FINAL REPORT

Impact Evaluation of PY2022 Custom Gas Installations in Rhode Island

RI Energy

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List of acronyms used in this report

CDA	comprehensive design approach
C&I	commercial and industrial
CI	confidence interval
EMS	energy monitoring system
HVAC	heating, ventilation, and air conditioning
ISP	industry standard practice
M&V	measurement and verification
MA	Massachusetts
MBSS	model-based statistical sampling
PA	program administrator
PY	program year
PY2021	program year 2021
PY2022	program year 2022
PY2022	program year 2022
RI	Rhode Island
RR	realization rate
SEMP	strategic energy management partnership
ST, non-ST	steam trap, non-steam trap
TMY3	typical meteorological year 3

1 INTRODUCTION

This section presents the objective and describes the organizational format for DNV's report of the Impact Evaluation Program Year (PY) 2022 Custom Gas Installations for RI Energy (RIE).

1.1 Study purpose and objectives

The objective of this impact evaluation for program year 2022 (PY2022) Custom gas installations is to provide verification or re-estimation of energy (therms) savings for sampled custom gas sites through site-specific inspections, end-use monitoring, and analysis. Site-specific results were aggregated to determine realization rates (RR) for RI Energy's PY2022 custom gas installations. Custom gas evaluations for RI Energy starting from PY2016 are designed to be rolling/staged evaluations. The goal of this approach is to repeat measurement and verification (M&V) annually as the previous year's tracking data becomes available. The current study provides new results for PY2022 as Year 3 and aggregates with those the results of previous studies of PY2020 as Year 1 and PY2021 as Year 2.

This study:

- Separated sampling of steam trap and non-steam trap (non-ST) projects.
- Evaluated gross natural gas energy savings for RI custom non-steam trap gas projects, with targeted sampling precision of ±35% at 80% confidence for the current evaluation year.
- Combined current evaluation year results with results from the previous two evaluation years to report three-year rolling results, with targeted precision of (±20% relative precision at 80% confidence for three-year rolling.
- Evaluated five PY 2022 non-steam trap sites, which included conducting site visits with data collection through on-site metering or trend data collection.
- Conducted desk reviews of three PY-2022 steam trap sites, which included telephone interviews with facility personnel.

In PY2022, DNV discussed with RI Energy and the EERMC evaluation consultants (C-team) the approach to evaluating steam traps in the current year and upcoming evaluation cycles. During these discussions, the group determined that steam trap and non-steam trap sites have fundamentally different evaluation methodologies. Non-steam trap sites are evaluated through in-depth M&V, whereas the method for evaluating steam traps is to use a calibrated model that incorporates data from billing analysis from previously installed steam trap sites. Since there is uncertainty with steam trap evaluation results stemming from the calibrated model based on old billing analysis data, RIE and the C-team agreed to study steam trap and non-steam trap sites separately. In agreement with RIE and the C-team, DNV designed separate samples for steam trap and non-steam trap sites. Furthermore, RIE and the C-team agreed to report the results of steam trap and non-steam trap sites separately in PY2022. The following sections in this report primarily focus on the sampling and evaluation results for the non-steam trap sample. The steam trap evaluation, methodology, and results are discussed in detail in the Steam Trap Memo in APPENDIX C. The subsequent sections in this report defer discussion of steam traps to APPENDIX C unless otherwise necessary.

This program evaluation performed site-based M&V impact evaluations to quantify the achieved natural gas energy savings using five RI custom gas non-steam trap sites from projects completed in PY2022.

For non-ST three-year rolling results, the PY2022 results were combined with PY2020 and PY2021 non-ST results to produce an overall RR for updating statewide prospective realization rates.

1.2 Organization of report

The remainder of this report is organized as follows:

- Section 2: Methodology and Approach. The methods associated with sampling and the M&V tasks are described in this section.
- Section 3: Data Sources. The study used various data sources including RIE’s tracking data, individual application project files etc.
- Section 4: Analysis and Results. The results associated with the program evaluation of PY2022, and the latest three-year rolling results are presented in this section.
- Section 5: Conclusions, Recommendations, and Considerations. Conclusions and recommendations from analyzing the M&V findings are presented in this section.

2 METHODOLOGY AND APPROACH

The approach to evaluating gas projects in PY2022 is outlined in the steps below:

1. Reviewed the 2022 RI custom gas population data.
2. Designed a sampling plan per a sample design memo (APPENDIX D) using annual savings to represent custom gas projects for evaluation to achieve the expected statistical precision targets using a three-year rolling sample.
3. Two separate samples were developed: one for steam trap and one for non-steam trap sites. The steam trap sample is discussed in APPENDIX C.
4. The samples were stratified by total savings at each location/account, including SEMP categories when applicable.
5. Developed a project work plan outlining the sample design, scope of work, timeline, and budget for this evaluation.
6. Extrapolated the final evaluated impact for the 2022 sample to the remaining 2022 population as reported in the program tracking system.
7. Reported annual and combined results with the previous two years of impact evaluation results to produce a three-year rolling realization rate.

2.1 Description of sampling strategy

PY2020, PY2021, and PY2022 results will be pooled to use for PY2025 planning and reporting. In subsequent years, the realization rate will reflect the pooling of the three most recent impact results. Further details of sample design can be found in APPENDIX D.

Based on the results achieved in the previous studies, this sample design assumed the error ratios shown in Table 2-1 for the targets listed. The sample design for this study assumed the results would pool with prior (and future) custom gas results. In PY2022, the sample was designed to have an annual expected relative precision of ±35% with an 80% confidence interval. This annual target also allows the study to achieve the three-year target of ±20% precision at 80% confidence. DNV used a model-based statistical sampling (MBSS) technique to develop the sample design. The sampling unit is the sum of all projects installed in the evaluated program year for an account or location if the account serves multiple locations.

Table 2-1. Sampling targets

Annual sampling target	Error ratio
±35% expected relative precision – 80% CI	0.55 (non-stream trap)

2.1.1 PY2022 sample frame

The initial population for this program impact evaluation was the set of custom gas projects rebated in 2022.

Table 2-2 shows the distribution of all tracking records and the associated savings by RI Energy.

Table 2-2. PY2022 population distribution of custom gas accounts

Distribution	Number of applications	Gas savings (therms)	% savings
Custom design approach (CDA)	1	10,555	0.7%
Custom – Prescriptive	10	19,909	1.4%
Less than 1,000 therms savings	37	15,462	1.1%
C&I custom general	149	1,405,261	96.8%
Grand total	197	1,451,187	100%

Custom design approach (CDA) projects, Custom – Prescriptive projects, and sites that saved less than 1,000 therms were excluded from the final population. CDA projects were removed because RIE studies them separately, and custom prescriptive projects were removed because their evaluation is not representative of custom programs. Sites with less than 1,000 therms of savings were removed because small savers typically have less rigorous savings estimates and covered <2% of the total program savings and are not cost effective to evaluate. Table 2-3 shows the selected sample frame after dropping the small sites, CDA projects, and prescriptive measures.

Table 2-3. PY2022 adjusted (final) project population frame

Site type	Number of projects	Gas savings (therms)
Non-steam trap	110	1,056,259
Steam trap	39	349,002
Total	149	1,405,261

2.1.2 PY2022 sample design

Table 2-4 shows the selected sample for this project. DNV determined that each independent program evaluation year would need to achieve a ±35% precision at an 80% confidence interval to maintain a three-year pooled result of ±20% precision at 80% confidence for gross therms savings RRs. DNV estimated that five sampled non-steam trap sites would result in an expected relative precision of ±35% precision at an 80% confidence interval which meets the current-year target precision required for the three-year precision goal. More details on the sample design are shown in the Sample Design Memo in APPENDIX D.

Table 2-4. PY2022 Non-steam trap project sample design

Category	Stratum	Number of sites (n)	Sampled sites (n)	Total therms	Expected relative precision @ 80% CI
Non-steam trap	1	68	3	411, 321	±35%
Non-steam trap	2	11	2	644,938	

2.1.3 Rolling sample design

The expected precision from the PY2022 sample design was combined with the achieved PY2020 and PY2021 study results to estimate a combined three-year rolling precision result of ±13.6% at 80% confidence. Table 2-5 provides the combined expected precision based on this sample design. The table also shows the reported therm savings and design RPs for each respective year in the three-year rolling cycle.

Table 2-5. PY2020, PY2021, and PY2022 combined expected precision at 80% confidence interval

Program Year	Therms savings	Error ratio	Sample (n) Design	Sample (n) Achieved	RP @80% CI Design
PY2020	1,280,693	0.55	8	8	±8.9%
PY2021	752,277	0.55	4	4	±21.9%
PY2022	1,056,259	0.55	5	5	±35.0% (expected)
PYs (2020, 2021, & 2022)	3,089,229	N/A	17	17	±13.6% (expected)

N/A = Did not calculate.

2.1.4 PY2022 final sample disposition

The final (achieved) sample included five non-steam trap sites listed in Table 2-6. The summary table includes the site ID, the type of visit conducted, and the types of data collected for each site. Results for the sites are detailed in APPENDIX A.

Table 2-6. Site-level information for the type of visit and data collected

Site ID	Type of site visit	Data collected: Site interview	Equipment verification	Trend data	M&V data
RIG22N079	On-site	X	X	X	X
RIG22N040	On-site	X	X	X	X
RIG22N012	On-site	X	X	N/A	X
RIG22N061	On-site	X	X	X	N/A
RIG22N073	On-site	X	X	X	N/A

N/A = Not applicable to evaluated measures, trend data was not received, or metering was not conducted

2.2 Site M&V planning

The site evaluation (M&V) plan played an important role in establishing approved field methods and ensuring that the objectives for each site evaluation were met. The M&V plan for each evaluated site provided detailed information on the procedures for accomplishing those objectives.

DNV submitted individual M&V plans for each evaluated site. These plans were reviewed by RI Energy. Each site plan included the following sections:

- **Project description** – A description of how the project saves energy.
- **Tracking savings** – A short description of how the tracking savings were estimated and their source, including:
  - Analysis method.
  - Key baseline assumptions.

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

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

– Methods for verifying the measure installation and current operation.
– Methods for observing and/or assessing building use and occupancy.
– Identification of the tracking and expected evaluator baseline of each measure.
– The data to be collected by DNV. Where several similar items were installed or were being controlled, the site evaluation plan described and justified the sampling rate of the equipment to be monitored.
– Site staff interview questions (to understand the baseline operation and determine if any changes in the operation of the impacted system occurred after the project was installed).
– The data provided or to be provided by the site (e.g., EMS trends, production, pre-metering) and/or RI Energy.
– The expected site evaluation analysis method to be used, including any deviations from the implementer savings estimation method. In general, the same methodology used to estimate tracking savings was used to estimate evaluated savings. DNV presented an alternative methodology only if the tracking methodology was flawed, unfeasible, or a more accurate methodology that utilized post-installation data was available.
– Key parameters that are determined through the site evaluation preparation to compare to those used in the original savings estimate.
– Measurement verification equipment to install on select equipment and quantity of devices intended for installation.

DNV responded to RI Energy M&V plan comments and in most cases, submitted a revised M&V plan before the site visit.

2.3 Data collection

DNV performed a site contact interview and scheduled a site visit to perform the tasks described in the site M&V plan. Data collection occurred from February 2024 to June 2024.

2.3.1 Customer outreach

Using the information provided in the project files, project engineers reached out to customer site contacts. During this initial outreach, the engineers discussed the purpose of the site evaluation, the scope of measures installed, the availability of onsite trend/EMS/production data, any other applicable parameters, and confirmed that the site would allow DNV to conduct a site visit.

All five primary sites selected for evaluation agreed to an on-site visit, so no backups were needed for any sites. Table 2-6 above also details the site-level information and the types of data collected at each on-site visit.

2.3.2 Site visit

Each initial site visit consisted of verification of installed equipment, a discussion with facility personnel regarding the baseline characteristics of the measure, the installation of M&V equipment, the collection of available trend data, and/or the creation of a plan to gather trend data coinciding with the M&V period.

2.3.3 M&V plan update

DNV submitted an updated site M&V plan to RI Energy after the completion of the initial site visit. These updated plans for each site included the following information based on the site visit:

- Any deviations from the plan that occurred during the visit or were expected to occur; deviations occurred when a portion of the proposed M&V plan was not feasible for unforeseen reasons.
- A summary of the data in progress of being collected, information that will not be available for analysis purposes, and a list of tasks to complete on the return for meter pickup.

