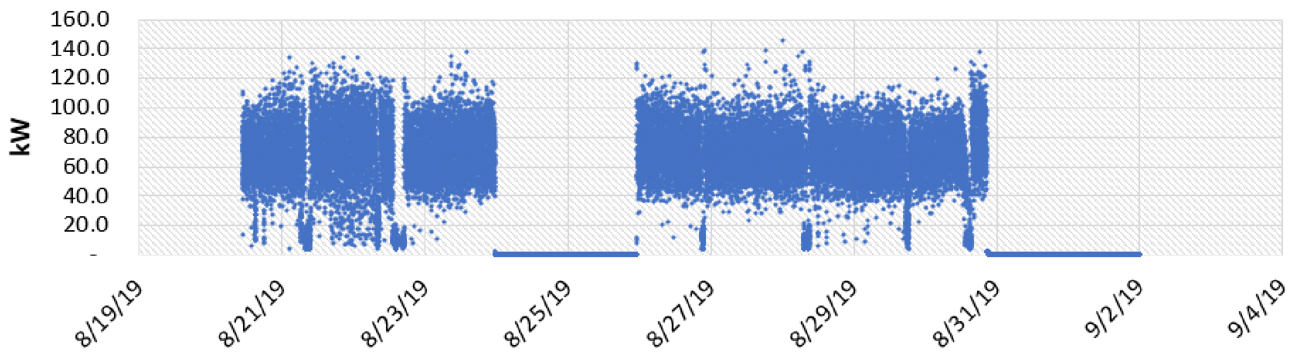


Figure 4. Metered baseline kW data heat map

		Hour																							
Weekday	**Date**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
Tue	8/20/19											68.0	68.4	68.3	68.0	58.9	65.5	69.0	67.2	64.7	68.0	68.3	70.0	71.1	72.2
Wed	8/21/19	73.1	70.6	70.2	72.2	72.2	70.5	53.6	47.8	11.6	49.8	74.7	75.2	73.3	73.9	73.9	71.7	71.7	73.0	71.7	73.0	71.7	70.6	70.4	66.9
Thu	8/22/19	73.0	71.8	72.5	71.7	72.2	71.1	72.0	55.5	46.0	76.6	72.4	71.4	69.8	29.9	10.2	9.4	9.0	68.0	66.8	68.0	67.6	67.5	68.1	69.1
Fri	8/23/19	68.3	70.2	71.0	68.3	70.0	69.0	69.0	70.5	73.5	71.1	72.2	73.1	70.0	72.4	72.6	72.8	73.4	71.6	71.8	70.5	70.6	72.2	72.2	35.6
Sat	8/24/19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sun	8/25/19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	64.8
Mon	8/26/19	73.3	74.3	73.0	71.5	71.3	70.9	73.4	73.0	73.8	72.7	71.9	72.4	71.7	71.2	71.0	69.4	71.6	70.4	69.1	69.6	67.0	33.6	68.7	68.6
Tue	8/27/19	68.2	68.3	68.8	69.3	67.1	67.8	67.4	68.0	66.7	68.9	70.4	69.5	70.7	71.8	71.7	69.2	68.3	69.3	68.3	69.1	70.7	68.0	69.6	68.7
Wed	8/28/19	71.6	69.5	69.1	70.1	69.5	69.0	66.7	31.8	21.8	70.9	73.4	69.8	72.1	72.6	67.5	66.6	69.4	70.4	67.8	68.5	69.1	68.8	67.0	65.2
Thu	8/29/19	64.6	67.0	65.7	62.9	64.9	66.3	66.5	67.7	67.6	69.3	70.8	70.3	69.1	70.8	70.0	69.4	68.5	38.8	47.5	68.2	69.1	68.7	66.7	67.3
Fri	8/30/19	68.9	68.5	68.1	67.2	71.6	72.4	72.1	72.5	71.6	72.1	73.3	72.4	69.8	49.2	17.6	54.8	77.7	80.0	81.6	79.9	48.5	0.0	0.0	0.0
Sat	8/31/19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sun	9/1/19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Figure 5 shows the monthly gas usage for the new gas oven starting from January, 2021 through May, 2023. It also shows the average gas usage for each month through through that period, which is used later to estimate the annual gas use increase as well as the baseline and post-case electricity use.

Figure 5. New gas oven monthly gas usage from 1/2021 – 5/2023

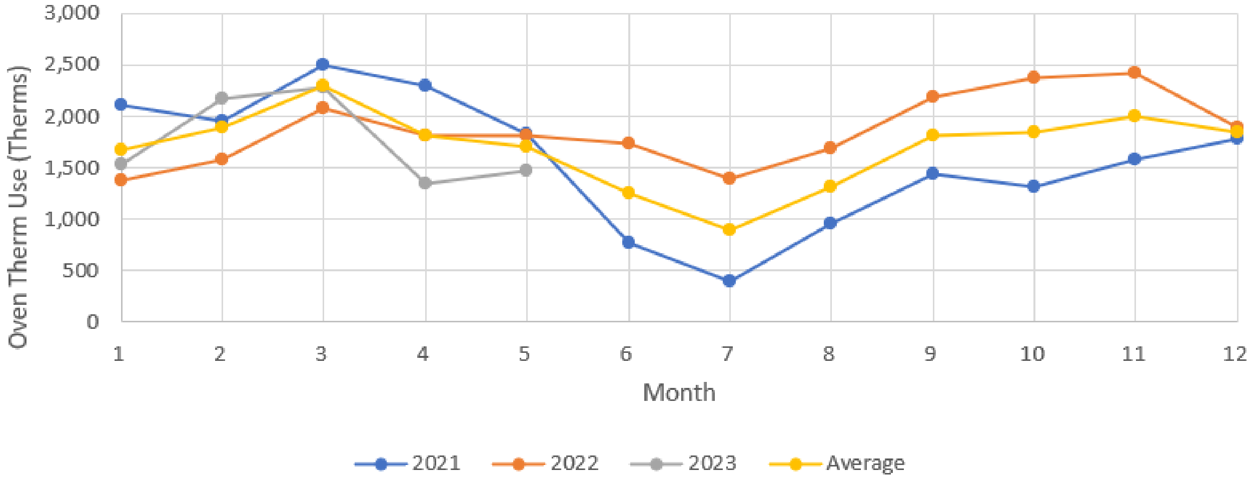


Figure 6 shows the gas oven's hourly gas usage rate in therms/hour collected from the site's BMS from 1/21/21 – 5/23/21. The data is in 5-minute intervals. A period of time when the oven was off is not shown on the chart below, because the important thing in the chart is the average gas usage rate when the oven is on, which is 6.45 therms/hour. The data in Figure 6 was collected during the implementation phase, not the evaluation phase.

Figure 6. New gas oven hourly gas usage from 1/21 – 5/23

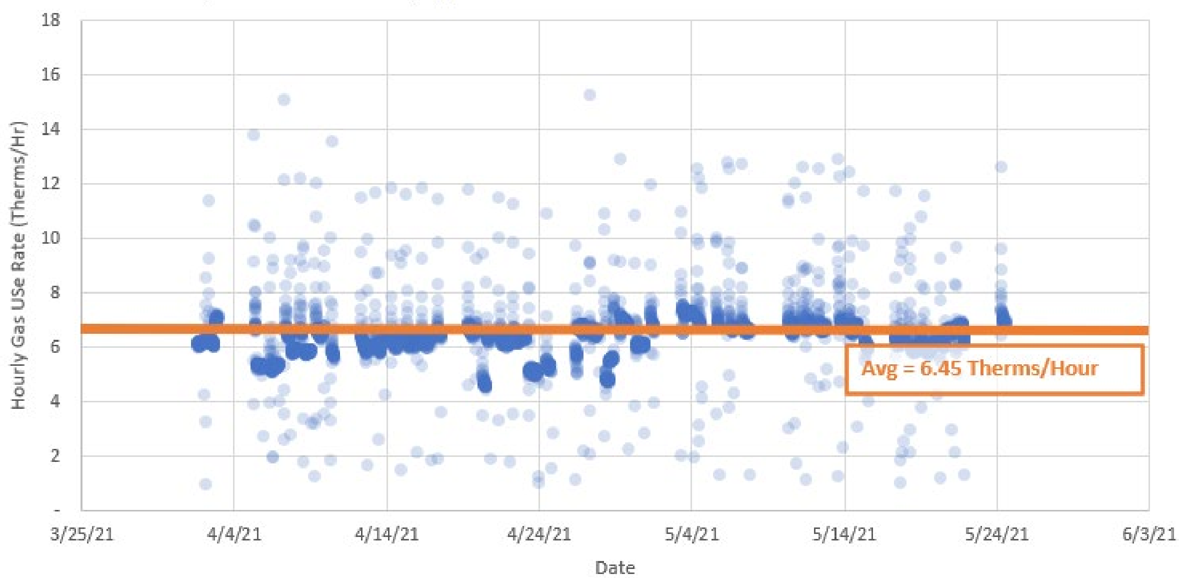


Figure 7 shows specification sheets for the new gas oven. When all the zones are engaged, the burner load is 0.09 +0.11 +0.11 + 0.13 + 0.21 = 0.65 MBtu/hR which is 6.5 therms/hour. This corresponds very closely to the data shown in Figure 6, that showed an average gas usage rate of 6.45 therms/hour.

Figure 7. Specifications and gas use rate in MBtu/Hr for new gas oven

Job: 9154
Engineer: JSR
Date: 1/11/2019

Line Speed 20 fpm

	Dryer 1						
Zone	**Supply**	**Max Temp**	**Burner Load**	**Return**	**Make-up**	**Exhaust**	
1 Upper	2,238 acfm @ 180°F		0.09 MBtu/hr	1,559 acfm @ 159°F	439 acfm	2,165 acfm @ 159 °F	1,853 scfm
1 Lower	1,100 acfm @ 180°F		0.11 MBtu/hr	n/a	100%	Exhaust into z1 Upper	
2	2,238 acfm @ 250°F		0.11 MBtu/hr	1,556 acfm @ 245°F	421 acfm	667 acfm @ 245 °F	501 scfm
3	2,238 acfm @ 300°F		0.13 MBtu/hr	1,516 acfm @ 297°F	419 acfm	713 acfm @ 297 °F	499 scfm
4	2,238 acfm @ 425°F		0.21 MBtu/hr	1,633 acfm @ 331°F	166 acfm	1,000 acfm @ 331 °F	670 scfm
5	0 acfm @ °F		0.00 MBtu/hr	0 acfm @ 0°F	0 acfm	0 acfm @ 0 °F	0 scfm
6	0 acfm @ °F		0.00 MBtu/hr	0 acfm @ 159°F	0 acfm	0 acfm @ 0 °F	0 scfm
					Total Exhaust	**4,545 acfm @ 223 °F**	**3,524 scfm**

2.3 Evaluation Methods and Findings

This section describes the evaluator methods and findings.

2.3.1 Evaluation Description of Baseline

The evaluators have classified this measure as an early replacement. The baseline is the pre-existing condition which consisted of the pre-existing electric oven. The documentation indicates that the project was done in order to achieve cost savings, and that the existing electric oven was in good working order and had been installed in the 1980s. Additionally, the site contact indicated that the new oven is able to produce 25% more than the old oven in the same period of time because of its larger size, but that demand for product has actually decreased, leading to a reduction in operating hours . However, this does mean that the baseline oven would need to run more hours to produce the same amount of output as in the post case.