The update provided RI Energy the current status of the site evaluation and communicated any anticipated or resulting deviations from the plan.

2.4 Site analysis

As previously shown in Table 2-6, the evaluation team evaluated all five projects with data from metering, billing, or customer's trend data. Results were normalized to typical production or weather data. For weather-dependent measures that resulted in savings, the site analysis involved normalizing energy saving models to weather data using Typical Meteorological Year 3 (TMY3) data from the closest representative weather station to each site.

2.5 Site reporting

DNV submitted draft site reports to RI Energy for all five on-steam trap sites, after which RI provided comments or questions to the engineer who led the site analysis. The engineer responded to comments and questions until a final agreement was reached on the analysis approach, the results, and the report itself. Each site report contains the following sections:

- Project summary and results – Provides a brief description of how the evaluated measures at the site save energy and a high-level summary of why the site evaluation results may differ from the tracking estimates. The site results are also presented in this section.
- Evaluated measures – Describes the evaluated measures, including, but not limited to:
  - Applicant's baseline and proposed conditions
  - Applicant savings calculation methods
  - Evaluator assessment of the applicant savings calculation methods
  - Measure verification results and methods for verifying measures
  - The data collected by DNV, summarized in graphical or tabular form for each data point
  - The data provided by the site and/or RI Energy, with key data summarized in graphical or tabular form
  - Site evaluation baseline used
  - The site evaluation analysis method used, identifying any deviations from the original savings estimation method
  - Key savings parameters determined through the site evaluation, and a comparison to those used in the original savings estimate
  - A summary of the evaluated savings calculated and the primary drivers for differences between the tracking savings estimates and site evaluation savings estimates

An internal quality assurance lead reviewed all five sites. This review determined if the reports complied with the requirements for the deliverable and if the document communicated information clearly and consistently.

2.5.1 Measure event type and baseline review

Table 2-7 shows the measure event types used in RI Energy tracking information and site evaluations. Site RIG22N079was classified by the applicant as a new construction/replace on failure. The evaluators determined the measure to be new construction with the distinction that the pre-existing equipment had not failed but was beyond its useful life. All other projects were classified as retrofits in the application but reclassified as add-on retrofits by the evaluators because the measures added on equipment to existing systems with remaining useful life.

Table 2-7. Measure event type in RI Energy tracking information and site evaluations

Site ID	Measure type	RI Energy application #	Tracking event type	Site evaluation event type
RIG22N079	Energy management system	13140161	Retrofit	Add-on Retrofit
RIG22N040	Energy management system	13242101	Retrofit	Add-on Retrofit
RIG22N012	Pipe Insulation	12891673	Retrofit	Add-on Retrofit
	HVAC Controls	12697991	Retrofit	Add-on Retrofit
	HVAC Controls	13406021 / 11705177	Retrofit	Add-on Retrofit
	HVAC Controls	13670467	Retrofit	Add-on Retrofit
RIG22N061	HVAC Controls	13741057	Retrofit	Add-on Retrofit
	Process equipment	9291886 / 11907162	New Construction	Lost Opportunity
RIG22N079	Process equipment	9465570 / 11979059	New Construction	Lost Opportunity

After the measure event type was evaluated, the evaluator selected the evaluated baseline for the event type. Measures classified as retrofit (and add-on) used pre-existing conditions as a baseline. DNV assessed whether retrofit cases called for a dual baseline and determined that all the retrofit cases in this year's sample were single baseline. Measures classified as new construction (and lost opportunity) used ISP or code as the baseline. The evaluation team completed an independent review of the baseline for each sampled project. Using site data project documentation and interviews at the facility, DNV assessed the reasonableness of the baseline for each sampled project. The evaluators reclassified the evaluation event type as needed to be more specific but noted that they are effectively the same when considering the baseline conditions and savings.

2.6 Sample expansion

2.6.1 Site weight calculation

Weights are calculated similarly to previous rounds of custom gas program evaluations and are determined by dividing total number of tracking observations in the stratum by the number of evaluated observations Using PY2020–PY2022 results, a three-year rolling realization rate can be calculated. The annual realization rates are weighted based on the proportion of first-year tracked savings across the three-year evaluation period to calculate an overall three-year realization rate. APPENDIX B provides more details about the calculation of three-year results and weights.

3 DATA SOURCES

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

- PY2022 tracking data provided by RI Energy
- PY2022 parent/child tracking data provided by RI Energy
- PY2020 and PY2021 tracking data
- PY2020, PY2021, and PY2022 program impact evaluation results
- Project files, which typically include one or more of the following:
  - Original applications
  - Offer letters
  - BCR screenings
  - Invoices
  - Minimum requirements documents
  - Technical assistance studies
  - Applicant savings calculations that match claimed savings
  - Post-installation inspection reports
  - Commission results if available
- Onsite observations and data collection, including inspection and verifications of equipment, nameplate data, staff interviews, vendor interviews, and spot measurements of various parameters, including kW and longer-term metering measurements
- Billing, and/or EMS trend data

4 ANALYSIS AND RESULTS

DNV was able to collect trend data, metered data, or a combination for each site. Site level reports were compiled for each site and can be found in APPENDIX E.

The PY2022 Custom Gas study achieved its targeted precisions for that individual year's projects as well as for the combination of the latest three years (PY2020, PY2021, and PY2022). The following subsections provide more details on the PY2022 results.

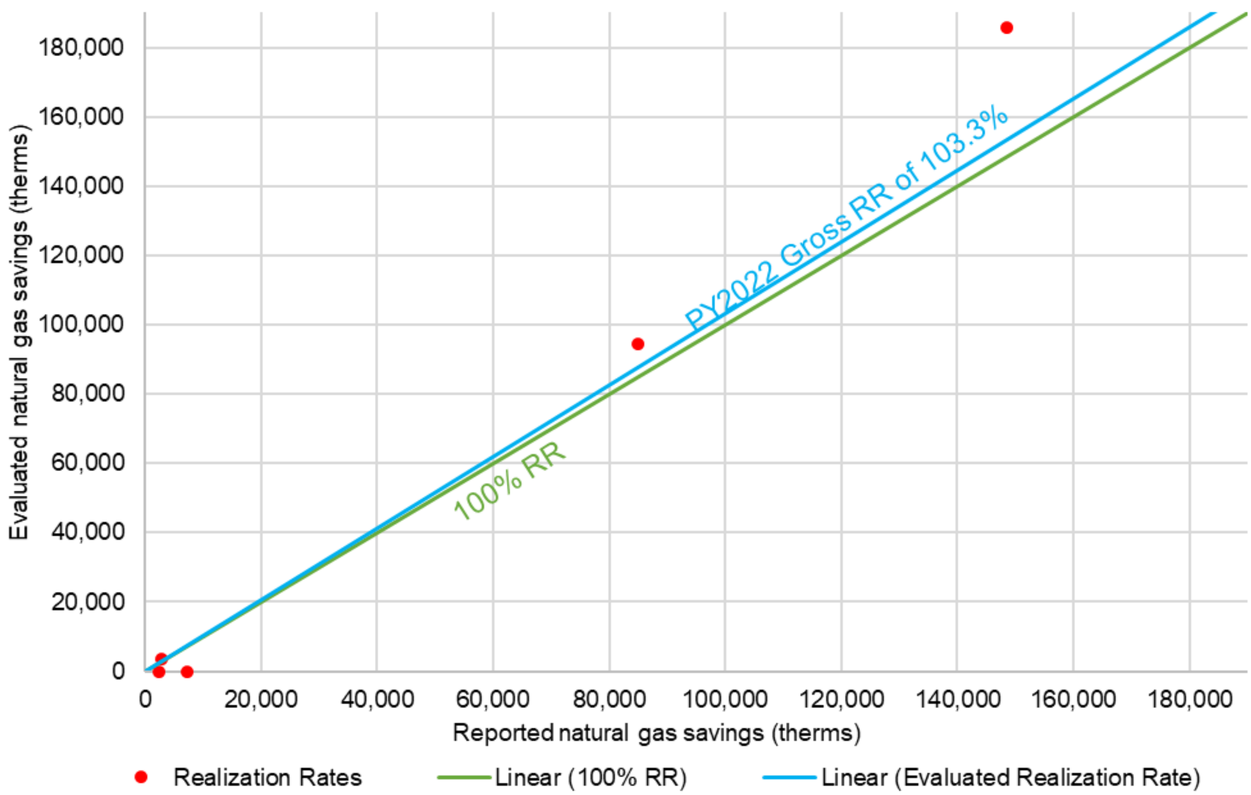
4.1 PY2022 results

This section provides an overview of the results from comparing PY2022 tracking and evaluated results.

4.1.1 Site-level results

Figure 4-1 illustrates the comparison of reported (x-axis) and evaluated (y-axis) annual natural gas savings for each of the five sites included in the program evaluation sample for PY2022. The red points in the graph representing each site contribute to the blue evaluated PY2022 Gross RR line. The difference in the evaluated realization rate line and the tracking savings with 100% RR (green) shows the magnitude of difference between tracking savings and evaluated savings. APPENDIX A summarizes the five sites for which M&V activities were completed, with statistics such as the site ID, the verified measure description, tracking savings, and RR.

Figure 4-1. PY2022 reported and evaluated annual natural gas savings



In Figure 4-1, there are two sites that were evaluated as zero savers. RIG22N040 and RIG22N079 were both energy management system projects that resulted in zero savings because the facilities already had existing energy management systems that performed the same functions as the proposed EMS. Among the smaller savings sites shown at the bottom left corner of the figure, the two zero savers contribute heavily to the relatively low performance of small savings sites.

DNV notes that these two zero savers also contribute to the negative impact of baseline discrepancies for the overall sample as shown later in Section 4.1.2. The lower savings stratum included 2 sites with zero savers and one site with over 100% realization rate. The higher savings stratum performed well with both sampled sites having realization rates over 100%. Despite the performance of the smaller sites, the overall realization rate is over 100% because of the better-performing large sites in the sample. The single-year non-steam trap realization rate for PY2022 are reported in Table 4-1.

Table 4-1. PY2022 single-year realization rate for non-traps and traps

Parameter	Tracking savings	Realization ratio	RP	ER
Non-steam trap	1,056,259	103.3%	18.6%	0.35

The single-year realization rate for PY2022 RI custom gas non-steam trap installations is 103.3% with an achieved relative precision of 18.6%. This is within the single-year target precision of ±35% at 80% confidence for non-ST sites. The approach for calculating the current year realization rate is outlined in APPENDIX B. This year's calculated error ratio is 0.35 compared to the expected 0.55 from the sample design. Due to the heteroscedasticity observed among the results for the 5 sampled sites, DNV notes that a minimum sample size of 5 or 6 is advisable for the next program year. DNV also notes that investigating a sampling option that has a higher number of sites will also allow the evaluators to understand whether there is a strong relationship in the population between project size (therm savings) and realization rate.

4.1.2 Discrepancy results

For each of the five sites included in the PY2022 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 breakdown of possible differences and how they are categorized is presented in Table 4-2.

Table 4-2. Possible 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

The evaluation team used the sum of weighted site-specific discrepancies to calculate the impact of adjustment factors between the program tracking and evaluated results at the population level. Table 4-3 presents the discrepancy factors and their impacts.

Table 4-3. PY2022 weighted discrepancy factors between tracking and evaluated results

Adjustment Factor	Site Counts	Impact on RR	Impact (%)
Baseline	2		-0.4%
Methodology	1		0.4%
Tracking/Admin	0		0.0%
Technology	3		1.2%
Quantity	0		0.0%
Operational	3		1.2%
Interactive	0		0.0%
Historical Operations Adjustment			0.9%
Total			3.25%

In PY2022, technology and operational adjustments had the largest impact on overall RR, primarily due to discrepancies found in equipment efficiencies and operating load in the larger saving projects.

Adjustment percentages found in Table 4-4 are the magnitude of changes from tracking to evaluated reported at the site level. The combination of non-operational and operational adjustments sums to the percent increase or decrease in tracking to evaluated savings (realization rate). The percentages are the total adjustments for operational and non-operational adjustments when compared to site-level savings.

Table 4-4. Non-operational and operational weighted discrepancies – PY2022

Site ID	Tracking savings (therms)	Evaluated savings (therms)	Site-level adjustments		Combined ops/non-ops increase or decrease (%)	Realization rate (%)
			Non-operational	Operational		
RIG22N079	7,246	0	-100.0%	0.0%	-100%	0%
RIG22N040	2,457	0	-100.0%	0.0%	-100%	0%
RIG22N012	2,880	3,534	-1.0%	23.7%	23%	123%
RIG22N061	148,462	185,599	12.2%	12.8%	25%	125%
RIG22N073	85,009	94,442	2.7%	8.4%	11%	111%

Section 3 of each site report presents detailed information on site-specific differences. Site reports are included in APPENDIX E.