2.3.2 Evaluation Calculation Method

The evaluators calculated savings using a custom 8,760 savings analysis based on metered operational data. The evaluator's as-built model was based on the average baseline and post-case input power profiles, as well as the hourly and monthly post-case gas usage data from the facility's gas meter that is dedicated to this new oven. All the data that is used in the evaluator analysis is shown in Figure 1 through Figure 6. In addition to this data, the evaluator accounted for the fact that the new oven is able to produce 125% of the output compared to the old oven in the same period as the old oven, meaning that the old oven would have had to operate for 125% of the annual hours that the new oven operates to achieve the same throughput.

The steps for calculating the evaluator energy savings are as follows:

1. From the monthly gas usage data from 1/21 through 5/23 in Figure 5, the average annual gas use of the new oven is 20,358 therms.
2. From the hourly gas usage data of the new oven shown in Figure 6, the average hourly gas usage rate is 6.45 therms/hour. This means that the new oven is operating 20,368 therms / 6.45 therms/hour = 3,157 hours/year.
3. Because the new oven can produce 125% of the output compared to the old electric oven because of its increased size, the old oven would have operated for 3,157 x 125% = 3,946 hours/year.
4. Based on the baseline oven's kW data shown in Figure 3 and Figure 4, the average baseline kW when the electric oven operates is 66.9 kW, and 0 kW when the oven is off. When this kW of 66.9 kW is multiplied by 3,946 hours/year, the baseline electrical use (normalized to post-case production), is 264,084 kWh.
5. Based on the post-case oven's kW data shown in Figure 1 and Figure 2, the average operating kW of the oven when it is "on" is 5.6 kW and 1.4 kW when it is "off". When the oven's post-case "on" kW of 5.6 is multiplied by the

oven's post-case "on" operation hours of 3,157 and added to the oven's "off" kW of 1.4 kW and is multiplied by the ovens off hours of 5,703, the total annual post-case oven energy is 25,189 kWh.

6. The total electricity savings is 264,084 – 25,189 = 238,895 kWh.
7. The total annual increase in gas use (from step 1) is 20,358 therms.

3 Final Results

This project involved the replacement of an electric infrared drying oven with a new gas oven.

The evaluator performed an 8,760 hourly analysis informed by site inspection and metered data collected by the evaluator and provided by the site-contact to calculate project savings. The evaluator's analysis indicated that the tracking analysis did not consider the fact that the new oven is able to produce 125% of the output in the same amount of time as the old oven, meaning that the old oven would have operated fewer hours to generate the same amount of product. This is the main reason the evaluated savings are higher than the tracking savings because the evaluation approach normalized to production, whereas the tracking analysis normalized to operating hours. The tracking approach is not an appropriate comparison because the facility only produces the amount of product they can sell, and they adjust their operation schedule accordingly.

Table 5 provides a comparison of the key parameters.

Table 5. Summary of key parameters

	BASELINE		PROPOSED / INSTALLED	
Parameter	Tracking	Evaluation	Tracking	Evaluation
	Value(s)	Value(s)	Value(s)	Value(s)
Oven On kW	66.9	66.9	6.0	5.6
Oven On kW Reduction			60.9	61.4
Oven Off kW	0.0	0.0	0.0	1.4
Production Adjustment Factor	1.00	1.25	1.00	1.00
Oven On Hours/Year	3,382	3,946	3,382	3,157
Oven Off Hour/Year	6,378	4,814	6,378	5,603
Oven On kWh/Year	226,344	264,084	20,292	17,595
Oven Off kWh/Year	0	0	0	7,594
Oven Total kWh/Year	226,344	264,084	20,292	25,189
Oven kWh Savings/Year	0		206,052	238,895
Oven On Gas Use Rate (therms/hr)	0		7	6
Oven Gas Use (therms/yr)	0		21,983	20,358

3.1 Explanation of Differences

The evaluated savings are higher than the applicant-reported values predominantly because of a calculation adjustment to normalize savings to production, rather than operating time. The evaluators classify this as a calculation adjustment because the evaluators use a modified algorithm compared to the tracking algorithm. The second adjustment involves accounting for the post-case "off/stand-by" kWh, which was not accounted for in the tracking analysis. The last minor adjustment is caused by a different post-case "on" kW value for the new oven.

Table 6 provides a summary of savings deviations.

Table 6. Summary of deviations

Measure	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
11996709/ 11259894	Calculation	Baseline production adjustment factor	19%	Increased savings - evaluation findings indicate that the new oven can process 125% of the parts that the old oven can in the same amount of time, meaning that the baseline oven needs to operate for more hours than the post-case oven to produce the same amount.
11996709/ 11259894	Operation	Oven "Off/Stand-by" kWh	-4%	Decreased savings – The tracking calculations did not account for the post-case oven using energy in "off/stand-by" mode, even though the oven was observed to use 1.4 kW when in this mode (See Figure 2. Metered post-case oven kW data – heat map
11996709/ 11259894	Operation	Oven "On" kW Reduction	1%	Increased savings – The tracking calculations showed that the "on" kW reduced from 66.9 kW to 6.0 kW, whereas the evaluator calculations (based on post-case measured data), showed the "on" kW reduced from 66.9 kW to 5.4 kW. This caused the savings to increase.
Final RR			**116%**	

3.2 Lifetime Savings

This measure has been classified as early retirement. The baseline is the pre-existing condition which consisted of the pre-existing electric oven. Since the existing oven was in good operation and has operated successfully since the 1980s when it was installed, the evaluators believe that this oven would have continued to operate satisfactorily in perpetuity had this project to achieve cost savings not occurred.

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

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

where:

LAGI = lifetime adjusted gross impact (kWh)

FYS = first year savings (kWh)

EUL = measure life (years)

Table 7 provides a summary of key factors that influence the lifetime savings.

Table 7**. Lifetime savings summary**

Factor	Tracking	Application	Evaluator
Lifetime savings	3,090,780 kWh	3,090,780 kWh	3,583,426 kWh

First year savings	206,052 kWh	206,052 kWh	238,895 kWh
Measure lifetime	15 years	15 years	15 years
Baseline classification	New Construction	New Construction	Early Retirement

3.2.1 Ancillary impacts

The ancillary impacts include the addition of 20,358 therms, per Table 8.

Table 8. Evaluation gas use increase results summary

PA Application ID	Measure Name		Annual Increase in Gas Use (Therms)
11996709/11259894	Natural Gas Hot Air Impingement Drying Oven	Tracked	21,983
		Evaluated	20,358
		Realization Rate	93%

RI CUSTOM ELECTRIC EVALUATION SITE-SPECIFIC REPORT

DNV SITE ID: 2021-RICE21S053

Report Date: 29 November 2023

Application ID(s)	12623135	
Project Type	C&I Retrofit	
Program Year	2021	
Evaluation Firm	DMI	
Evaluation Engineer	Multiple	
Senior Engineer	Mickey Bush	

1 EVALUATED SITE SUMMARY AND RESULTS

The building is a 200,000 ft² prison intake facility constructed in 1982, with a north-wing addition constructed in 1992. The building is occupied all day, year-round. The retrofit project is a replacement of 16 three phase dry-type 480 volt to 208 volt transformers varying in size from 15 kVa to 112.5 kVa, which were original to the building. The measure saves energy by installing transformers with lower core losses (also known as "no-load" losses [NLL]) and lower winding losses (also known as load losses, LL).

The tracked savings for this measure is 64,926 kWh. There are no other fuel savings other than electric.

This site is an operational evaluation because the site's occupancy and use are not currently affected by COVID and the site contact was able to accommodate an on-site evaluation with full M&V.

Table 1-1. Evaluation Results Summary

PA Application ID	Measure Name		Annual Electric Energy (kWh)	% of Energy Savings On-Peak	Summer On-Peak Demand (kW)	Winter On-Peak Demand (kW)
Totals	High Efficiency Transformer	Tracked	64,926	45.4%	7.4	7.4
		Evaluated	65,873	45.4%	7.5	7.5
		Realization Rate	101%	100%	101%	101%

1.1 Explanation of Deviations from Tracking

The evaluated savings are slightly greater than the applicant reported savings because the evaluator included load losses.

1.2 Recommendations for Program Designers & Implementers

The evaluator recommends updating the custom express Transformer Savings Tool with the new baseline no load loss data set provided by the transformer vendor.

1.3 Customer Alert

There are no customer alerts and the customer has not requested a copy of the final site report.

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. Table 2-1 summarizes the measures evaluated for this site.

Table 2-1. Measure description

Measure	Project ID	Parameter
M1	12623135	Replacement of 16 transformers (480V/208V) ranging from 15 kVA to 112.5 kVA with 16 high-efficiency transformers (480V/208V) with the same capacities.

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.

2.2 Applicant Description of Baseline

The applicant considered this project to be a retrofit (early replacement), so the pre-existing transformers are the baseline for the measure. The applicant did not provide documentation on the reasoning for classifying the measure as a retrofit, but National Grid's 2018 custom express Transformer Savings Tool only applies to retrofit projects. The tool assumes that existing transformers are being replaced for energy efficiency and that the pre-existing transformers were installed prior to adoption of the Federal transformer efficiency standard (TP-1) in Massachusetts in 2000. The pre-existing transformers were original to the buildings, so they were installed prior to 2000.

Table 2-2. Applicant baseline key parameters

		BASELINE	
Measure	**Parameter**	**Value(s)**	**Source of Parameter Value**
M1	Quantity	1 x 15 kVA 8 x 30 kVA 4 x 45 kVA 2 x 75 kVA 1 x 112.5 kVA	Applicant savings calculations and MRD
M1	Annual operating hours	8,760	Applicant savings calculations
M1	No load losses	15 kVA – 229 watts/unit 30 kVA – 403 watts/unit 45 kVA – 566 watts/unit 75 kVA – 860 watts/unit 112.5 kVA – 1,168 watts/unit Total – 8.6 kW	Applicant savings calculations

2.2.1 Applicant Description of Installed Equipment and Operation

There were 16 high efficiency transformers installed across the facility, each with an efficiency exceeding the TP-1 efficiency standard from 2000 as well as the current DOE efficiency requirements enacted in 2016. The rated capacity (kVA) of each installed transformer is the same as the pre-existing unit being replaced (one for one replacement).

Table 2-3. Application proposed key parameters

		Installed	
Measure	**Parameter**	**Value(s)**	**Source of Parameter Value**
M1	Quantity	1 x 15 kVA 8 x 30 kVA 4 x 45 kVA 2 x 75 kVA 1 x 112.5 kVA	Applicant savings calculations and MRD
M1	Annual operating hours	8,760	Applicant savings calculations
M1	No load losses	15 kVA – 35 watts/unit 30 kVA – 57 watts/unit 45 kVA – 78 watts/unit 75 kVA – 111 watts/unit 112.5 kVA – 164 watts/unit Total – 1.2 kW	Applicant savings calculations

2.2.2 Applicant Energy Savings Algorithm

Savings were calculated using a one-line calculation, using the 2018 NGrid Transformer Savings Tool (version 3), comparing "no load" losses (NLL) between the base case transformers and the proposed transformers. The savings tool does not calculate winding losses or load losses because the transformers are assumed to be lightly loaded; therefore, any load losses would be minimal.

kWh Saved = (Baseline NLL – Proposed NLL) / 1,000 watts/kW * 8,760 hours

The Transformer Savings Tool calculates baseline NLL for a typical pre-TP1 transformer using a regression line developed from the values in Table 2-4.

Table 2-4. Baseline No Load Losses

Size kVA	NLL watts
30	403
45	598
75	835
112.5	1,198
150	1,463
225	1,744

The values in Table 2-4 are included in the 2018 Transformer Replacement Program Manual (Table 4, pg. 16). According the Program manual, the NLL data was obtained from an unnamed transformer manufacturer and is the average of measured losses for transformers loaded below 5% of their rated capacity. The manual states that "the number of data points in each transformer size was adequate for statistic validity of the data regarding no load losses."

The quadratic fit used to calculate no-load losses in watts in the Transformer Savings Tool is:

$$NLL = -0.02392x^2 + 12.681x + 43.68$$

Where x = The capacity of the transformer in kVa.

It should be noted that a fit of the data in Table 2-4 does not exactly match the coefficients below, but the coefficients above only result in a difference of 1-2% compared to a fit of Table 2-4.

The source of the proposed transformer NLL used in this tool is an applicant input and is based on manufacturer's cut sheets. (The manufacturer's NLL values are shown in Table 2-5.)

Demand savings are the sum of the wattage differences in NLL for each transformer. The energy savings are the demand savings multiplied by 8,760 annual hours, which is a user input.

A summary of the applicant saving calculations is below.

Table 2-5. Applicant savings calculations

Size kVA	Qty	Baseline NLL	Proposed NLL	Run Hours	Saved kWh
15	1	229	35	8,760	1,695
30	8	403	57	8,760	24,218
45	4	566	78	8,760	17,096
75	2	860	111	8,760	13,126
112.5	1	1,168	164	8,760	8,791
Total	**16**	**8.6 kW**	**1.2 kW**	**8,760**	**64,926**

The calculations for % on-peak and peak kW demand reduction assume that the reduction in no load losses is the same for each hour of the year; therefore, the % on-peak energy savings is 45.4% and the summer and winter peak demand reductions are 7.4 kW.

2.2.3 Evaluation Assessment of Applicant Methodology

The evaluator agrees with the calculation approach used by the applicant. The pre-existing transformers were installed prior to the TP-1 efficiency standard; therefore, using the Transformer Savings Tool is appropriate.

2.3 On-site Inspection and Metering

A site visit was conducted on October 26, 2022 to confirm the model numbers of the installed transformers and to meter the power of accessible transformers.

2.3.1 Summary of Site Visit

Due to security reasons the evaluator was not able to take pictures of the installed transformer nameplates and the evaluator was not able to access all of the installed transformers.

Table 2-6. Measure verification

Measure Name	Verification Method	Verification Result
M1 – High efficiency transformers	In person inspection	The nameplates for 5 installed transformers were observed and the installed models, E-Saver-80R, match the application. Due to space access restrictions not all of the transformers could be observed to verify the model number for each unit and the total count. The post inspection documentation indicates that 16 transformers were installed and the customer verified the quantity as well.

2.3.2 Measured and Logged Data

Long term metering was performed on five of the installed transformers. A summary of metered data collected is below.

Table 2-7. Data collected

ID	Size (kVA)	Data	Duration	Interval	Avg Amps	Rated Amps	Avg % Load
1	45	Input and Output Amps and Watts	48 days	15 minutes	19.0	125	15%
2	30	Input and Output Amps and Watts	48 days	15 minutes	10.5	83	13%
3	45	Output Amps	48 days	1 minute	10.4	125	8%
4	30	Output Amps	48 days	1 minute	9.6	83	12%
8	15	Output Amps	48 days	1 minute	17.9	42	43%

Where the % load is a calculated value for use in the savings calculations and is determined as shown below.

% Load = Average Amps / Rated Amps

Rated Amps = Rated kVA x 1,000 VA/kVA / Output Volts / Sqrt(3)

The output volts is 208 volts for each transformer based on the transformer rating and confirmed with metering of transformer 1 and 2 output.

Figure 2-1. Metered transformer amps

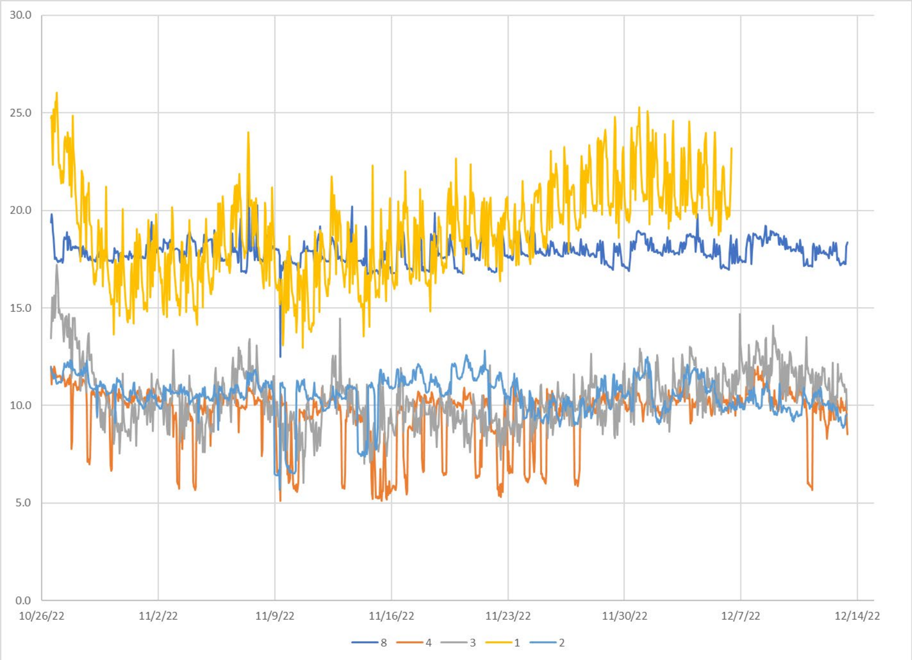
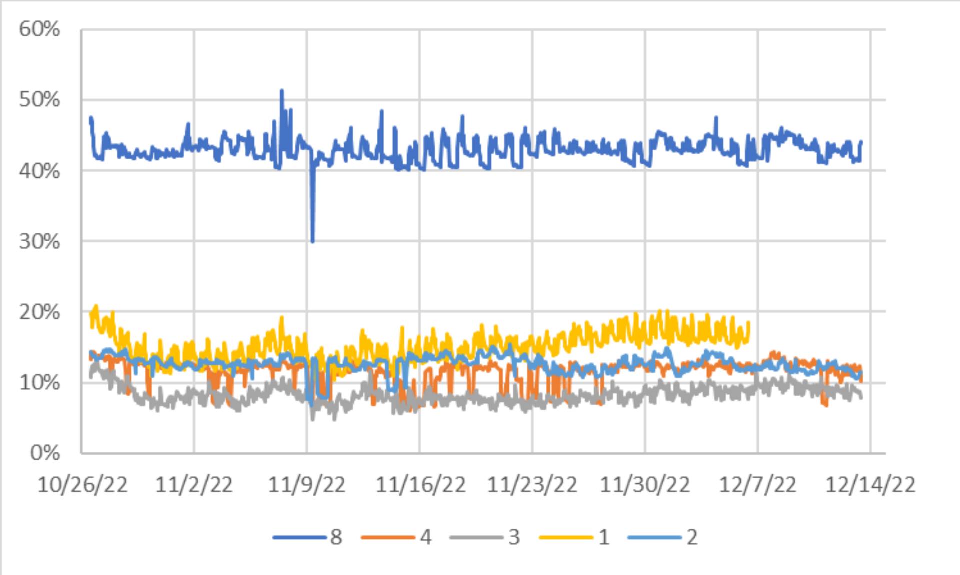


Figure 2-2. Metered transformer percent load



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 and classifies the measure as a retrofit (early replacement), because the pre-existing transformers were functioning. Per the 2018 Transformer Replacement Program Manual, transformer life can exceed 50 years; therefore, the pre-existing transformers would have had useful remaining life.

The evaluator agrees that the baseline efficiency should be based on pre-TP1 transformers.

National Grid and Eversource are currently funding a study in Massachusetts to determine if any updates should be made to the Transformer Savings Tool. As part of that study the transformer vendor who provided the 2018 baseline pre-TP1 no load losses used in NGrid's Transformer Savings Tool shared an updated table of pre-TP1 NLL based on additional transformers they have metered. Table 2-8 compares the original 2018 pre-TP1 NLL provided by the vendor to the new data set. The new data set includes the original 2018 data plus additional metering; therefore, the MA PA Transformer Savings Tool study is recommending that the tool baseline NLL be updated to reflect the larger data set.

.

Table 2-8. Baseline No Load Losses

Size kVA	2018 Tool NLL watts	Updated Data Set watts	New Set to 2018 Ratio
15	-*	297	-
30	403	452	112%
45	598	652	109%
75	835	854	102%
112.5	1,198	1,161	97%
150	1,463	1,506	103%
225	1,744	1,813	104%

*2018 data set did not include NLL for 15 kVA transformers. The tool uses a curve fit to calculate 15 kVA NLL.

The current MA PA Transformer Savings Tool study found that the tool baseline data was reasonable and is only updating the tool to incorporate additional metered data from the vendor; therefore, since the applicant savings in this projected used an appropriate tool with baseline data current at the time, the evaluator has determined that the applicant's baseline NLL were reasonable and should not be adjusted.

RI Energy should adopt the new tool being updated by National Grid and Eversource moving forward. If the new tool is adopted any future evaluations will also agree with the applicant and use the new tool baseline NLL.

2.4.2 Evaluation Calculation Method

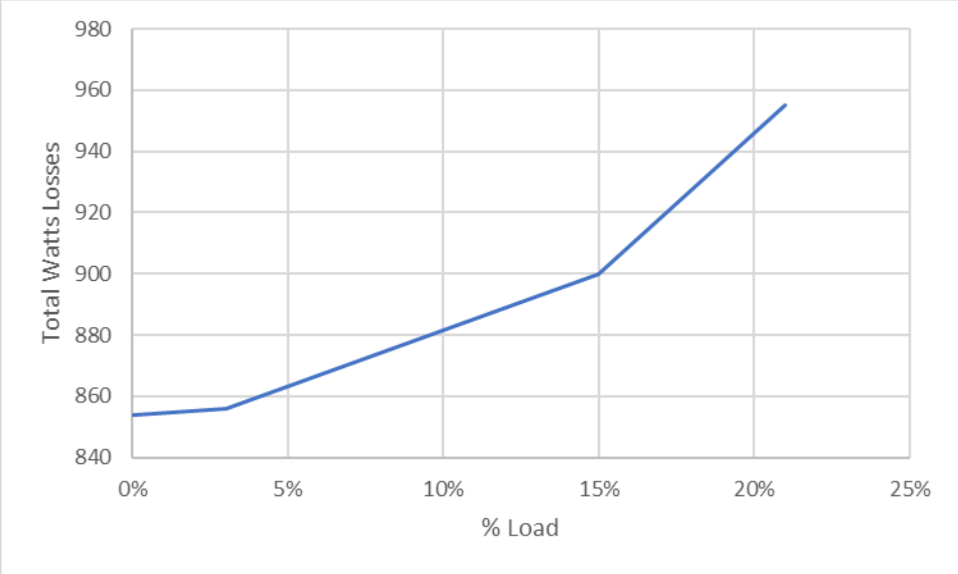
The evaluation used the same calculation approach as the applicant, but the evaluation included the load losses (LL) as described below. The evaluation could have only calculated total losses (NLL & LL), but NLL and LL are broken out separately in order to compare the evaluated calculations to the applicant calculations.