4.2 Combined three-year rolling non-steam trap results

The evaluators calculated the combined three year rolling gross RR and precisions using the results from PY2020, PY2021, and PY2022. The PY2021 and PY2022 results did not use historical ops adjustments, but the three-year rolling results use historical ops adjustments insofar as the results from PY2020 had those values applied to calculate their final ops adjustments. PY2020 results are not recalculated with the PY2022 ops adjustment, they only have historical ops adjustments from their own respective year and the imputations are not revisited using more recent ops adjustments. The combined three-year rolling results include PY2020, which has historical ops adjustments and is used to calculate the three-year weighted rolling average. The following Table 4-5 shows the results for non-steam trap populations for each year along with the three-year rolling results which consist of PY2020, PY2021, and PY2022.

Table 4-5. Three-year rolling non-steam trap results and statistics

Parameter	PY2020	PY2021	PY2022	PYs 2020+2021+2022
Tracking savings (therms)	556,583	752,277	1,056,259	2,365,119
Total sample size	8	4	5	17
Realization rate (RR)	64.44%	86.57%	103.25%	88.81%
Relative precision @ 80% CI (%)	±8.9%	±15.3%	±18.6%	±12.0%
Realized Savings (therms)	358,637	651,272	1,090,602	2,100,511

5 CONCLUSIONS, RECOMMENDATIONS, AND CONSIDERATIONS

5.1 Conclusions

5.1.1.1 PY2022 Performance

PY2022 custom gas non-steam trap projects saved an estimated 1.09 million therms, with 103.3% of the program year tracking savings realized based on the program evaluation sample for RI PY2022 sites. In PY2022, although the single-year realization rate for the program year is 103.3%, the poor performance of the lower-savings projects is masked by the better-performing high-savings projects even taking into account the higher weighting of the smaller sites. The evaluators found that lower-savings sites in the sample performed poorly primarily due to baseline discrepancies as well as measure performance. The recommendations presented in the sections below discuss the low-savings sites in further detail. However, since large savings sites performed relatively well, the overall realization rate for PY2022 is higher than previous years. The current results are accurate within agreed-upon precision standards and provide adequate planning and program reporting savings estimates.

A more detailed explanation of the PY2022 performance is found in Section 4.1. Site-specific details are shown in APPENDIX A and each site report is included in APPENDIX E.

5.1.1.2 Combined three-year rolling (PY2020, PY2021, & PY2022) Performance

Combined over the three-year rolling sampling period, the non-stream trap had a tracking gross savings of 2.4 million therms with a realized gross savings of 2.1 million therms. resulting in an 88.8% realization ratio as shown in Section 4.2.

5.2 Recommendations

5.2.1 R1: Realization rate

DNV recommends RI Energy use the three-year (PY2020, PY2021, and PY2022) non-stream trap RR of 88.8% for planning and program reporting, starting with PY2025 and continuing until new program impact evaluation study results are available.

Based on the results listed for PY2022, an individual program year sampling Error Ratio Target of 0.55 for non-steam trap and SEMP projects has been recommended for the 2023 RI custom gas impact evaluation to maintain the next three-year rolling savings program evaluation precision targets.

5.2.2 R2: Implement more rigorous review for estimating energy management system savings

DNV recommends that project implementers critically review methodology for estimating savings for energy management systems. Among the lower-savings projects, two of the three projects resulted in zero savings. The energy savings methodology for these sites consisted of performing billing analysis to determine annual gas heating usage and applying a vendor estimated percentage to estimate savings. For RIG22N040, the applicant savings methodologies claimed savings were 10% of the annual gas usage. For RIG22N079, the applicant savings methodology claimed savings were 15% of the annual gas usage. Neither case included reasoning to justify the percentage ratios used in the savings estimation. DNV postulates that if a more rigorous methodology review for estimating gas savings was implemented, the applicant may have been able to upgrade or enhance the functions of the proposed measure and increase savings.

5.2.3 R3: Implementers should inquire about lifetime of the measure:

For one site, RIG22N012, pipe insulation was installed and in place for one year at a school before the facility was decommissioned and no longer used. Before funding a project, the implementors should inquire about the future of the building and if the customer intends to use the measure for its full lifetime or if there are any anticipated changes to the lifetime of the equipment or the facility. For the insulation project for the school in particular, it is not clear when initial discussions began regarding the potential for decommissioning the school, but the implementors should inquire about the future of buildings/equipment so that these projects can be screened appropriately.

5.2.4 R4: Flag the specific equipment used for the two zero savings projects for additional review of baseline assumptions

Sites RIG22N040 and RIG22N079 were both from the same vendor and achieved zero savings primarily from incorrect baseline assumptions. DNV recommends that implementers pay additional scrutiny to the review of baseline assumptions for sites that may install this measure. DNV recommends that projects be flagged by implementors for additional review of the baseline assumptions used in savings analyses for specific sites as well as whether the measure should be further supported by program incentives. If RIE deems that the measure should be further supported by program incentives, RIE should also establish a more explicit and standard methodology for estimating energy savings for projects of this type.

5.3 Considerations

5.3.1 C1: Ensure baseline equipment is not equivalent to proposed energy efficiency measures

DNV recommends that the project implementer ensure that baseline equipment is not equivalent to the proposed energy efficiency measures. In PY2022, DNV found through the evaluation of sites RIG22N040 and RIG22N079 that the existing heating systems already had an existing controls with most of the key the functionality claimed by the proposed energy efficiency measure. Both sites used the same implementation vendor. This consideration differs from Recommendation 3 in that this consideration is specific to the underlying equipment, whereas the recommendation pertains to the savings methodology.

5.3.2 C2: Ensure equipment efficiency inputs are accurate

DNV recommends that the project implementer ensure that the inputs for equipment efficiency are as accurate as possible. In PY2022, discrepancies with equipment efficiency were a large contributing factor to the overall discrepancy for the program year. DNV observed that among those sites, the efficiency values used were incorrect and there were readily available efficiency values that were more accurate.

5.3.3 C3: Consider further separation of steam trap and non-steam trap evaluation

DNV recommends that the project implementer consider further separation of the steam trap and non-steam trap studies to avoid the potential of telegraphing overconfidence with the steam trap evaluation methodology. Since there are still inherent uncertainties associated with the steam trap calculator, DNV recommends that steam traps be part of their own separate study and have a separate report to further distinguish the difference in evaluation methodologies and results.

APPENDIX A. SITE EVALUATION RESULTS & REALIZATION RATES

This Appendix includes the site ID, the verified measure description, tracking savings, and site RR that were used to calculate over realization rates for the program. The realization rates for all categories are shown in Table A-1.

Table A-1. Evaluated site summary

Sample ID	Applications	Measure description	Tracking savings	Evaluated savings	Realization rate
RIG22N079	13140161	Runwise energy management system	7,246	0	0.0%
RIG22N040	13242101	Runwise energy management system	2,457	0	0.0%
RIG22N012	12891673	Pipe Insulation	2,880	3,534	123%
RIG22N061	12697991, 13406021 / 11705177, 13670467, 13741057	HVAC controls	148,462	185,599	125%
RIG22N073	9291886 / 11907162, 9465570 / 11979059	Process equipment	85,009	94,442	111%

APPENDIX B. 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 year 1 realization rate is different from the current year (year 3), or year 2, as an imputed operational adjustment was necessary for the first year. This section describes the calculation of the current year realization rate, as well as the operational adjustments used for year 1, which is included in the 3-year rolling result.

Basic structure

We have samples for three successive periods: 1, 2, and 3. In this evaluation these samples are 1) PY2020, 2) PY2021, and 3) PY2022. Samples 2 and 3 are full samples with operational adjustments for all sampled sites. Sample 1 had non-operational results for all sites and operational results for only a subset of sites. The three-year realization rate has imputed operational adjustments for the PY2020 results.

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 3 periods combined

$= S_1 + S_2 + S_3$

q_y = period-y savings as a fraction of the 3-period total

$= S_y/S_T$

SW_y = full sample weighted savings represented by "good" sites, i.e., those with operational data for period y

SW_T = full sample weighted savings represented by "good" sites, i.e., those with operational data for all 3 periods combined

$= SW_1 + SW_2 + SW_3$

f_{g1} = fraction of Period-1 savings represented by "good" sites, i.e., those with operational data

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

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

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

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

SE(X) = standard error of estimate X

RSE(X) = relative standard error of estimate X

=SE(X)/X

Period 1 operational realization rates: RR_{o1}

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

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

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 B-1, 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. The imputed ops adjustment for year 1 (2020) is based on ops adjustments from sites evaluated in 2018, 2019, and those sites with ops adjustments available in 2020.

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

		Annual RR Results						
		2016	2017	2018	2019	2020	2021	2022
Ops Adjustment Sources	2016	Full Sample						
	2017		Full Sample		-3) Full Sample			
	2018			Full Sample*	-2) Full Sample*	-2) Full Sample*		
	2019				-1) Partial Sample	-1) Partial Sample		
	2020					1) Partial Sample		
	2021						Full Sample	
	2022							Full Sample

*No imputation was done for this year. This sample was reweighted due to lack of ops adjustment for two sites, but treated as a full sample because the reweighting allowed us to consider the operational adjustment valid for all sites.

- Overall Operational Adjustment for Period 1 are calculated as

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

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 formula can be expanded as

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

[1] RR_{-2} and RR_{-1} denote two earlier years prior to the current three-year rolling period, which were used as part of the operational adjustments for RR_1.

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

$= a_{og1}\ RR_{og1} + a_{-2}RR_{o-2} + a_{-1}RR_{o-1},$

Where

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

$a_{-2} = (1-f_{g1})(S_{-2}/S_{(-2,-1,1)g})$

$a_{-1} = (1-f_{g1})(S_{-1}/S_{(-2,-1,1)g})$

This expansion expresses the overall Period 1 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:

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

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

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

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

Periods 2 and 3 combined RR

1. **The operational and non-operational realization rates** RR_{N2}, RR_{N3} and RR_{O2}, 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 RRs

   $RR_2 = RR_{o2}\ RR_{N2}$

   and

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

3. **Standard error:** First calculate the relative standard errors:

   $RSE(RR2) = sqrt[RSE^2(RR_{o2}) + RSE^2(RR_{N2})]$

   and

   $RSE(RR_3) = sqrt[RSE^2(RR_{o3}) + RSE^2(RR_{N3})]$

This formula is approximately correct, assuming that even though RR_{N2}, RR_{N3} and RR_{O2}, RR_{O3} are from a common sample, they are essentially unrelated so can be treated as independent.

4. The standard errors are then calculated from the RSEs.

$SE(RR_2) = RR_2\, RSE(RR_2)$

and

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

Three-year combined RR

RR calculation

The three-year RR is the savings-weighted average of the three separately estimated RRs:

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

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.

SE calculation

While the first term, RR_1, is determined in part from the operational portions of other years, since RR_1 is not use for any adjustment to RR_2 or RR_3, and since the program year results used to make operational adjustments to RR_1 are no longer included in the three-year rolling period, the three years may be treated as independent estimates to calculate standard errors. This is a change from the prior three program years where the RRs could not be treated as independent, because at least one year's RR contained imputed operational adjustments from at least one other year in the three-year rolling period. This change allows us to use a simplified SE calculation as compared to the prior three reporting cycles.

The standard error for the three-year rolling period is calculated as:

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

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_3, 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 C. STEAM TRAP MEMO

Memo to:
Ann Clarke, RI Energy
David Jacobson, Jacobson Energy
Copied to:
Srikar Kaligotla, DNV
Rick Boswell, DNV

Prepared By: Laengheng Khoun, DNV

Date: August 20, 2024

"2022 RI Custom Gas Steam Trap Memo"

Summary

This memo outlines the results for the steam trap sites sampled for the impact evaluation of the 2022 Custom Gas program administered by RI Energy in Rhode Island. The evaluators conducted steam trap desk reviews and interviews for three steam trap sites and determined 100% RR for all sites.

DNV recommends that RIE and the C-team assess whether to continue to stay in alignment with the steam trap evaluation methodology used in Massachusetts custom gas evaluations or deviate in the next evaluation cycle.

The evaluation approach for steam traps is in alignment with the steam trap approach used to evaluate the 2020 Custom Gas program administered by National Grid in Rhode Island and the PY2022 Custom Gas program in MA. The approach used is based on the following:

- Evaluators calibrated the steam trap tool to account for all operational and non-operational characteristics of the steam system.
- Both implementers and evaluators use the same tool to model steam traps savings.

The evaluators acknowledge that the steam trap evaluation methodology involves the use of the steam trap tool which is based on billing analysis data primarily sourced from old studies dating back to 2015. Although there are uncertainties associated with using the steam trap tool, DNV followed the steam trap evaluation methodology that is used in Massachusetts gas evaluations to stay in alignment.

2022 steam trap results

Four steam trap projects installed at three sites were included in the impact evaluation of 2022 RI Custom Gas program. The evaluation results of each of the three evaluated steam trap sites are presented in Table C-1.

Table C-1. 2022 steam trap results summary

Site ID	Application number	Tracking errors (yes/no)	Steam trap tool used	Tracked savings (therms)	Evaluated savings (therms)	Realization rate	Lifetime savings (therms)

RIG22S017	13270072, 13494634	No	2018 RI Energy Steam Trap Tool	17,640	17,640	100%	105,840
RIG22S035	13839873	No	2018 RI Energy Steam Trap Tool	15,229	15,229	100%	91,374
RIG22S041	13457745	No	2018 RI Energy Steam Trap Tool	8,436	8,436	100%	50,616
Overall				**41,305**	**41,305**	**100%**	**247,830**

For each steam trap site, evaluators reviewed the applicants' savings calculation files and determined there were no calculations or methodology errors. Evaluators determined the applicants used the current RI Energy Steam Trap Tool to calculate tracking savings for all steam trap projects installed at the three evaluated sites. Evaluators conducted phone interviews with the participants at each of the three evaluated sites and determined that all steam systems impacted by the evaluated steam trap projects were in place at the time of the evaluation. Based on information gathered through the project files reviews and interviews with the site contact, evaluators determined the projects were installed and operated as intended and did not identify major or minor discrepancies. For RIG22S035, the site contact provided an updated steam trap audit summary table, which shows all the relevant steam traps operated at the time of the evaluation and their specifications matched the specifications shown in the ex-ante calculator. For RIG22S017 and RIG22S041, the site contacts verbally confirmed that there were no discrepancies in the steam traps repaired/replaced and all steam traps were still functioning. The overall realization rate for steam trap projects installed in program year 2022 is 100%.

In conclusion, there were no discrepancies found among the sampled steam trap sites. DNV recommends that RIE and the C-team assess whether to continue to stay in alignment with the steam trap evaluation methodology used in Massachusetts custom gas evaluations or deviate in the next evaluation cycle.

Steam trap evaluation approach

The following steps outline the methodology DNV used to evaluate steam trap sites in custom gas evaluations. This methodology was developed by DNV for the PY2022 Custom Gas program evaluation and was agreed upon by RIE and the C-team.

1. Review project files and compare them to tracking data.
    a. Identify any difference in tracking savings vs. application file savings. In this case, application file savings refers to the detailed savings calculations that support the incentive application. The evaluator reported the difference and classified it as an "Administrative error" difference.
2. Confirm if the current RI Energy steam trap tool (STT) was used (labelled as the "Steam Trap Repair / Replacement Custom Express Spreadsheet").
    a. If a different tool was used than the one that was current when the project was initiated, the evaluator recalculates the ex-ante savings using the correct tool and the applicant inputs. The difference in savings was reported and classified it as a "Methodology" difference.
3. Confirm if the steam distribution system, not individual traps, is still in place at the time of evaluation.
    a. If the steam system is no longer in place, the evaluated first-year savings is calculated using the following algorithm:

$$First\ Year\ Savings = \frac{Number\ of\ months\ system\ was\ in\ place}{72\ Months} \times STTResults$$

72 is the number of months corresponding to the 6 year lifetime value used for steam trap projects. The evaluator reports the difference and classified it as an “Other” difference.

Lifetime savings is calculated as follows:

$$Lifetime\ Savings = \ First\ Year\ Savings \times 6\ Years$$

4. Identify any major discrepancies (orders of magnitude) through an interview or on-site verification. These major discrepancies highlight issues or common trends among steam trap evaluations.

    a. Periodically, the statewide STT will be recalibrated using a billing analysis model of an attempted census of participants. The calibration pool will exclude participants with billing data that fails quality screening and those that report non-routine events (NRE). The NRE’s will be identified during surveys of potential billing analysis candidates. The calibrated model will be released as the next authorized version of the STT.

APPENDIX D. SAMPLE DESIGN MEMO

Memo to:	Memo No:	RIG2022_01
Ann Clarke, Rhode Island Energy		
Dave Jacobson, Jacobson Energy	From:	DNV
	Date:	1/10/2024
Copied to:	**Prep. By:**	Laengheng Khoun, DNV
Srikar Kaligotla, Rick Boswell, Nate Carron, Randall Monger, DNV		Rick Boswell, DNV

RIG2022 | Sampling Memorandum

Evaluation Objectives

The primary objective of this study is to quantify the gas savings (therms) attributable to the Rhode Island Energy (RIE or RI Energy) 2022 C&I Custom Gas program. This will enable RIE and DNV to assess whether the custom gas portion of the C&I gas program is achieving the expected savings and to identify any recommendations for improvement. DNV will aggregate site-specific findings to determine realization rates for the RI custom gas projects for both 2022 projects alone and a three-year rolling average.

The key objectives of this evaluation are:

1. Evaluate savings impacts of PY2022 custom gas projects which will be pooled with the results of the PY2020 and PY2021 studies. This study will aim to quantify:
    - Achieved gas energy savings for custom projects statewide, with a targeted combined sampling precision of ±20% at 80% confidence when pooled with the results from the PY2020 and PY2021 studies.

Overview of approach

The DNV team will undertake the following tasks listed below to meet the goals and research objectives of the impact evaluation. For the PY2022 evaluation, DNV is proposing a sample of on-sites for non steam trap measures and a sample of desk reviews for steam trap measures. This is discussed further in sections 6 and 7 below.

1. Review the 2022 RI custom gas population data.
2. Design a sampling plan using annual savings to represent custom gas projects for evaluation to achieve the expected statistical precision targets using a three-year rolling sample.
3. Two separate samples will be developed, for steam trap and non-steam trap sites.
4. The samples will be stratified by total savings at each location/account and ST or non-ST measures, including SEMP categories when applicable.
5. Develop a project work plan outlining the sample design, scope of work, timeline, and budget for this evaluation.
6. For steam trap (ST) sampled sites:
    a. Review project files and compare them to tracking data.
        i. Identify any difference in tracking savings vs. application file savings. The evaluator will report the difference and classify it as an Admin error.
    b. Confirm if the legacy RI and current RIE steam trap tool (STT) was used (labelled as the “Steam Trap Repair / Replacement Custom Express Spreadsheet”).

i. If a different tool was used than the one that was current at the time of the project, fill in the correct tool with the applicant inputs and recalculate savings. The evaluator will report the difference and classify it as a Methodology difference.

c. Confirm if the steam system (not the traps themselves) is still in place at the time of evaluation.

i. If the steam system is no longer in place, the adjusted first-year savings is represented by the following:

$$First\ Year\ Savings = \frac{Number\ of\ months\ system\ was\ in\ place}{72\ Months} \times STTResults$$

The evaluator will report the difference in first year savings and classify it as an “Other” difference.

Lifetime savings is represented by the following:

$$Lifetime\ Savings = \ First\ Year\ Savings \times 6\ Years$$

d. Identify any major discrepancies (orders of magnitude) through an interview or on-site verification. These major discrepancies will highlight issues or common trends among steam trap evaluations.

i. The steam trap site evaluation will only examine and evaluate those parameters that a billing analysis may not capture, like orders-of-magnitude errors in data entry or when the steam system has been decommissioned.

7. For non-steam trap (non-ST) sites

a. Review the engineering formulas, calculations, and factors used to develop the tracking savings for each sampled participant to develop site-specific M&V plans.

b. Conduct internal quality control review of M&V plans and review/approval of M&V plans by RI Energy.

c. Perform virtual or on-site visits to collect non-operational adjustments with the option for metered data collection or trend data collection (whether virtual or on-site) to collect operational adjustments. RI Energy and DNV will decide on the evaluation method site-by-site. DNV will consider the pandemic's impacts on the site's operation, overall consumption impact on the site, and visitation policies. DNV will independently analyze achieved annual gross energy savings (therms) for each sample site evaluation.

d. Produce site-specific final site reports detailing the findings and results from each sample site, including a discussion of why evaluation results differ from the tracking estimate.

8. Extrapolate the final evaluated impact for the 2022 sample to the remaining 2022 population as reported in the program tracking system.

9. Report results for steam trap and non-steam trap populations separately.

10. Combine results with the previous two years of impact evaluation results to produce a 3-year rolling realization rate. If there is a 100% RR across all steam traps sites, it will not be appropriate to calculate or report a RP for steam trap sites. In this scenario, DNV will combine ST and non-ST results and roll up to produce a 3-year rolling realization rate but will not report a RP for that three-year rolling result which is consistent with the previous studies. The evaluation team did not report a RP for three year rolling beginning in PY2021 since the C-Team and RIE elected to not evaluate steam trap sites and assume the realization rate was 100% across all ST sites.

Tracking data review and sample design

DNV reviewed the tracking data of all 2022 C&I custom gas projects, including the parent/child project status.

Tracking data review

This task was completed for the 2022 population before submitting this sampling memo. DNV reviewed project parameters found in the raw tracking data files received from Rhode Island Energy to uniformly classify measures as a steam trap or non-steam trap projects to prepare the data for the sample design process.

The data included a total of 197 applications (including 9 parent applications) for 114 unique accounts. The total tracking savings is 1,404,591 therms which is the savings for the entire 2022 population before adjusting the population frame for sample design.

A total of 15 applications that include CDA (comprehensive design analysis), Prescriptive Custom and SEM applications were removed from the population frame. Furthermore, 38 unique applications (1% of the unadjusted program savings) that claimed <1000 therms were also removed from the population frame. PY2022 claimed 1.4 million annual energy (therms) savings. Sampling was done at the account level for most of the sites, but a some were split into two sites when the site included both steam trap and non-steam trap measures (previously combo-sites). Of the 114 sites, 78 of these are non-ST, and 36 are ST sites. The 114 sites in the sample frame includes 95 unique service addresses. 19 of the 95 unique service addresses had both non-steam trap and steam trap measures at the same location. If any sites with both non-steam trap and steam trap measures are selected in the primary sample, DNV proposes to still perform a desk review for steam trap measures and full M&V for non-ST measures separately (if applicable) as outlined in the approaches described above. DNV will not modify the non-ST site visit to include a steam trap inspection to ensure that the approach to evaluating steam trap measures (desk review) is equivalent across all sites in the steam trap sample.

The total therms savings in the population frame from PY2022 shows an increase from the previous years. PY2020's population frame reported 1,280,693 therms, PY2021's sample frame reported 752,277 therms[2], and PY2022's frame reports 1,400,985 savings as shown in Table D-1 below.

Table D-1. PY2022 Gross annual energy savings in the population frame

Total Unique Accounts (Sampling Unit)	Applications	Total Therms Savings
114	144	1,400,985

Sampling plan

In the PY2022 sample design, two separate samples were developed for ST and non-ST populations. The samples are created separately because ST and non-ST projects are evaluated using fundamentally different approaches. The general principle for the design is each independent program evaluation year would need to achieve a ±35% precision at an 80% confidence interval to maintain a three-year pooled result of ±20% precision at 80% confidence for gross therms savings RRs. DNV used a Model-Based Statistical Sampling (MBSS) technique to develop the sample design.

An error ratio of 0.55 for non-trap sites was used, which is consistent with the PY2021 sample design. The error ratio for steam trap sites was reduced to 0.15 to account for less variation in steam trap site results. DNV designed two options which meet the annual and three-year precision targets.

The first option yields a slightly better precision but would require more sites for non-steam trap strata. The second option has a slightly worse precision but benefits from having fewer non-steam trap sites to evaluate. However, another caveat of the second option is that the non-trap strata alone does not meet the ±35% precision target. The precision target is only met when combining with the steam trap strata, but the target is not met if only the non-trap results are reported. If DNV reduces the sampled non-trap sites from four sites in Option 2 to 3 sites, the total expected relative precision for 2022 would exceed the ±35% target. Both options are presented below:

[2] This therms value is only the non-steam trap therm savings for PY2021 which is what was used to calculate annual precision for PY2021.