kWh Saved = {(Baseline NLL – Prop NLL) + (Baseline LL – Prop LL)}/ 1,000 watts/kW * 8,760 hours

Baseline Load Losses

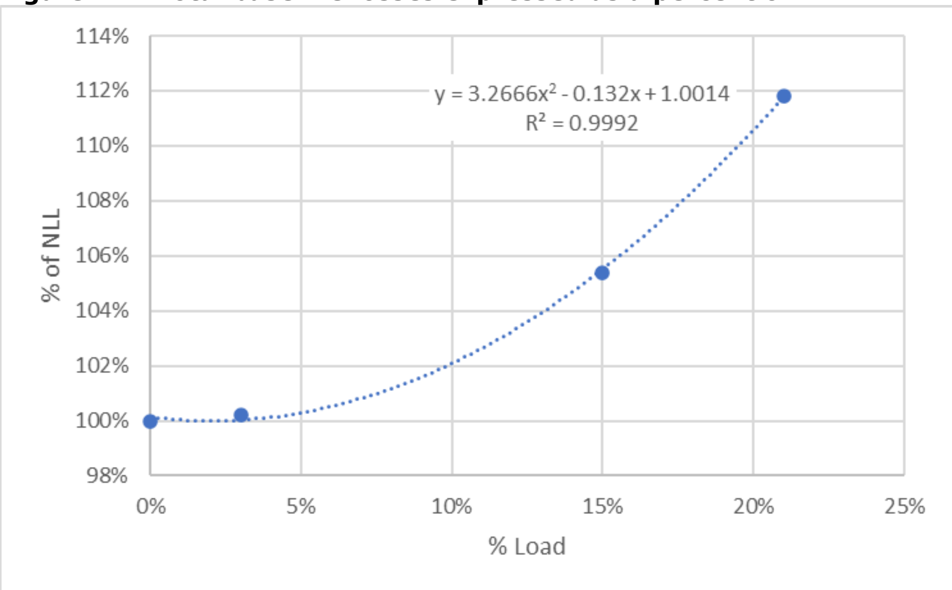
The load losses are dependent on the transformer load. The transformer vendor who provided the baseline NLL data has provided a curve for total losses (NLL & LL) versus percent load for a baseline (pre-TP-1) 75 kVA transformer.

Figure 2-3. 75 kVA baseline (pre-TP-1) total losses



In order to determine the total losses for all transformer sizes, the 75 kVA losses were calculated as a ratio of the NLL as shown in Figure 2-3. This relationship is assumed to apply to all transformer sizes.

Figure 2-4. Total baseline losses expressed as a percent of NLL



The percent load for each transformer is based on the long-term metered data. The percent load for the metered transformers 1, 2, 3, 4 & 8 is shown in Table 2-7. The percent load for the other 11 transformers is the average of the five metered units. The load losses are the total losses calculated from **Figure 2-3** minus the NLL discussed in Section 2.4.1.

Table 2-9. Baseline load losses

ID	Size	Avg % Load	Total (% of NLL)	Total Losses Watts	Load Losses watts
1	45	15%	106%	689	37
2	30	13%	104%	469	17
3	45	8%	101%	661	8
4	30	12%	103%	466	13
8	15	43%	155%	459	162
Other 11 units	6 x 30 2 x 45 2 x 75 1 x 112.5	18%	108%	30 kVA – 491 45 kVA – 707 75 kVA – 927 112.5 kVA – 1,260	30 kVA – 38 45 kVA – 55 75 kVA – 72 112.5 kVA – 98

Installed Losses

The evaluator attempted to meter the input and output of installed transformers to determine the installed transformer losses. Input and output power for transformer #2 was metered and the losses are ~2% of the input power. Separate meters were used for the input and output measurements and each meter has an accuracy of ~0.5%. Due to the low losses (~2%) of the installed high efficiency transformer even a meter accuracy of 0.5% can have a big percent impact on the calculated losses.

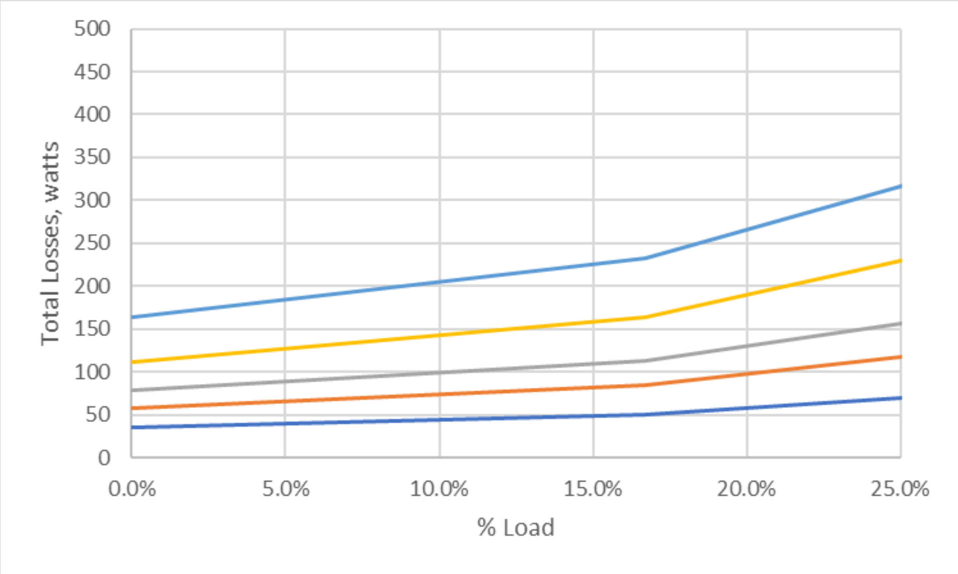
Additionally, the high efficiency transformer results in an ~80% reduction in losses (proposed losses is 20% of baseline losses); therefore, even a 5% change in the installed losses will only result in a 1% change in savings (5% of 20% = 1%).

Due to the concerns with meter accuracy and the lack of sensitivity of installed losses to the savings the evaluator determined that the best approach for calculating savings is to use the same approach as the applicant and use manufacturer's performance data to calculate the installed transformer losses. The applicant used manufacturer's data for the NLL and the evaluator used the same data for the NLL (see Table 2-5) as well as additional manufacturer's performance data for LL (see Figure 2-4).

Installed Transformer Load Losses

Manufacturer's performance curves were used to determine the installed transformer load losses as a function of metered loading. The manufacturer provided performance curves for total losses for each model / size of the installed transformers; they are shown in Figure 2-4.

Figure 2-5. Installed total losses



Similar to the baseline, the metered % load was used along with the manufacturer's performance curve to calculate the installed transformer total losses and the load losses are the total losses minus the NLL. The NLL in Table 2-10 are the same as the applicant values in Table 2-5.

Table 2-10. Installed load losses

ID	Size	Avg % Load	Total Losses Watts	NLL watts	Load Losses watts
1	45	15%	105	78	27
2	30	13%	71	57	14
3	45	8%	85	78	7
4	30	12%	69	57	12
8	15	43%	141	35	106
Other 11 units	6 x 30 2 x 45 2 x 75 1 x 112.5	18%	30 kVA – 88 45 kVA – 118 75 kVA – 171 112.5 kVA – 241	30 kVA – 57 45 kVA – 78 75 kVA – 111 112.5 kVA – 164	30 kVA – 31 45 kVA – 40 75 kVA – 60 112.5 kVA – 77

A summary of the evaluated savings calculations is shown in Table 2-11.

Table 2-11. Evaluated savings calculations

Size kVA	Qty	Baseline		Proposed		Run Hours	Saved kWh
		NLL	LL	NLL	LL		
15	1	229	125	35	106	8,760	1,858
30	8	403	29	57	26	8,760	24,409
45	4	566	34	78	29	8,760	17,281
75	2	860	73	111	60	8,760	13,346
112.5	1	1,168	99	164	77	8,760	8,979
Total	**16**	**8.6 kW**	**0.7 kW**	**1.2 kW**	**0.6 kW**	**8,760**	**65,873**

% On-Peak Savings and Peak Demand Reduction

The evaluator agrees with the applicant that NLL savings are the same for each hour of the year. The evaluator found the transformer percent load and associated LL are not dependent on the hour of the day or day of the week (see Table 2-12); therefore, the LL are also consistent for each hour of the year. Since both the NLL and LL savings are the same for each hour of the year, the percent % on-peak energy savings is 45.4% and the summer and winter peak demand reduction are 7.5 kW (see Table 2-11).

Table 2-12. Example of metered percent load profile

Hour	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
0	9.0%	8.5%	8.8%	9.4%	9.3%	8.9%	8.7%
1	8.4%	8.2%	8.2%	9.1%	8.9%	8.4%	8.5%
2	8.4%	8.1%	8.2%	9.1%	8.8%	8.5%	8.5%
3	8.3%	8.1%	8.1%	9.0%	8.5%	8.4%	8.4%
4	8.2%	7.9%	8.0%	8.8%	8.4%	8.2%	8.3%
5	8.2%	7.9%	7.8%	8.8%	8.4%	8.2%	8.3%
6	8.4%	8.1%	8.0%	9.0%	8.7%	8.5%	8.5%
7	8.5%	8.2%	8.1%	8.8%	8.6%	8.3%	8.6%
8	8.1%	8.2%	7.6%	8.3%	7.9%	8.1%	8.1%
9	7.4%	7.5%	7.4%	7.7%	7.2%	8.1%	7.3%
10	8.0%	7.5%	8.0%	8.1%	7.9%	8.7%	7.8%
11	8.8%	8.1%	8.8%	8.9%	8.6%	9.2%	8.7%
12	8.6%	8.3%	8.5%	8.7%	8.1%	9.0%	8.8%
13	8.1%	7.7%	7.9%	7.9%	7.7%	8.3%	7.9%
14	7.9%	7.6%	8.3%	8.1%	7.7%	8.4%	7.8%
15	8.3%	7.8%	9.0%	8.6%	8.2%	8.7%	8.5%
16	7.9%	7.7%	8.7%	8.1%	7.8%	8.2%	8.1%
17	7.1%	7.3%	8.0%	7.8%	7.2%	7.7%	7.4%
18	7.7%	7.8%	8.7%	8.3%	7.9%	8.4%	8.1%
19	7.7%	7.9%	8.7%	7.9%	8.1%	8.0%	8.2%
20	7.7%	7.8%	8.7%	8.1%	8.2%	8.0%	8.2%
21	8.0%	8.1%	9.2%	9.1%	8.4%	8.4%	8.4%
22	8.9%	9.0%	9.9%	9.3%	8.7%	9.3%	8.9%
23	8.7%	9.0%	9.6%	9.4%	9.0%	9.1%	8.9%

3 FINAL RESULTS

This section summarizes the evaluation results determined in the analysis above and includes a summary table of savings by major end-use and application.

Table 3-1. Summary of key parameters

Parameter	BASELINE		PROPOSED / INSTALLED	
	Tracking Value(s)	Evaluation Value(s)	Tracking Value(s)	Evaluation Value(s)
Quantity	16	16	16	16
NLL	8.6 kW	8.6 kW	1.2 kW	1.2 kW

LL	0.0 kW	0.7 kW	0.0 kW	0.6 kW
Hours	8,760	8,760	8,760	8,760

3.4 Explanation of Differences

The evaluated savings are 1.5% greater than the tracking savings due to including the linear losses.