Option 1:

Table D-2. Option 1 Sample Design for Custom Gas Program 2022

Trap vs. Non-Trap	Accounts	Total Therms	Error Ratio	Sample Size (N)	Expected Relative Precision
Trap	36	349,002	0.15	3	0.13
No Trap	78	1,051,983	0.55	5	0.35
Total	114	1,400,985	0.45	8	**0.26**

DNV will report separate results for non-steam trap and steam trap results. For the three-year rolling results, the table below shows the expected combined precision using the actual precisions from PY2020 and PY2021 under option 1:

Table D-3. Option 1 Three-year Expected Combined Precision

Year	2020	2021[3]	2022
Therms	1,280,693	752,277	1,400,985
Sample Size	8	4	8
Annual Precision	9%	22%	26%
Expected Combined Precision			**12.1%**

Option 2:

Table D-4. Option 2 Sample Design for Custom Gas Program 2022

Trap vs. Non-Trap	Accounts	Total Therms	Error Ratio	Sample Size (N)	Expected Relative Precision
Trap	36	349,002	0.15	3	0.13
No Trap	78	1,051,983	0.55	4	0.38
Total	114	1,400,985	0.45	7	**0.29**

DNV will report separate results for non-steam trap and steam trap results. For the three-year rolling results, the table below shows the expected combined precision using the actual precisions from PY2020 and PY2021 under option 2:

Table D-5. Option 2 Three-year Expected Combined Precision

Year	2020	2021[4]	2022
Therms	1,280,693	752,277	1,400,985
Sample Size	8	4	7
Annual Precision	9%	22%	29%
Expected Combined Precision			**13.2%**

DNV proposes electing Option 1 since the ±35 target is met for both non-steam trap and steam trap strata separately if RIE chooses to report non-steam trap results by themselves. The expected annual and 3-year rolling precisions are shown for each option for planning purposes to show that 3-year precision targets are being met with the number of sites proposed. However, DNV notes that in PY2021, the evaluators did not report a 3-year combined precision (reported as N/A) since steam traps were not evaluated and assumed to have a 100% RR. Similarly, in PY2022 since the 3-year combined precision would roll in PY2021 results, it is not appropriate to report a 3-year combined precision. DNV proposes to report the 3-year

[3] The 2021 values are reflective of only non trap sites because a realization rate was assumed for steam traps in 2021 instead of a realization rate estimated from an evaluation.

[4] The 2021 values are reflective of only non trap sites only because a realization rate was assumed for steam traps in 2021 instead of a realization rate estimated from an evaluation.

combined precision as N/A which is consistent with the approach from the last program year but continues to target 1-year precisions that would allow for 20% precision at the 80% confidence level assuming the availability of 3 years of evaluated results.

APPENDIX E. SITE REPORTS

Individual site reports can be found in the following pages.

RI CUSTOM GAS EVALUATION SITE SPECIFIC MEASUREMENT AND VERIFICATION REPORT

Site ID: RIG22N073

Report Date: 7/19/24

Program Administrator	National Grid	
Application ID(s)	9291886 (parent),11907162 (child); 9465570 (parent),11979059 (child)	
Project Type	New construction	
Program Year	2022	
Evaluation Firm	DNV	
Evaluation Engineer	Matthew Piana	
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1 EVALUATED SITE SUMMARY AND RESULTS

The evaluated project was installed at a plastic fabrication facility. The facility produces plastic that is used for food packaging purposes. The project consisted of the installation of two types of ovens, a machine direction orientation oven (MDO oven) and a transition direction orientation oven (TDO oven). The MDO oven is heated using a hot oil thermal fluid heater and the TDO oven is heated using direct fired burners. These two ovens combined amount to a production line of over 100 meters in length. As the plastic film passes through the two ovens, it is heated and stretched in order to achieve the desired width and thickness. As the plastic passes through the two ovens, it enters at a width of approximately two meters and exits the end of the production line at a width of approximately eight meters. The two installed project measures are defined as the following:

- M1: install a direct fired transition direction orientation oven (TDO oven)
- M2: install a thermal fluid heater machine direction orientation oven (MDO oven)

Both measures were installed as part of a production expansion at the facility where a new production line was installed. Gas savings result from the difference in efficiencies between the installed and baseline systems. The total tracking savings for these two measures are 85,009 therms.

The evaluation results are presented in Table 1-1. The tracking analysis included spreadsheets that model gas consumption based on operational data of the TDO oven and thermal fluid heater. The evaluator visited the site and confirmed the installation and operation of the newly installed equipment. The evaluator also conducted an interview with the site contact to learn more about the operation of the direct-fired TDO oven and thermal fluid heater MDO oven. The evaluator did not install any metering for this site due to the availability of trend data from the computer systems monitoring the direct-fired TDO oven and the thermal fluid heater MDO oven. The evaluated first-year savings are 11% more than the applicant estimated savings value.

Table 1-1. Evaluation results summary

PA Application ID	Measure Name		Annual Savings (therms)
9291886 (parent)/11907162 (child)	M1: Direct-fired transition direction orientation oven (TDO oven)	Tracked	72,905
		Evaluated	79,506
		Realization Rate	109%
9465570 (parent)/11979059 (child)	M2: Thermal fluid heater machine direction orientation oven (MDO oven)	Tracked	12,105
		Evaluated	14,936
		Realization Rate	123%
	Total	**Tracked**	**85,010**
		Evaluated	**94,442**
		Realization Rate	**111%**

1.1 Explanation of deviations from tracking

The evaluated first-year savings are 11% higher than the applicant-reported savings. The evaluator-collected trend data showed the thermal fluid heater MDO oven and the TDO oven were both operating at a lower level of efficiency than the applicant predicted in their calculations. By adjusting the efficiency in both baseline and installed cases, the evaluator had a realization rate of 111% for the overall project. Further details regarding deviations from the tracking savings are presented in Section 3.

1.2 Recommendations for program designers & implementers

There are no recommendations at this time.

1.3 Customer alert

There are no customer alerts.

2 EVALUATED MEASURES

The following sections present the evaluation procedure, including the findings from an in-depth review of the supplied applicant calculations and the evaluation methodology determined to be the best fit for the site and information available. The evaluated project consisted of two measures: the installation of a TDO oven and a thermal fluid heater.

2.1 Application information and applicant savings methodology

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

2.2 Applicant description of baseline

The applicant classified both M1 and M2 as new construction measures with machinery of the same capacities and lower efficiencies as the baseline. The baseline base for M1 is a TDO oven where the necessary heat is supplied by hot oil from a thermal fluid heater operating with an efficiency of 68%. For M2, the baseline case is an MDO oven running on a thermal fluid heater with an efficiency of 71.4%. Table 2-1 summarizes the critical applicant baseline parameters.

Table 2-1. Applicant baseline key parameters

		BASELINE	
Measure	**Parameter**	**Value(s)**	**Source of Parameter Value**
M1: Direct-fired transition direction orientation oven (TDO oven)	Thermal efficiency	68%	Vendor quote
M1: Direct-fired transition direction orientation oven (TDO oven)	Annual operation hours	8,000 hours	Customer assumed
M1: Direct-fired transition direction orientation oven (TDO oven)	Required hourly load to heat oven air	2,529,534 Btu/hour	Post-installation operational data
M2: Thermal fluid heater machine direction orientation oven (MDO oven)	Thermal efficiency	71.4%	Vendor quote
M2: Thermal fluid heater machine direction orientation oven (MDO oven)	Annual operation hours	8,000	Customer assumed
M2: Thermal fluid heater machine direction orientation oven (MDO oven)	Average hourly load	984,545 Btu/hour	Post-installation operational data contractor-collected
M1 and M2	Annual pounds of plastic production	113,819,200 lbs	Applicant estimated in the calculation spreadsheet

2.2.1 Applicant description of installed equipment and operation

Table 2-2 summarizes the key proposed applicant parameters with the installed insulation.

Table 2-2. Applicant proposed key parameters

Measure	Parameter	PROPOSED/INSTALLED Value(s)	PROPOSED/INSTALLED Source of Parameter Value
M1: Direct-fired transition direction orientation oven (TDO oven)	Thermal efficiency	90.1%	Vendor quote
M1: Direct-fired transition direction orientation oven (TDO oven)	Annual operation hours	8,000 hours	Customer-assumed
M1: Direct-fired transition direction orientation oven (TDO oven)	Required hourly load to heat oven air	2,529,534 Btu/hour	Post-installation operational data
M2: Thermal fluid heater machine direction orientation oven (MDO oven)	Thermal efficiency	80.2%	Vendor quote
M2: Thermal fluid heater machine direction orientation oven (MDO oven)	Annual operation hours	8,000 hours	Customer assumed
M2: Thermal fluid heater machine direction orientation oven (MDO oven)	Average hourly load	984,545 Btu/hour	Post-installation operational data contractor collected
M1 and M2	Annual pounds of plastic production	113,819,200 lbs	Applicant estimated in the calculation spreadsheet

2.2.2 Applicant energy savings algorithm

The applicant used spreadsheet-based models to calculate savings for both M1 and M2. The spreadsheet models utilize post-installation operational data from the TDO and MDO ovens to calculate savings for both M1 and M2. To calculate the savings for M1 (TDO oven) the applicant used the following algorithms:

$$Savings_{TDO} = G_{baseline} - G_{installed}$$

where:

$G_{baseline}$ = TDO oven baseline gas consumption
$G_{installed}$= TDO oven installed gas consumption

The applicant calculated the TDO oven installed gas consumption according to the following algorithm:

$$G_{installed} = \frac{\dot{G}_{avg} \times h}{100{,}000}$$

where:

h= Annual operation hours of TDO oven (8,000 hours)
$\dot{G}_{avg}$= average hourly gas consumption (BTU/hour)
$100{,}000$= BTU to therm conversion factor

In order to calculate the average hourly gas consumption, the applicant used operational data from the TDO oven. Within the TDO oven there are 37 burners. These 37 burners are split into three zones. The three zones are preheating, stretching, and annealing. There are 11 burners in the preheating zone, (each with a capacity of 160kW or 545,939 Btu/hr), 10 burners in the stretching zone (each with a capacity of 54 kW or 184,254 Btu/hr), and 16 burners in the annealing zone (each with a capacity of 54 kW or 184,254 Btu/hr). Using operational firing rate data from the TDO oven burners, the applicant calculated the average hourly gas consumption for each zone according to the following algorithm:

$$\dot{G}_{zone} = \sum_{1}^{n} fr \times c$$

where:

$\dot{G}_{zone}$= hourly gas consumption of zone (kW)
fr = firing rate (%)
c = capacity of zone's burner (preheating: 160 kW, stretching: 54 kW, annealing: 54 kW)
n = number of burners in zone (preheating: 11, stretching: 10, annealing: 16)

The applicant then summed the gas consumption of the three zones to get hourly gas consumption values according to the following algorithm:

$$\dot{G}_h = \sum_{1}^{3} \dot{G}_{zone}$$

where:

$\dot{G}_h$= hourly gas consumption (kW)
$\dot{G}_{zone}$= hourly gas consumption of zone (kW)

The applicant then took an average of all the hourly gas consumption values ($\dot{G}_h$) to get the average hourly gas consumption value of the TDO oven ($\dot{G}_{avg}$) according to the following algorithm:

$$\dot{G}_{avg} = \dot{G}_h \times 3{,}412$$

where:

$\dot{G}_{avg}$= average hourly gas consumption of TDO oven
$\dot{G}_h$= average hourly gas consumption of TDO oven zones
3,412= kW to Btu/hr conversion

In order to calculate the TDO oven baseline gas consumption, the applicant calculated the required energy to heat the TDO oven air based on oven operational data. The TDO oven utilizes a heat recovery system in order to reduce its heating load. The heat recovery system mixes hot exhaust air from the TDO oven with air from the production floor and sends it to the TDO oven. This reduces the heating load of the TDO oven by supplying air to the oven that is hotter than air from the production floor. In the baseline case, the oven is heated using a thermal fluid heater rather than direct fired burners and no heat recovery system is involved. The applicant calculated the required hourly energy to heat the TDO oven air (load) according to the following algorithm:

$$\dot{A} = 1.08 \times (T_o - T_i) \times CFM_{avg}$$

where:

$\dot{A}$= required hourly energy to heat air, load (Btu/hour)
1.08 = air constant (Btu-min/ft^3-hr-°F)
T_o= average temperature of air exiting heat recovery (337 °F)
T_i= average temperature of air entering heat recovery (151 °F)
CFM_{avg}= average rate of air supplied to TDO oven by fans (12,573 ft^3/min)

The applicant then used the required hourly energy to heat air value to calculate the baseline gas consumption of the TDO oven according to the following algorithm:

$$\dot{G}_{baseline} = \frac{\dot{A}}{\eta_{btfh}}$$

where:

$\dot{G}_{baseline}$= baseline hourly gas consumption (Btu/hour)
$\dot{A}$= required hourly energy to heat air (Btu/hour)
η_{btfh}= efficiency of baseline TDO oven (68%)

The applicant then used the baseline hourly gas consumption to calculate the baseline annual gas consumption according to the following algorithm:

$$G_{baseline} = \frac{\dot{G}_{baseline} \times h}{100{,}000}$$

where:

$\dot{G}_{baseline}$= baseline hourly gas consumption (Btu/hour)
h= annual operation hours (8,000 hours)
100,000= Btu to therm conversion factor

To calculate the savings for M2 (MDO oven) the applicant used the following algorithms:

$$Savings_{MDO} = G_{baseline} - G_{installed}$$

where:

$G_{baseline}$= MDO oven baseline gas consumption
$G_{installed}$= MDO oven installed gas consumption

The applicant calculated the MDO oven baseline gas consumption according to the following algorithm:

$$G_{baseline} = \frac{\dot{D}_{avg} \times h}{\eta_{MDO-b} \times 100{,}000}$$

where:

h= Annual operation hours of TDO oven (8,000 hours)
$\dot{D}_{avg}$= average hourly heating demand (Btu/hour)
η_{MDO-b}= baseline MDO oven thermal fluid heater efficiency (71.4 %)
100,000= Btu to therm conversion factor

The applicant determined the average hourly demand based on post-installation thermal fluid heater operational data according to the following algorithm:

$$\dot{D}_{avg} = \dot{v} \times (T_o - T_i) \times 60 \times 0.45 \times 8.35$$

where:

$\dot{v}$= flow of hot oil, therminol 55 (199 gallons/minute)
T_o= hot oil outlet temperature (390 °F)
T_i= hot oil inlet temperature (368 °F)
60= per minute to per hour conversion
0.45= heat capacity of therminol 55 (Btu/lb-°F)
8.35= density of therminol 55 (lb/gallon)

The applicant calculated the MDO oven installed gas consumption according to the following algorithm:

$$G_{installed} = \frac{\dot{D}_{avg} \times h}{\eta_{MDO-i}}$$

where:

h= Annual operation hours of TDO oven (8,000 hours)
$\dot{D}_{avg}$= average hourly heating demand (Btu/hour)
η_{MDO-i}= installed MDO oven thermal fluid heater efficiency (80.2 %)

2.2.3 Evaluation assessment of applicant methodology

The evaluator found the overall applicant evaluation methodology to be appropriate, however the evaluator adjusted the efficiencies of the baselines for the TDO and MDO ovens according to the difference between the proposed efficiencies and the installed efficiencies calculated from operational data. The applicant did not adjust the baseline efficiencies in this manner. In addition, the evaluator found applicant used heat capacity and density of therminol 55, which did not match the spec sheet. The evaluator updated the calculation to use heat capacity of 0.602 Btu/lbF and density of 6.28 lb/gallon per the specification sheet for therminol 55 at 380°F.

2.3 On-site inspection and metering

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

2.3.1 Summary of on-site findings

During the site visit, the evaluator verified that the TDO and MDO ovens were installed and operational. The site contact gave the evaluator a tour of the newly installed production line and showed the evaluator the on-board computer systems that continuously monitor and log operational parameters. The evaluator found the installed machinery to match the scope of the project. The evaluator did not install any metering while on site and was not permitted to take any photos. Table 2-3 summarizes the evaluator measure verification.

Table 2-3. Measure verification

Measure Name	Verification Method	Verification Result
M1: Direct-fired transition direction orientation oven (TDO oven)	Visual verification and site contact interview	Measure installed and operating as intended
M2: Thermal fluid heater machine direction orientation oven (MDO oven)	Visual verification and site contact interview	Measure installed and operating as intended

2.3.2 Measured and logged data

The evaluator did not deploy any data logging equipment on site. The site contact provided the evaluator with operational data for the TDO and MDO ovens for the month of May 2024. Table 2-4 presents the operational data provided to evaluators by the site contact.

Table 2-4. Evaluation data collection

Source	Parameter	Interval	Duration
TDO oven EMS	Firing rate of all 11 preheating burners	Varied	1 month
TDO oven EMS	Firing rate of all 10 stretching burners	Varied	1 month
TDO oven EMS	Firing rate of all 16 annealing burners	Varied	1 month
TDO oven EMS	Preheating supply fan speed	Varied	1 month
TDO oven EMS	Annealing supply fan speed	Varied	1 month
TDO oven EMS	Dryer supply fan speed	Varied	1 month
TDO oven EMS	Heat recovery temperature supply 1	Varied	1 month
TDO oven EMS	Heat recovery temperature supply 2	Varied	1 month
TDO oven EMS	Heat recovery temperature exhaust 1	Varied	1 month
MDO thermal fluid heater EMS	Hot oil flow	5-min	1 month
MDO thermal fluid heater EMS	Hot oil inlet temperature	5-min	1 month
MDO thermal fluid heater EMS	Hot oil outlet temperature	5-min	1 month
Site contact	Pounds of plastic produced	1-month	17 months

M1: Direct-fired transition direction orientation oven (TDO oven):

Within the TDO oven there are three sections: preheating, stretching, and annealing. Within each of the three TDO oven sections, there is a series of burners. The direct-fired burners in each section of the TDO oven provide heat the plastic as it travels through the oven in order to aid in stretching it to the desired width and thickness. The capacity of these burners varies by section of the TDO oven. Preheating burners have a capacity of 160 kW (545,939 Btu/hr), stretching burners a capacity of 54 kW (184,254 Btu/hr), and annealing burners a capacity of 54 kW (184,254 Btu/hr). As outlined in Table 2-4, the evaluator gathered firing rate data on all 37 TDO oven burners. The evaluator used these firing rates to determine the rate at which gas is burned in the TDO oven. Figure 2-1 shows the firing rate for all 11 burners in the preheating section of the TDO oven for the month of May 2024.

Figure 2-1. Firing rate of TDO oven preheating burners

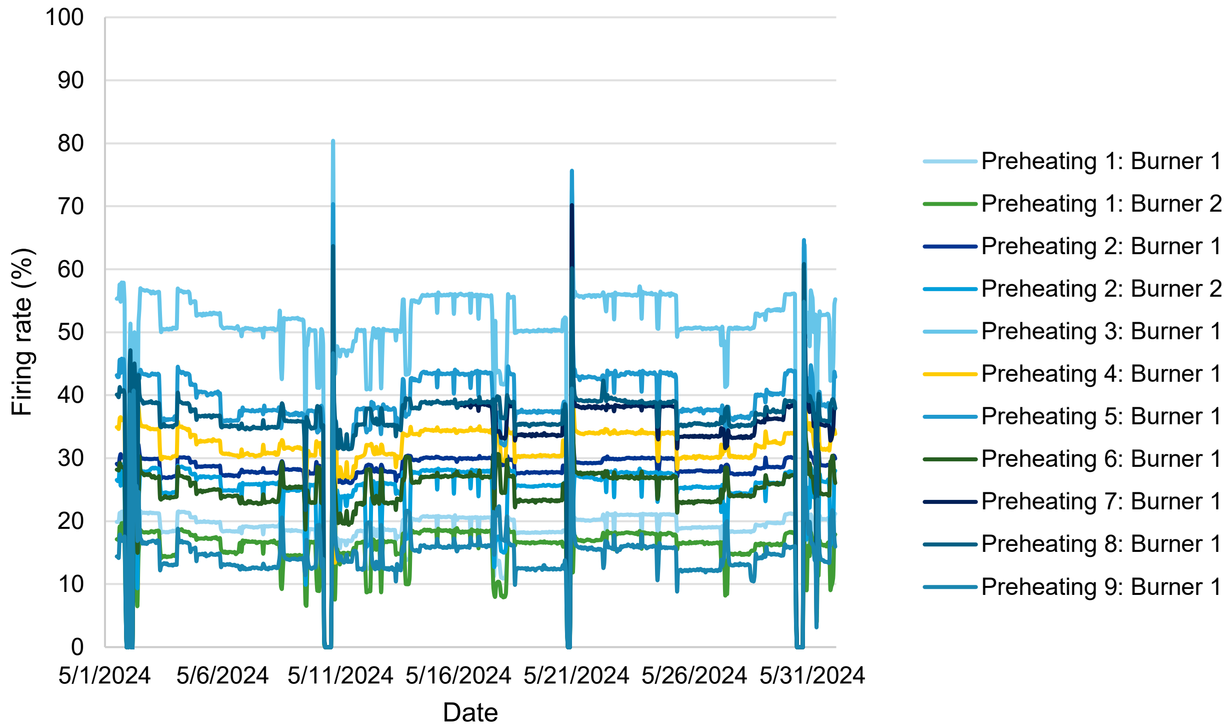


Figure 2-2 shows the firing rate for all ten burners in the drawing section of the TDO oven for the month of May 2024.

Figure 2-2. Firing rate of TDO oven drawing burners

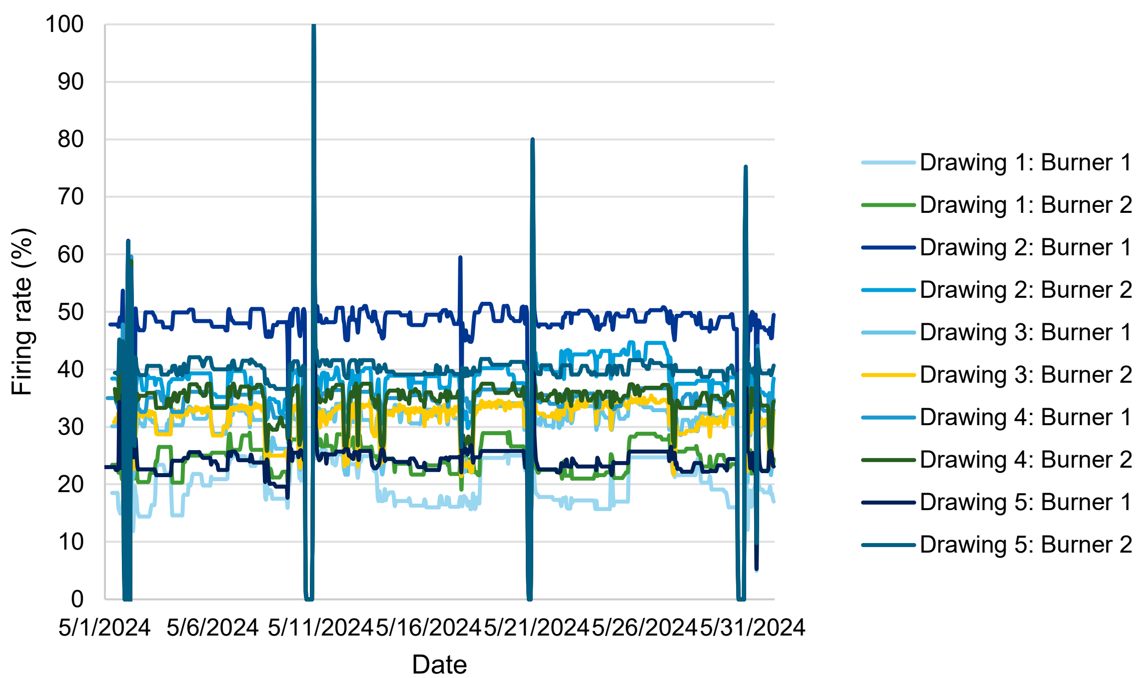
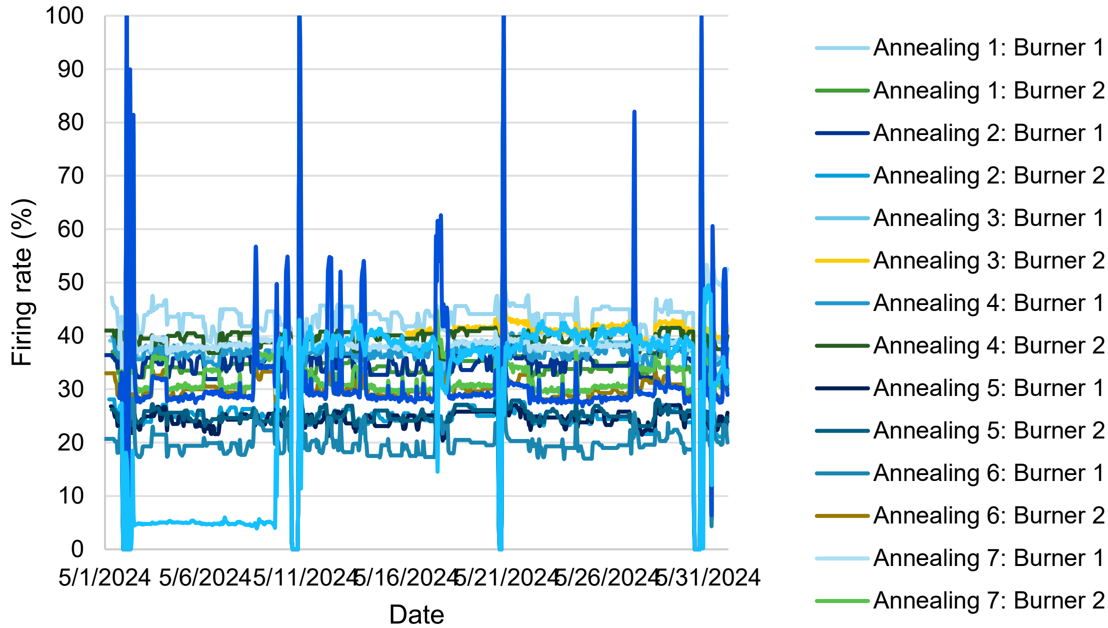