Table 3-2. Summary of deviations

Measure	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
M1	Applicant Calculation Methodology – Analysis methodology	Load Losses	1.5%	The evaluator included baseline and proposed load losses, which lead to an increase in savings.
Final RR				**1.5%**

3.5 Lifetime Savings

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

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

where:

LAGI = lifetime adjusted gross impact (kWh)

FYS = first-year savings (kWh)

EUL = measure life (years)

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

Table 3-3. Lifetime savings summary

Factor	Tracking	Application	Evaluator
Lifetime savings	1,623,150 kWh	1,623,150 kWh	1,646,818 kWh
First year savings	64,926 kWh	64,926 kWh	65,873 kWh
Measure lifetime	25 years	25 years	25 years
Baseline classification	N/A	N/A	Retrofit

3.5.1 Ancillary impacts

There are no ancillary impacts associated with the measure.

RI CUSTOM ELECTRIC EVALUATION SITE-SPECIFIC REPORT

DNV SITE ID: 2021-RICE21-N120

Report Date: 29 November 2023

Application ID(s)	12730322	
Project Type	C&I Initial Purchase & End of Useful Life	
Program Year	2021	
Evaluation Firm	DMI	
Evaluation Engineer	Tadgh Murphy	
Senior Engineer	Mickey Bush	

1 EVALUATED SITE SUMMARY AND RESULTS

The site consists of 14 elementary schools, 2 middle schools, and 2 high schools for 18 total schools. The project is to install 1,200 ENERGY STAR certified air purifiers. These were installed in K-12 schools across a Rhode Island school district. The measure saves energy by using air purifiers with higher efficiency than the baseline. There are no other fuel savings other than electric. This site is an operational evaluation because the site's occupancy and use are not currently affected by COVID and the site contact was able to accommodate an on-site evaluation with full M&V.

Table 1-1. Evaluation Results Summary

PA Application ID	Measure Name		Annual Electric Energy (kWh)	% of Energy Savings On-Peak	Summer On-Peak Demand (kW)	Winter On-Peak Demand (kW)
Totals	High efficiency air purifier	Tracked	295,369	25%	26.7	14.2
		Evaluated - ops	46,396	69%	5.15	5.30
		Realization Rate	16%	43%	19%	37%

RR = Realization rate
NR = Not reported by program
N/A = Not applicable

1.1 Explanation of Deviations from Tracking

The evaluated savings are less than the applicant reported savings primarily due to the assumption in the applicant's calculations that the air purifiers will always be operating at full load and the applicant not modelling the correct flow rate and performance of the installed units.

1.2 Recommendations for Program Designers & Implementers

The evaluator recommends confirming that the modelled units are the units actually installed. This application modelled one type of air purifier that did not match what was ultimately installed. Project savings should have been updated post-installation to match the units actually used.

Saving should also be adjusted for partial load operation in future air purifier projects.

For verifying large quantities of installations, the post inspector should take a complete count of all units in a sample of places rather than a partial count of units in all places. Taking only a partial count will not confirm the required quantity of units for any place.

This project has a low realization ratio, mainly because the applicant's tool failed to account for the ability of both installed and baseline units to operate at a part load. It was reasonable for the program administrator to accept the applicant's calculation approach because the applicant used a DOE/ EPA savings calculator tool. However, in the future, this evaluation may serve as the basis for an estimate of part load operation of air purifier units.

1.3 Customer Alert

The customer has not requested a copy of the final site report.

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. Table 2-1 summarizes the measures evaluated for this site.

Table 2-1. Measure description

Measure	Project ID	Parameter
M1	12730322	Installation of 1,200 high-performance air purifiers.

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.

2.2 Applicant Description of Baseline

The applicant measure event type is lost opportunity – initial purchase. The baseline performance values come from an EPA and DOE savings calculator for air purifiers which provided default baseline unit standby power and efficiency. Standby power is measured in watts while efficiency is in cfm/watt. These values make use of applicant inputted unit CADR (clean air delivery rate) in cfm and annual unit run hours. In the table below only the CADR and run hours are applicant inputs. Other values are defaults of the tool. The unit CADR value does not match the capacity of the units actually installed. The source of the applicant flow capacity is unknown.

Table 2-2. Applicant baseline key parameters

		BASELINE		
Measure	**Parameter**	**Value(s)**	**Source of Parameter Value**	**Note**
M1	Quantity	1,200 Units	Applicant Input	
M1	CADR (Clean air delivery rate)	338 CFM	Applicant Input	
M1	Air purifier efficiency	2 CFM/Watt	Saving Calculator default	
M1	Standby Power	2 Watt	Saving Calculator default	
M1	Annual Run Hours	2,780 Hours	Applicant Input	

2.2.1 Applicant Description of Installed Equipment and Operation

There were 1,200 ENERGY STAR certified air purifiers installed across 18 school buildings. The source of the applicant modelled input air purifier flow capacity and efficiency are unknown; they cannot be found in any other application documents nor do they match the units observed by the evaluator on site.

Table 2-3. Application proposed key parameters

		Installed		
Measure	**Parameter**	**Value(s)**	**Source of Parameter Value**	**Note**
M1	Quantity	1,200	Applicant input	
M1	CADR (Clean air delivery rate)	338 CFM	Applicant input	This number is only ever referenced in the savings calculator.
M1	Air purifier efficiency	4.1 CFM/Watt	Applicant Input into Savings Calculator	This number is only ever referenced in the savings calculator.
M1	Standby Power	1.1 Watt	Saving Calculator default	
M1	Annual Run Hours	2,780 Hours	Applicant Input	

2.2.2 Applicant Energy Savings Algorithm

The savings algorithm source is an EPA and DOE savings calculator for ENERGY STAR certified devices. The inputs to the calculator are the flow capacity, efficiency, run time of the proposed equipment, and quantity of equipment.

The applicant estimates annual hours with hours per day (10) and days per year (278):

$$t = \frac{hours}{day} * \frac{days}{year}$$

Where:

t = Annual hours of operation

While no source for 278 days/year is available, it appears to include some operation during breaks and weekends.

The baseline operating and standby power usage were found as follows:

$$O_{baseline} = t * \frac{\left(\frac{C}{eff_{baseline}}\right)}{1000\,Watt/kW}$$

$$S_{baseline} = \frac{(8{,}760 - t) * P_{baseline}}{1000}$$

Where:

$O_{Basline}$ = Baseline operating energy (kWh/year)
$S_{Baseline}$ = Baseline standby energy (kWh/year)
C = Capacity (CFM)
$eff_{Baseline}$ = Baseline efficiency (CFM/Watt)
$P_{Baseline}$ = Baseline standby power (Watt)

To find the energy usage of the installed equipment:

$$O_{Installed} = t * \frac{\left(\frac{C}{eff_{Installed}}\right)}{1000\,Watt/kW}$$

$$S_{Installed} = \frac{(8{,}760 - t) * P_{Installed}}{1000}$$

Where:

$O_{Installed}$ = Installed operating energy (kWh/year)
$S_{Installed}$ = Installed standby energy (kWh/year)
C = Capacity (CFM)
$eff_{Installed}$ = Installed efficiency (CFM/Watt)
$P_{Installed}$ = Installed standby power (Watt)

The total savings are found by subtracting the installed energy from the baseline energy and multiplying by the quantity of installed units:

$$Savings = [(O_{baseline} + S_{baseline}) - (O_{Installed} + S_{Installed})] * n$$

Where:

n = Quantity

A summary of the applicant saving calculations is below.

Table 2-4. Applicant savings calculations

Modelled Case	Qty	Operating				Standby			Total kWh
		Operating Hours	cfm	Cfm/Watt	kWh	Watts	Hours	kWh	
Baseline	1,200	2,780	338	2.0	563,784	2.00	5,980	14,352	578,136
Installed	1,200	2,780	338	4.1	275,017	1.08	5,980	7,750	282,767
Savings	0	0	0	2.1	288,767	0.92	0	6,602	295,369

The calculations for % on-peak and peak kW demand reduction are unknown because there are no calculations to support the values. The tracked values for % on-peak are 25%, summer peak demand reduction of 26.7 kW, and winter peak demand reduction of 14.2 kW.

2.2.3 Evaluation Assessment of Applicant Methodology

The application documents indicated that there were two different model units actually installed, both of which have different specifications than the modelled inputs. The savings calculations should have accounted for the different units purchased.

The applicant assumed that each unit (baseline and installed) will only ever operate at its design CADR. No adjustment was made to reflect that many units operate at a part load.

2.3 On-site Inspection and Metering

The site visit was conducted on October 5, 2022 where meters were installed to track the energy usage of a random sample of air purifiers across two elementary schools, one middle school, and one high school. In total 27 plug load loggers recording at 15-minute intervals were used, with 4 at each of the elementary schools, 9 in the middle school, and 10 in the high school. The meters were retrieved on January 4, 2023 such that the data includes both normal school days, weekends, and breaks. A spot measurement of the fan power of one unit at different fan speed settings was also taken, see Figure 2-1.

2.3.1 Summary of Site Visit

The site contact was the facility operations manager for the entire district; she was not able to be present for the site visit. The contact explained in an interview that each unit will operate as the faculty and staff wished, but were consistently turned off during after-school hours by the janitorial staff. Each classroom had 2-3 units and office spaces would often, but not always, have 1 unit. As a result, the logged run hours vary widely among the units metered.

Most project documents do not include unit counts for each school in the district, and instead only count the total number installed across the district; 1,200 units. This is the quantity of units that the savings analysis uses. However, each school has its own MRD with a specific unit count. The sum total of all the units in the MRDs is 1,291 units. The source of the 91 unit surplus is unknown because no other project documents provide school-by-school unit counts.

To verify the installed count for the whole district, a full count was performed at each visited school and compared to the count indicated by that school's MRD. This verification method differs from the post inspection method of verifying only 20% of units from every school. A 20% sample of every school will not verify the total quantity of any school, so a total count of some schools was performed instead and generalized for the whole district.

The observed count is generally equal to the accepted count used in the evaluation analysis and the amounts used in the ex-ante estimate of savings and the invoiced total. The number of installed units accepted by the evaluator for schools not visited was estimated. Any % difference between the observed count and the MRD count for a particular school type was applied to other schools of that type not visited. For example, there is a 15% difference between what was observed in High School 2 and High School 2's MRD, so a 15% penalty was applied to High school 1's MRD count. This methodology resulted in an evaluator accepted count equal to that of the applicant's other project documents because the surplus 91 units of the MRD were exactly penalized out during the site visit unit counting.

Table 2-4. Unit count verification

School	Visited?	MRD Count	Observed Count	Accepted Count	=1-(Accepted/MRD)
Elem 1	No	61	-	61	0%
Elem 2	Yes	41	41	41	0%
Elem 3	No	55	-	55	0%
Elem 4	No	46	-	46	0%
Elem 5	No	52	-	52	0%
Elem 6	No	46	-	46	0%
Elem 7	No	66	-	66	0%
Elem 8	No	51	-	51	0%
Elem 9	No	47	-	47	0%
Elem 10*	Yes	43	42	43	0%
Elem 11	No	52	-	52	0%
Elem 12	No	47	-	47	0%
Elem 13	No	51	-	51	0%
Elem 14	No	44	-	44	0%
Middle 1**	No	6	-	6	0%
Middle 2	Yes	165	136	136	18%
High 1***	No	217	-	185	15%
High 2	Yes	201	171	171	15%
Sum****	-	1,291	-	1,200	7%

* The accepted count for Elementary School #10 is equal to its MRD count and not its observed count for two reasons. The first reason is that the similar Elementary School #2 had its observed count match its MRD count exactly. The second reason is that the discrepancy between Elementary School #10's observed count and its MRD count is only a single unit. The evaluator may have missed a unit during the walkthrough of Elementary School #10, so the MRD count was determined to be acceptable.

**Because only six units were expected to be installed in Middle School #1, Middle School #2 was not deemed to be similar to Middle School #1. Middle School #2's 18% difference was not applied to the Middle School #1 MRD count.

***High School #2 was deemed to be similar to High School #1. High School #2's 15% difference was applied to the High School #1 MRD count.

****The accepted sum total for the school district is equal to the invoiced number of units and the number of units used is the same as the tracking estimate of savings.

Table 2-5. Measure verification

Measure Name	Verification Method	Verification Result
M1 – High efficiency air purifier	In person inspection	Total district wide unit quantity was verified, installed unit models matched invoiced unit models. It was not possible to visually distinguish between the two models; the nameplate was obscured against a wall for nearly every unit. The meter data could be used to infer that there were multiple models installed. The project invoice also confirmed that two different models were purchased in a quantity that matches the applicant savings analysis.

Included below are pictures from the site visit.

Image 2-1. Installed unit

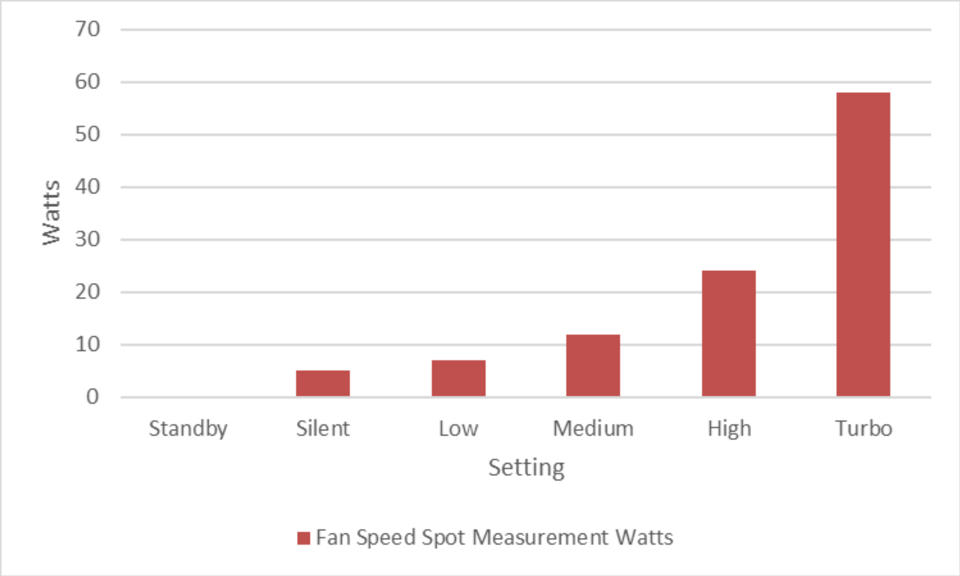
Image 2-2. Visible unit nameplate

When installed on the wall, the unit's nameplate was not visible to the evaluator. The two installed models, SPA-700A and SPA-780A, are indistinguishable by appearance. Image 2-2 shows the nameplate on the back of one unit. Most units were installed on the wall, and nameplate information could not be gathered.

2.3.2 Measured and Logged Data

A spot check of power usage at each fan speed was taken of one unit and is recorded below.

Figure 2-1. Fan speed spot measurement



The model that was spot measured is not definitively known, but is likely the SPA-780A model. Note here that the standby power is 0.5 watts. Standby is a distinct setting that has no fan operation. There is no “off” setting; only standby mode exists. The two installed models have different rated capacities and efficiencies. When operating at its maximum fan speed, the unit model can be inferred by its power. The model SPA-700A has a rated power of 49 watts, while the model SPA-780A has a rated power of 62 watts. This rated power corresponds to the “turbo” fan speed. The long term metered data did show that it is common for units to never operate at full power, and inferring unit model based on power was not possible for every metered unit.

An example logger’s data is summarized below for a unit inferred to be a model SPA-700A. The logger tag is TG-201. The model of this unit was inferred from its maximum metered power. This unit, like many units, spent a significant amount of its operational time at low load. The standby power for this unit is about 0.5 watts, matching the unit’s specifications sheet.

Figure 2-2. Histogram of metered power for one purifier

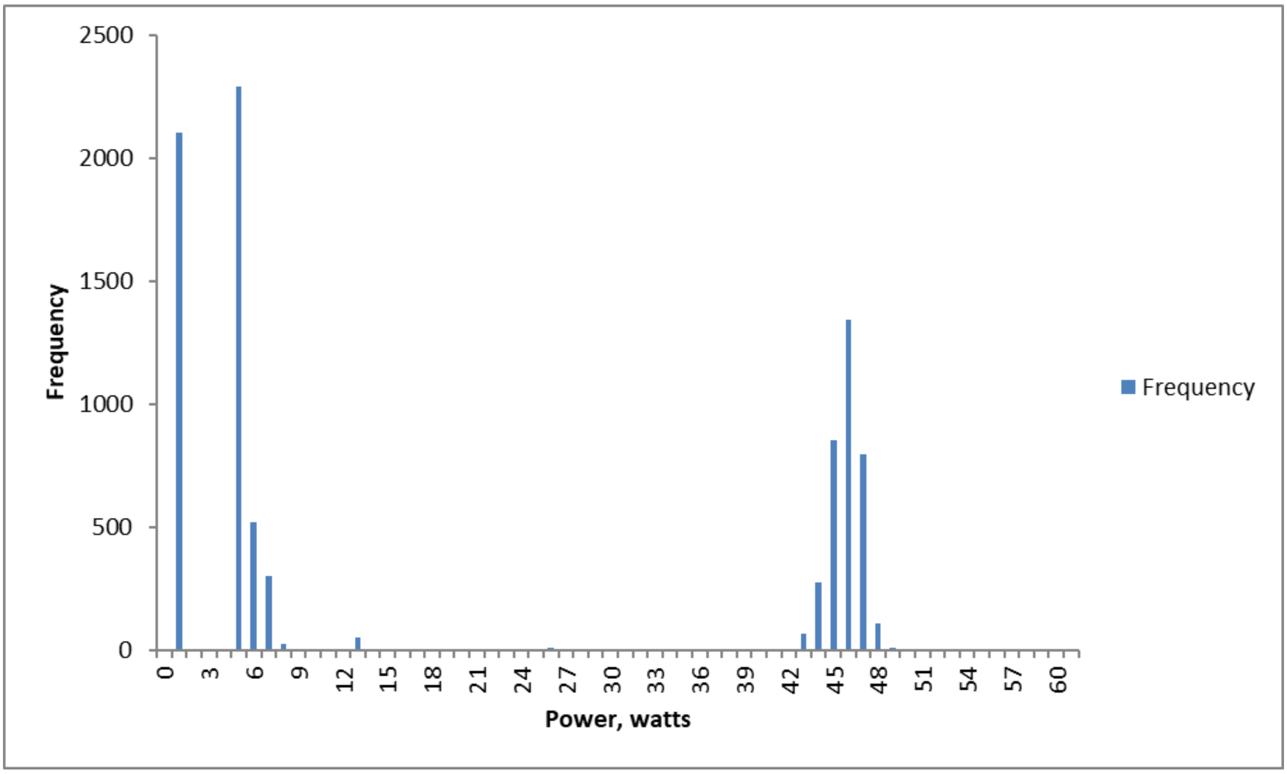
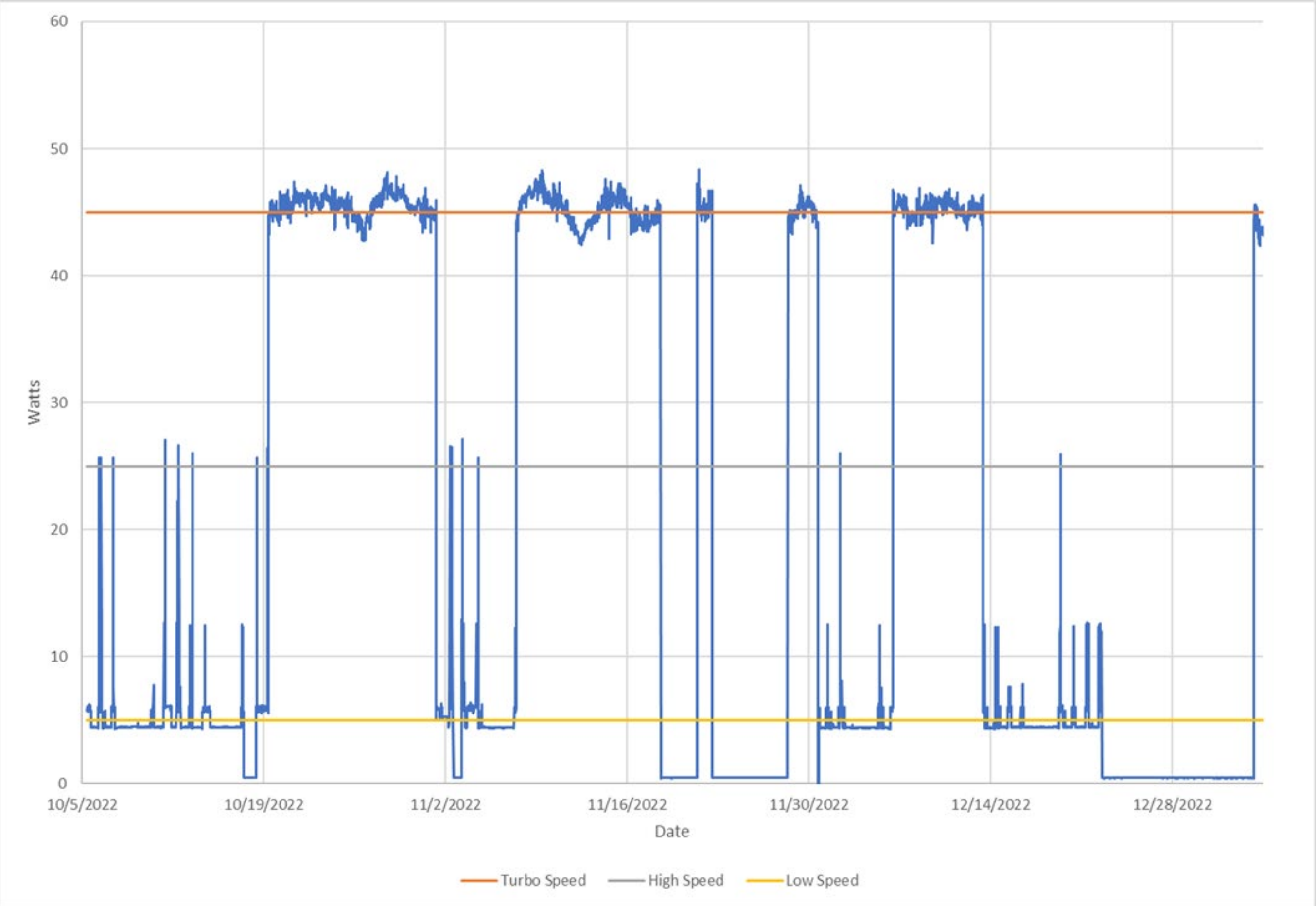