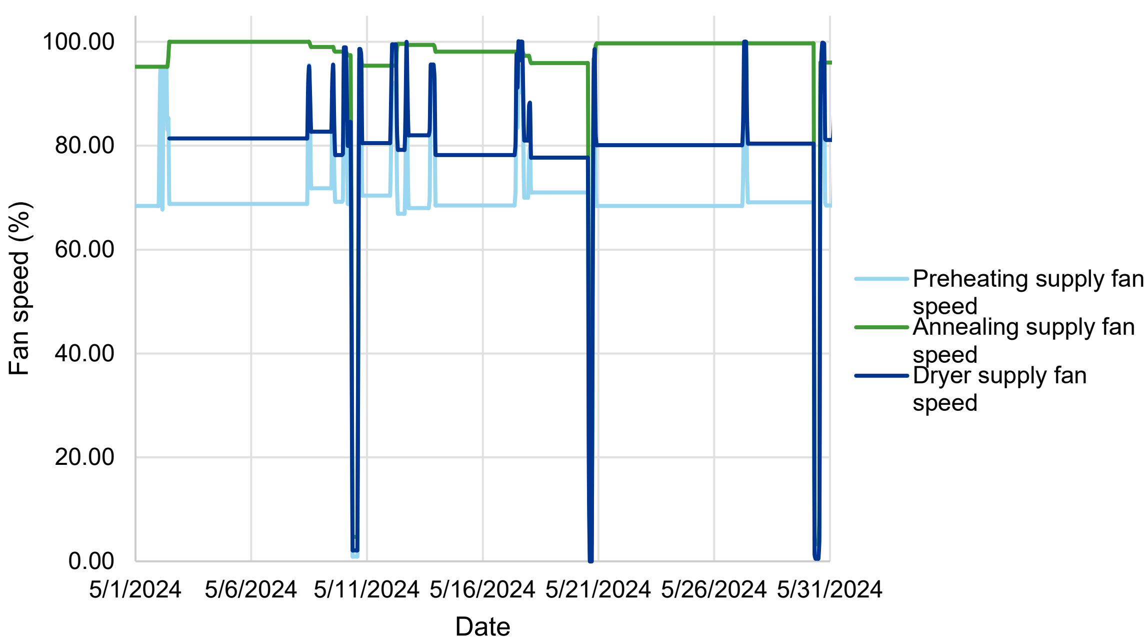
Figure 2-3 shows the firing rate for all 16 burners in the preheating section of the TDO oven for the month of May 2024.

Figure 2-3. Firing rate of TDO oven annealing burners



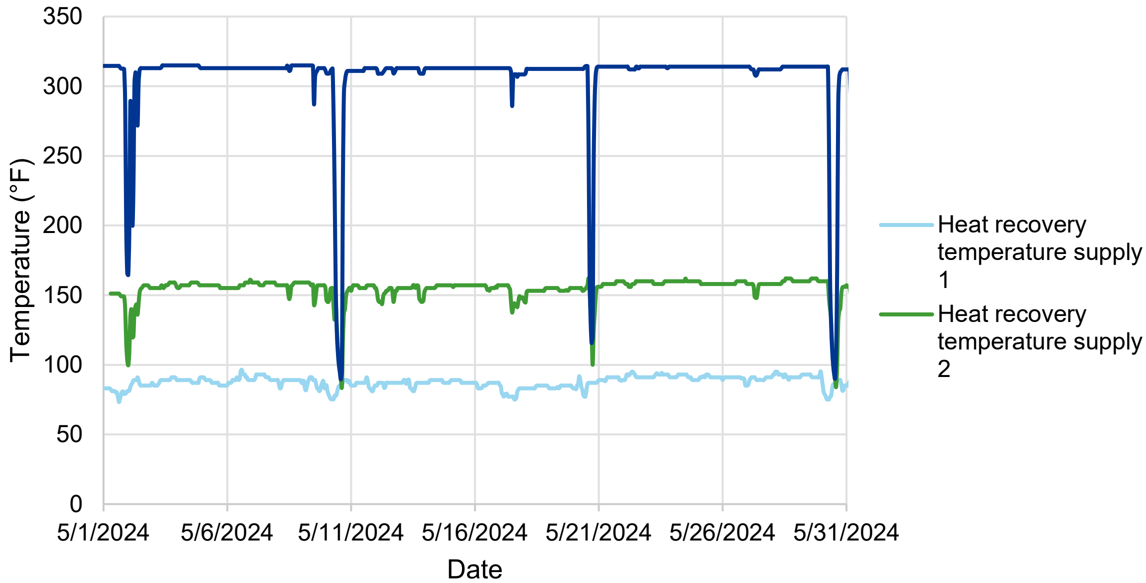
Each section of the TDO oven is supplied with the required amount of air in order to maintain ideal conditions for the combustion of the burners and the heating of the plastic. As outlined in Table 2-4, the evaluator gathered the fan speeds for each section of the TDO oven from the TDO EMS system. Figure 2-4 shows the fan speeds for the preheating, annealing, and dryer sections of the TDO oven for the month of May 2024.

Figure 2-4. Fan speeds TDO oven



In addition to the fan speeds of each section of the TDO oven, the evaluator also gathered the temperatures of the TDO oven air streams from the TDO oven EMS system. These temperatures allow for the calculation of the hourly load required to heat the TDO oven air. Figure 2-5 shows the temperatures of the air flows in the heat recovery system for the month of May 2024.

Figure 2-5 Temperatures of air flows heat recovery system TDO oven



M2: Thermal fluid heater machine direction orientation oven (MDO oven):

Figure 2-6 shows the gallon per minute flow rate of the hot oil in the MDO oven thermal fluid heater system for the month of May 2024. This thermal fluid heater hot oil flow rate was used in combination with the hot oil inlet and outlet temperatures from Figure 2-7 in order to calculate the operating load of the MDO oven and its efficiency.

Figure 2-6 Thermal fluid heater hot oil flow rate

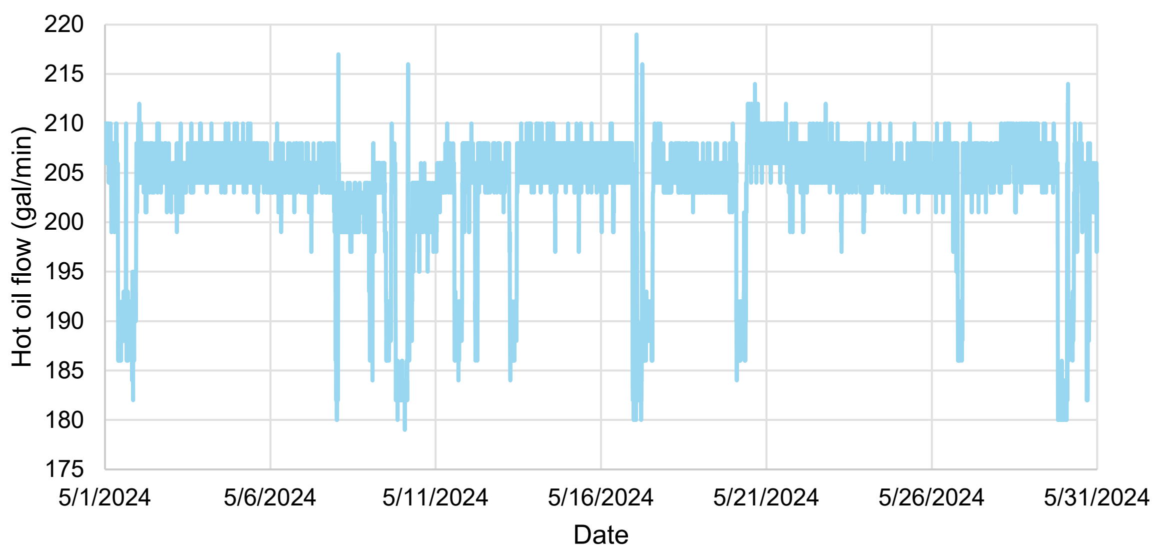


Figure 2-7 shows the inlet and outlet temperatures of the hot oil in the MDO oven thermal fluid heater system for the month of May 2024.

Figure 2-7 Thermal fluid heater hot oil inlet and outlet temperatures

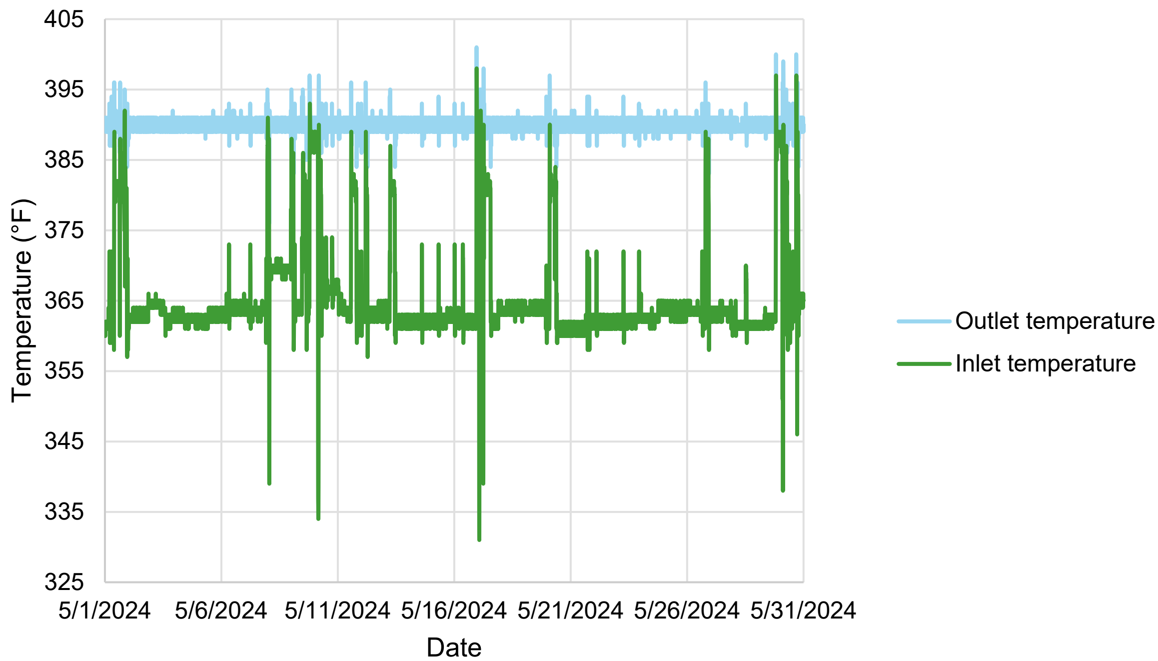
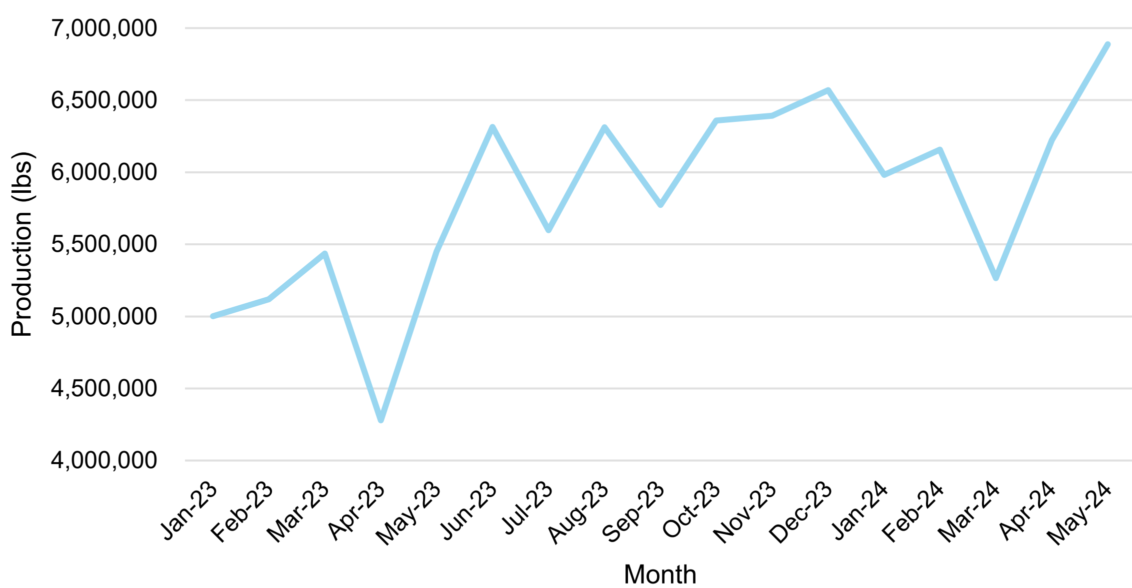