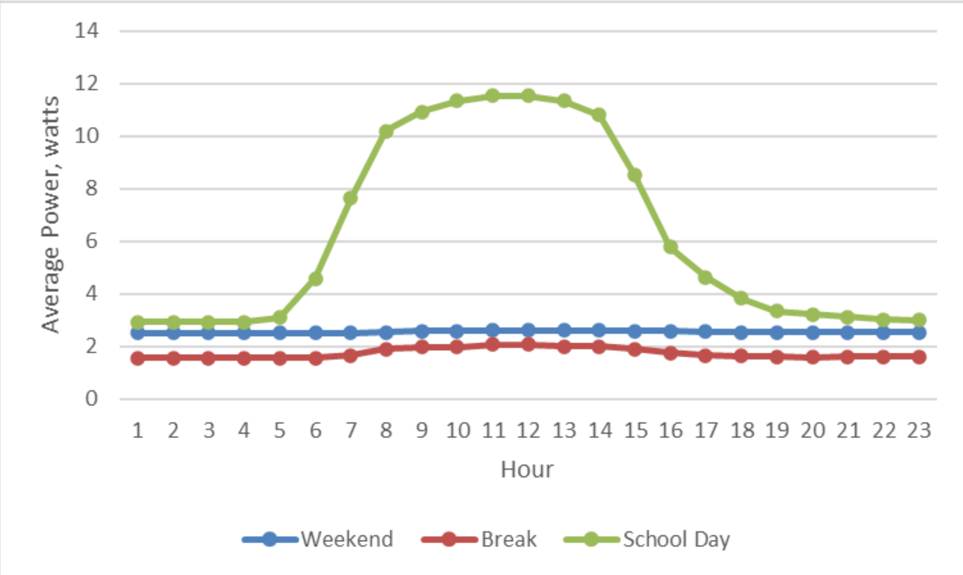
Figure 2-3. Timeseries of power for one purifier



The 3 horizontal lines in Figure 2-3 represent an estimate of turbo, high, and low power at 45, 25, and 5 watts respectively.

It is also important to note the difference in operation between the type of day (either school day, school break, or weekend). Figure 2-4 highlights the difference in operating profile for the different day types. Using the school calendar, the data was split into school days, weekends, and breaks. School days are defined as days in which class is in session, weekends are all Saturdays and Sundays, and breaks constitute weekdays in which there is no class in session. For clarity, Saturdays and Sundays are always considered weekends and never break days, even if there is a long weekend or an extended break from classes. The hourly-averaged power is shown below by the type of day for all meters. No summer break data could be collected, so most summer break operation was assumed to be identical to that of other breaks that were metered (i.e. thanksgiving and winter break). However, summer school, considered separately from summer break, was considered as operation "partway between" a full school day and a break day. See section 2.4.2 for more detail.

Figure 2-4. Average power by time of day



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 and classifies the measure as lost opportunity initial purchase. The evaluator reviewed the project files and did research into possible baselines for this measure. The Rhode Island TRM includes a measure for air cleaners that references the applicant's calculator. The TRM only has a deemed savings value, and does not explicitly define baseline unit performance.

The evaluator did market research to confirm the features of a baseline unit. The Association of Home Appliance manufactures maintains a directory of approximately 600 air purifiers both with and without ENERGY STAR certification. A random sample of 10 non-certified units in the directory all had at least three different operating fan speeds in addition to standby mode. There were no sampled units with more than 5 speeds. This confirms that a baseline unit has the ability to operate at part-load power. However, the directory does not contain information on the rated full speed power or efficiency of a baseline unit; therefore baseline efficiency could not be determined from the market research.

The ENERGY STAR minimum standard for air purifier certification is not measured for the same pollutant that the analysis uses. The ENERGY STAR standard is 2.9 cfm/watt for smoke, while the efficiency used in the analysis is the dust rated cfm/watt. Dust is the primary pollutant in the schools, and so the ENERGY STAR minimum performance standard was not used to define the baseline.

The evaluator accepted the applicant baseline unit efficiency from the DOE tool (2.0 cfm/watt dust) but redefined the unit operation to allow for part-load fan speeds. The evaluator also accepts the applicant baseline unit standby power from the DOE tool, 2.0 watts.

2.4.2 Evaluation Calculation Method

The evaluation used the same calculation form as the applicant, but made adjustments for the different installed models and operation at different school types. The formula used by the applicant found in 2.2.2 is duplicated 6 times to differentiate between the two installed model types and the 3 school types (one duplication per pair of model-school combination).

Unit Quantity

It was assumed that there are 600 of each of the two models used, SPA-700A and SPA-780A because it was not possible to distinguish between models during the site visit. This is supported by the invoice for 600 of each model. Because it was not possible to distinguish between models during the site visit, each school is assumed to have 50% of its units be model SPA-700A and 50% of its units be model SPA-780A. See Table 2-6 for the summary of the unit count.

Table 2-6. Unit quantity

School	SPA-700A	SPA-780A	Total
Elem	351	351	702
Middle	71	71	142
High	178	178	356
Total	600	600	1,200

Annual Run Hours

The meter interval represents a greater fraction of break time than is expected for the entire year, so annual purifier run hours cannot be determined directly from extrapolation. Using the school district calendar, each meter's data was separated into school days, weekends, summer school, and break days. Average daily run time for each purifier and each day type was taken to be the fraction of time the meter recorded >3 watts, multiplied by 24 hours/day. Time not spent operational (<3 watts) was assumed to be spent in standby mode. There is no mode that is truly off. Units have only an on (at different possible speeds), and a standby mode.

The school district calendar was used to find the total annual school days, weekends, and break days. The daily run time for each day type was multiplied by the annual days of that type, and summed to estimate each purifier's annual run hours. The summer break period was not metered and was assumed to have an identical runtime fraction as the break days that were metered. No distinction between different breaks was made in this analysis. Summer school, however, was considered as a different day type with operation "partway between" a full school day and a break day.

Summer school was included in only the high schools' operation. Based on an interview with the Principal of Summer School, the high schools were modelled with summer school for 25 days at an average occupancy of 20%. Summer school days displace days otherwise included in the district calendar as break days. Run hours for summer school are the average of a school day's and a break day's, weighted by the occupancy level. School days have a weight of 20% and break days have a weight of 80%.

$$\%_{SS} = (\%_{SD} - \%_B) * 20\% + \%_B$$

Where:

$\%_{SS}$ = Run time percentage (Summer school)

$\%_{SD}$ = Run time percentage (School day)

$\%_B$ = Runtime percentage (Break)

See Table 2-7a and Table 2-7b below for example calculations for two of the metered purifiers one for a school with summer school and one for a school without summer school.

Table 2-7a. Annual run hours for sample purifier without summer school

Day Type	Daily Runtime Fraction	Hours/day	Days/year	Annual Hours
Weekend	23%	5.5	104	576
Break	54%	13.0	81	1,054
School Day	13%	3.2	180	581
Summary	-	-	365	3,136

Table 2-7b. Annual run hours for sample purifier with summer school

Day Type	Daily Runtime Fraction	Hours/day	Days/year	Annual Hours
Weekend	15%	3.7	104	384
Break	0%	0.0	56	0
Summer School	8%	1.9	25	47
School Day	39%	9.4	180	1,683
Summary	-	-	365	2,114

For units with summer school, there are 104 weekend days, 56 break days, 25 summer school days, and 180 school days.

Annual runtime was calculated for each purifier metered, and purifiers belonging to the same school type were averaged together to calculate annual run hours per school type. Table 2-8 shows the annual run hours for each school type and unit. Distinctions between the two unit types could not be made because it was not possible to consistently determine which unit type a logger was metering.

Table 2-8. Annual run hours

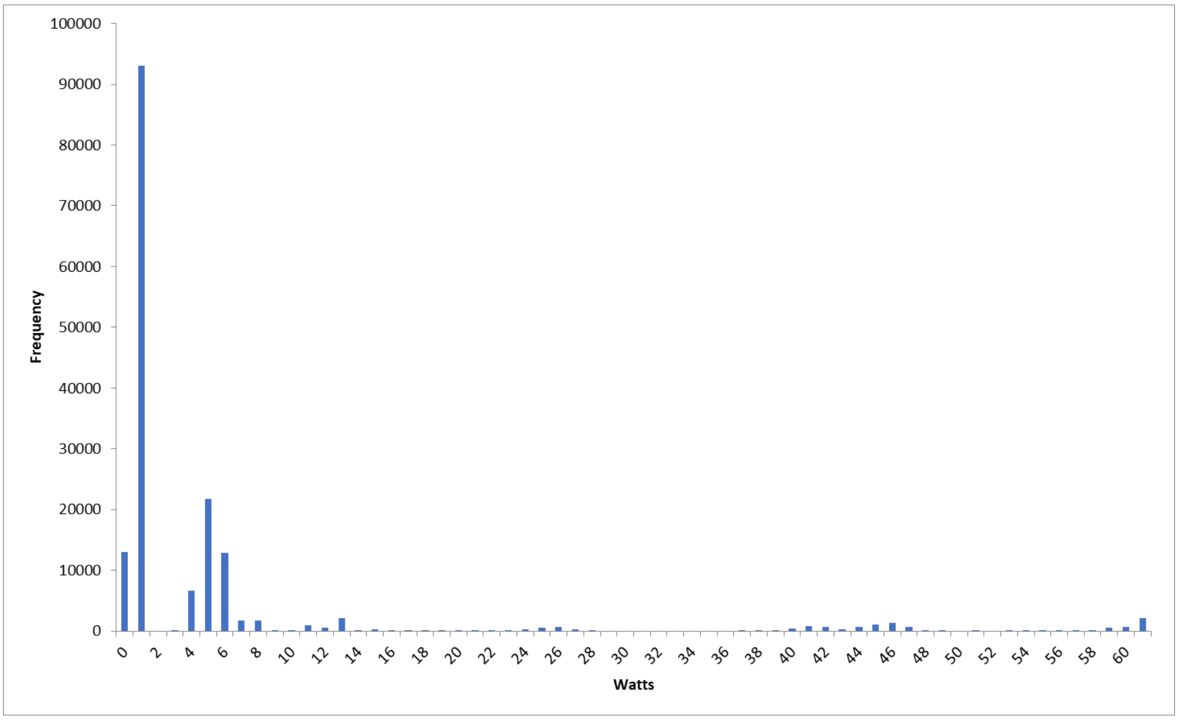
School	SPA-700A	SPA-780A
Elem	2,064	2,064
Middle	2,874	2,874

High	3,656	3,656

Installed Operating and Standby Power

Figure 2-5 details the data logged for every meter and shows that much of the runtime is spent at part-load. Break data was a large portion of the meter period and was largely standby mode, and so was removed from the histogram to better display the operating power of the units. The histogram includes both school day and weekend data. This data serves as the basis for the need to model the units as operating at part load.

Figure 2-5. Histogram of all non-break data



Estimated average operating power and standby power was completed in a manner similar to estimating annual run hours. For each day type and for each purifier metered, both the average operating watts and standby watts were recorded for the metering period. The purifiers' annual average operating and standby power is the average of the three different day types weighted by run hours of each day type. See Table 2-9 for example calculations. These tables are for the same units as in Table 2-7.

Table 2-9a. Average operating and standby power for sample purifier without summer school

Day Type	Annual Hours	Avg Operating watts	Avg Standby watts
Weekend	576	8.0	0.5
Break	1,054	10.1	0.5
School Day	581	9.2	0.5
Summary	2,211	9.3	0.5

Table 2-9b. Average operating and standby power for sample purifier with summer school

Day Type	Annual Hours	Avg Operating watts	Avg Standby watts
Weekend	384	24.0	0.5
Break	0	0.0	0.5
Summer School	47	3.0	0.5
School Day	1,683	15.3	0.5
Summary	2,114	16.6	0.5

Summer school operating power was assumed to be 20% of the difference between school day operating power and break day operating power to model the reduced occupancy of summer school. Similarly, summer school standby power was assumed to be 20% of the difference between school day standby power and break day standby power. These adjustments for summer school operation were only applied to the high schools.

Annual average operating and standby power estimates were completed for each purifier metered, and purifier demand belonging to the same school type were averaged. Table 2-10 shows the operating and standby power for each school type. The data has not been split by model type because it was not possible to consistently distinguish between model types of each metered unit but in this table below the average power for all models is shown for both models listed in the invoices.

Table 2-10. Installed power

School Type	SPA-700A		SPA-780A	
	Operating Watts	Standby Watts	Operating Watts	Standby Watts
Elem	19.4	0.5	19.4	0.5
Middle	10.2	0.4	10.2	0.4
High	11.4	0.4	11.4	0.4

Baseline Operating Power

The ratio of the installed to baseline unit performance is assumed to be the same at all operating speeds assuming that the baseline units modulate at different speeds similar to the installed units. Therefore, the ratio of rated efficiencies is used to calculate the part-load power of the baseline units.

$$Perf\ Factor_{operating} = \frac{eff_{installed}}{eff_{baseline}}$$

The baseline power is the installed power multiplied by the performance factor, which is greater than 1.

$$O_{baseline} = O_{Installed} * Perf\ Factor_{operating}$$

Where:

$O_{baseline}$ = Baseline Operating power (Watts)
$O_{Installed}$ = Installed Operating power (Watts)
$eff_{Installed}$ = Efficiency of installed unit (CFM/Watt)

$eff_{Baseline}$ = Baseline efficiency (CFM/Watt)
$Perf\ Factor_{Operating}$ = Operating Performance factor

Table 2-11 displays the rated efficiencies, performance factor, and baseline operating power.

Table 2-11. Baseline operating power

Units	School	Installed Eff, cfm/watt	Baseline Eff, cfm/watt	Perf Ratio	Installed Operating Power, watts	Baseline Operating Power, watts
SPA-700A	Elem	3.78	2.0	1.9	19.4	36.7
	Middle	3.78	2.0	1.9	10.2	19.2
	High	3.78	2.0	1.9	11.4	21.5
SPA-780A	Elem	3.27	2.0	1.6	19.4	31.7
	Middle	3.27	2.0	1.6	10.2	16.7
	High	3.27	2.0	1.6	11.4	18.6

Baseline Standby Power

The same adjustment was also made for baseline standby power:

$$Perf\ Factor_{standby} = \left(\frac{P_{applicant\ baseline}}{P_{ES}}\right)$$

$$P_{baseline} = P_{Installed} * Perf\ Factor_{standby}$$

Where:

$P_{Baseline}$ = Baseline standby power (Watts)
$P_{Installed}$ = Installed standby power (Watts)
P_{ES} = Standby power from ENERGY STAR specifications sheet (Watt)
$P_{applicant\ baseline}$ = applicant rated baseline standby power (Watt)
$Perf\ Factor_{standby}$ = Standby Performance factor

Table 2-12 displays the rated baseline standby power, performance factor, and baseline standby power.

Table 2-12. Baseline standby power

Units	School	Installed Rated Standby watts	Baseline Rated Standby watts	Perf Factor	Installed Standby watts	Baseline Standby watts
SPA-700A	Elem	0.46	2.0	4.3	0.5	2.0
	Middle	0.46	2.0	4.3	0.4	1.9
	High	0.46	2.0	4.3	0.4	1.9
SPA-780A	Elem	0.5	2.0	4.0	0.5	1.8
	Middle	0.5	2.0	4.0	0.4	1.8
	High	0.5	2.0	4.0	0.4	1.7

Savings Calculations

Savings were calculated with the same formula as the applicant, but with the evaluation sets of baseline and installed operating and standby power, evaluation unit quantity, and annual run hours. A table of calculations is presented in Table 2-13.

Table 2-13. Table of savings calculations

Type		Annual Standby Hours	Annual Operating Hours	Installed					Baseline							Unit Qty	Savings kWh
				Metered Operating		Metered Standby		Total kWh	Operating			Standby			Total kWh		
Unit	School			Watts	kWh	Watts	kWh		Perf Factor	Watts	kWh	Perf Factor	Watts	kWh			
SPA-700A	Elem	6,696	2,064	19.4	40	0.5	3	43	1.9	36.7	76	4.3	2.0	13	89	351	16,081
	Middle	5,886	2,874	10.2	29	0.4	3	32	1.9	19.2	55	4.3	1.9	11	67	71	2,476
	High	5,068	3,692	11.3	42	0.4	2	44	1.9	21.4	79	4.3	1.9	10	89	178	7,931
SPA-780A	Elem	6,696	2,064	19.4	40	0.5	3	43	1.6	31.7	65	4.0	1.8	12	78	351	12,128
	Middle	5,886	2,874	10.2	29	0.4	3	32	1.6	16.7	48	4.0	1.8	11	58	71	1,881
	High	5,068	3,692	11.3	42	0.4	2	44	1.6	18.5	68	4.0	1.7	9	77	178	5,899
Summary		6,128	2,632	14.9	39	0.4	3	42	1.8	26.2	69	4.2	1.9	11	81	1200	46,396

% On-Peak Savings

Operating hours were assumed to only occur during on-peak hours because the total number of on-peak hours are less than the modelled operating hours. The difference between total annual on-peak hours and operating hours is the on-peak standby hours. On-peak kWh were calculated as the sum of the on-peak operating and standby energy. Here the 3,980 represents the total number of on-peak hours in the year.

$$Operating\ on\ peak\ savings = \frac{H * (W_{baseline} - W_{Installed}) * n}{1000}$$

$$Standby\ on\ peak\ savings = \frac{(3{,}980 - H) * (P_{standby} - P_{Installed}) * n}{1000}$$

Where:

H = On-peak operating hours
$W_{Baseline}$ = Baseline operating power (Watts)
$W_{Installed}$ = Installed operating power (Watts)
$P_{Standby}$ = Baseline standby power (Watts)
$P_{Installed}$ = Installed standby power (Watts)
n = Quantity

The percentage on-peak savings is the ratio of the on peak kWh savings to the total kWh savings.

$$peak\ \% = \frac{Operating\ savings + Standby\ savings}{Total\ savings}$$

Summer and Winter Peak kW Savings

The summer super peak periods are weekdays (excluding holidays) from 1PM to 5PM, and the winter summer peak periods are weekdays (excluding holidays) from 5PM to 7PM. Fraction of time that each metered purifier was running during those periods was recorded for both break and school days. All school days are assumed to have similar operating profiles regardless of the time of year, as are break days. Table 2-14 below shows a summary of the peak period runtime fractions:

Table 2-14. Super Peak Period Runtime Fraction

School	Summer Super Peak Period, 1PM-5PM		Winter Super Peak Period, 5PM-7PM	
	School Day	Break Day	School Day	Break Day
Elem	83%	4%	25%	4%
Middle	43%	33%	37%	34%
High	59%	24%	44%	24%

Using the kWh savings analysis wattage values, the demand of the baseline and the installed case for both school days and break days and for each school type was calculated according to the following formula:

$$peak\ kW = (r * n * W) + ((1 - r) * n * P)$$

Where:

r = Peak period run fraction (for each combination of: day type, baseline/installed, and school type), %
n = installed units
W = Operating power (kW)
P = Standby power (kW)

Peak kW savings were calculated for both school days and break days and for each school as the difference between baseline and installed. Savings were summed across all school types.

$$kW\ savings_{day\ type} = \sum_{school\ type} Peak\ kW_{baseline} - Peak\ kW_{installed}$$

The average peak period savings are the average of break day savings and school day savings, weighted by the count of each day type that has a peak period.

Table 2-15. Super Peak kW Savings

	Summer	Winter
Baseline	20.42	5.99
Installed	11.26	2.77
Savings	9.16	3.22

3 FINAL RESULTS

This section summarizes the evaluation results determined in the analysis above and includes a summary table of savings by major end-use and application.

Table 3-1. Summary of key parameters

Parameter	BASELINE		PROPOSED / INSTALLED	
	Tracking Value(s)	Evaluation Value(s)	Tracking Value(s)	Evaluation Value(s)
Annual Hours	2,780	2,632	2,780	2,632
Operating Power	169.0	26.3	82.4	14.9
Standby Power	1.1	1.9	2.0	0.4

3.4 Explanation of Differences

The applicant modelled a larger (in terms of cfm) and more efficient unit than was actually installed. Overestimating the cfm increased the baseline energy, and overestimating the installed unit efficiency increased the difference between installed and baseline power. However, the main driver of the low realization rate is the part load operating power. The application assumed that all operating hours were at full power, but the metered data did not support this assumption. Both of these errors affect the operating power in the model. To avoid double-counting savings losses from decreased operating power, the total kWh impact from decreased operating power was shared between the two errors.

A lower annual operating hours value was used by the evaluation, which decreased savings.

The drivers of the differences in on-peak %, summer kW savings, and winter kW savings are unknown because the applicant algorithm for calculating these values is not provided in the applicant documentation.

Table 3-2. Summary of deviations

Measure	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
M1	Hours of Operation	Annual Hours	-3.3%	The evaluator found the annual hours to be less than the applicant's. This reduced the hours for savings to occur.
M1	Pre-Project Error	Correct installed Unit	-34.2%	The applicant modeled units with larger CADR in both the baseline and installed cases as well as better CADR/watt installed efficiency than what was actually observed on site. Correcting to smaller, less efficient installed units decreased savings.
M1	Operating Load	Part Load Operating Power	-47.7%	The evaluator found the operating power to be less than the applicants. This decreased the difference between baseline and installed operating power.
M1	Analysis Methodology	Standby Power	+0.8%	The evaluator found the standby power to be less than the applicants. This increased the difference between baseline and installed standby power to increase savings.
Final RR				**15.7%**

3.5 Lifetime Savings

Because the measure is New Construction and is classified as a lost-opportunity single-baseline measure, the out-year factor is 100%. The evaluators calculated applicant and evaluated lifetime savings values using the following formula:

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

where:

LAGI = lifetime adjusted gross impact (kWh)
FYS = first-year savings (kWh)
EUL = measure life (years)
RUL = 1/3 of EUL (years)
Out-year % = 100% for this single-baseline measure

The evaluated lifetime savings are smaller than the tracking lifetime savings because the evaluated first-year savings are smaller than the tracking first-year savings. The annual savings loss is partially offset due to the evaluation using a longer measure life. The evaluation measure life is found in the Rhode Island TRM for air cleaners. The source of the applicant measure life is unknown. Table 3-3 provides a summary of key factors that influence lifetime savings.

Table 3-3. Lifetime savings summary

Factor	Tracking	Application	Evaluator
Lifetime savings	1,772,214 kWh	1,772,214 kWh	417,564 kWh
First year savings	295,369 kWh	295,369 kWh	46,396 kWh
Measure lifetime	6 years	6 years	9 years (RI TRM)
Baseline classification	N/A	N/A	Add-on single

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

3.5.1 Ancillary impacts

There are no ancillary impacts associated with the measure.