Figure 2-8 shows the production data provided to the evaluator by the site contact for January 2023 through May 2024. The evaluator used this production data in order to create a representative yearly production profile, which is discussed in Section 2.4.2.

Figure 2-8 Pounds of plastic produced by month



2.4 Evaluation methods and findings

This section describes the evaluator methods and findings.

2.4.1 Evaluation description of baseline

The evaluator reviewed the project files and interviewed the site contact to gather information on the baseline. The evaluator classified both measures as lost opportunity measures with single ISP baselines.

2.4.2 Evaluation calculation method

The evaluator reviewed the applicant savings spreadsheets and requested the necessary operational data from the site contact in order to update the savings calculations. The evaluator updated the applicant savings calculation spreadsheets based on the data the site contact provided for May 2024. Because the evaluator updated the applicant savings spreadsheets based on current operational data, the same equations from Section 2.2.2 apply to the evaluator calculations presented in this section.

The applicant calculated hourly loads for both the TDO and MDO ovens and multiplied these loads with 8,000 hours of annual operation to determine the baseline and proposed consumptions. Instead of using applicant estimated production load, the evaluator used May 2024 TDO and MDO oven operational data in combination with the production data from Figure 2-8 to correlate load and production and determined the baseline and installed consumptions based on these correlations. The evaluator also adjusted the baseline efficiencies of the TDO and MDO ovens based on the calculated efficiencies of the TDO and MDO ovens from May 2024 operational data. The TDO oven baseline efficiency was adjusted from 68% to 67% and the MDO oven baseline efficiency was adjusted from 71.4% to 66.2%, based on the pro-rated ratio between the evaluated installed efficiency and spec sheet efficiency the applicant used.

The evaluator also updated the heat capacity and density values of therminol 55, to 0.602 Btu/lbF and 6.28 lb/gallon, respectively, per the specification sheet for physical properties at 380°F.

The site contact provided the evaluator with operational data on the MDO oven thermal fluid heater at constant five-minute intervals. Figure 2-9 shows a sample of the MDO oven thermal fluid heater data the site contact provided, which was used to update the applicant savings spreadsheets.

Figure 2-9. MDO oven thermal fluid heater operational data

Date	Fuel inlet Flow ft^3/hr	Inlet Temp °F	Outlet Flow gal/min	Outlet Temp °F
5/1/2024 12:00:00 PM EDT	1750	360	208	389
5/1/2024 12:05:00 PM EDT	1735	360	208	389
5/1/2024 12:10:00 PM EDT	1812	360	208	391
5/1/2024 12:15:00 PM EDT	1719	362	210	390
5/1/2024 12:20:00 PM EDT	1688	362	210	390
5/1/2024 12:25:00 PM EDT	1735	360	208	390
5/1/2024 12:30:00 PM EDT	1735	361	210	390
5/1/2024 12:35:00 PM EDT	1735	361	206	390
5/1/2024 12:40:00 PM EDT	1735	361	210	391
5/1/2024 12:45:00 PM EDT	1688	362	210	391
5/1/2024 12:50:00 PM EDT	1673	361	206	390
5/1/2024 12:55:00 PM EDT	1735	361	206	390
5/1/2024 01:00:00 PM EDT	1735	361	210	390
5/1/2024 01:05:00 PM EDT	1704	362	206	390
5/1/2024 01:10:00 PM EDT	1688	362	208	390
5/1/2024 01:15:00 PM EDT	1688	361	208	390
5/1/2024 01:20:00 PM EDT	1673	361	208	389
5/1/2024 01:25:00 PM EDT	1719	361	206	390

The TDO oven operational data that site contact provided, was collected in a different control system, and more complex than that of the MDO oven thermal fluid heater. The site contact provided the evaluator with a large amount of TDO oven operational data which was necessary to update the applicant savings calculation spreadsheets. In total the site contact provided the evaluator with 83 tabs of excel data. Each tab of excel data corresponded to a different operational parameter of the TDO oven. Unlike the MDO thermal fluid heater operational data, the TDO oven parameters were not given at even five-minute intervals. Rather, each time a parameter change was logged by the TDO oven computer system, a new data point was generated at a random timestamp. This resulted in a complex dataset that needed to be formatted into weighted hourly averages by the evaluator in order to update the applicant savings calculation spreadsheets. Figure 2-10 shows a sample of the TDO oven thermal fluid heater data the site contact provided.

Figure 2-10. Sample of TDO oven operational data

1856 TPY			
StrTdoExa.DrwAnn.Sup.Bur.OutSet			
Stretching: TDO External Airing: Drawing Annealing: Supply: Burner: Output Setpoint			
Date	Time	Value	Unit
2024.05.01	10:32:07.434	25.9	%
2024.05.01	11:11:49.884	25.3	%
2024.05.01	11:43:29.444	25.8	%
2024.05.01	11:44:14.248	26.3	%
2024.05.01	12:08:08.356	25.8	%
2024.05.01	12:31:19.584	25.3	%
2024.05.01	12:38:25.362	25.8	%
2024.05.01	12:39:26.641	26.3	%
2024.05.01	12:44:48.086	25.8	%
2024.05.01	12:46:28.087	25.3	%
2024.05.01	12:52:20.740	25.8	%
2024.05.01	12:53:14.495	26.3	%
2024.05.01	12:56:01.861	25.8	%
2024.05.01	12:58:35.627	25.3	%

The evaluator handled the 83 tabs of TDO oven data with random timestamps by developing a Python script to read all 83 tabs and generate weighted hourly averages for each parameter for each hour of May 2024. The Python script processed all of the oprational data and output one CSV file with weighted hourly averages for all 83 parameters. With these weighted hourly averages, the evaluator updated the applicant savings spreadsheets.

After updating the applicant savings spreadsheets, the evaluator determined the evaluated therm per pound of plastic produced energy intensity for the TDO and MDO ovens. Using these energy intensities, the evaluator determined the evaluated gas consumption of the installed and baseline systems based on the plastic production values presented in Figure 2-8.

The evaluator utilized the first five months of 2024 production data to determine the average pounds of plastic produced per month. The average for the first five months of 2024 was 6,102,917 pounds of plastic. The evaluator calculated savings based on a yearly production profile where 6,102,917 pounds of plastic is produced each month.

3 FINAL RESULTS

This section summarizes the evaluation results determined in the analysis above. The evaluator found the TDO oven to be saving 9% more energy than the applicant calculated and the MDO oven thermal fluid heater to be saving 23% more. The evaluator calculated savings based on a monthly production of plastic basis as where the applicant calculated savings based on hourly loads and 8,000 annual hours of operation. Table 3-1 is a summary of key applicant and evaluated parameters.

Table 3-1. Summary of key parameters

Parameter	BASELINE		PROPOSED / INSTALLED	
	Tracking Value(s)	Evaluation Value(s)	Tracking Value(s)	Evaluation Value(s)
M1: TDO oven efficiency	68%	67%	90.1 %	88.6%
M1: TDO oven Btu/hr gas load	2,808,592	3,092,560	2,808,592	3,092,560
M1: TDO oven Btu/hr air heating load	2,529,534	2,739,549	2,529,534	2,739,549
M2: MDO thermal fluid heater efficiency	71.4%	66.2%	80.2%	74.3%
M2: Specific heat of heating fluid	0.45 Btu/lb×°F	0.602 Btu/lb×°F	0.45 Btu/lb×°F	0.602 Btu/lb×°F
M2: Density heat of heating fluid	8.35 lb/gal	6.28 lb/gal	8.35 lb/gal	6.28 lb/gal
M2: MDO thermal fluid heater Btu/hr load	984,545	1,138,614	984,545	1,138,614
M1 and M2: Annual pounds of plastic produced	113,819,200	73,234,999	113,819,200	73,234,999

3.1 Explanation of differences

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

Table 3-2. Summary of deviations

End-use	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
Process	M1 and M2: Annual production	Annual pounds of plastic produced	-1.4%	The evaluated annual plastic production is 40,584,201 pounds less than the applicant predicted load. This reduced the overall consumption for the production line and reduced the savings.
Process	M1: TDO oven heating load	Btu/hr heating load of TDO oven	7.1%	The evaluated TDO airflow is higher than applicant estimated, which increased the heating load for both baseline and installed cases.
Process	M1: TDO oven efficiency	Thermal efficiency of TDO oven	1.6%	The evaluated thermal efficiency of the TDO oven is less than the applicant proposed efficiency, for both baseline and installed cases. The higher efficiency difference resulted in a savings increase.
Process	M2: MDO oven heating load	Btu/hr heating load of MDO oven	2.1%	The evaluated hourly heating load of the MDO oven is higher than the applicant predicted load. This caused an increase in savings.
Process	M2: MDO oven heating load	heat capacity and density of heating fluid	0.5%	The evaluator updated the specific heat and density of heating fluid. This caused an increase in savings.
Process	M2: MDO oven efficiency	Thermal efficiency of MDO oven	1.1%	The evaluated thermal efficiency of the MDO oven is less than the applicant proposed efficiency, for both baseline and installed cases. The higher efficiency difference resulted in a savings increase.

3.2 Lifetime savings

The evaluator classified the measure as a lost opportunity with an ISP single baseline. The evaluator calculated applicant and evaluated lifetime savings values using the following formula:

$$LAGI = FYS \times EUL$$

where:

$LAGI$ = lifetime adjusted gross impact (therm)

FYS = first year savings (therm)

EUL = measure life (years)

The evaluated lifetime savings are greater than the tracking lifetime savings due to the combined results of higher savings for the TDO oven and lower savings for the MDO oven thermal fluid heater. Table 3-3 provides a summary of key factors that influence the lifetime savings.

Table 3-3. Lifetime savings summary

Factor	Tracking	Application	Evaluator
Lifetime savings	1,275,150 therms	1,275,150 therms	1,416,623 therms
First year savings	85,010 therms	85,010 therms	94,442 therms
Measure lifetime	15 years	15 years	15 years
Baseline classification	New construction	New construction	Lost opportunity

The evaluation uses the same 15-year measure life as the applicant of process equipment. The evaluator first-year savings are greater than the applicant and tracking savings value.

3.3 Ancillary impacts

There are no ancillary impacts associated with this project.

RI CUSTOM GAS EVALUATION SITE SPECIFIC MEASUREMENT AND VERIFICATION REPORT

Site ID: RIG22N040

Report Date: 6/06/2024

Program Administrator	Rhode Island Energy	
Application ID(s)	13242101	
Project Type	Retrofit	
Program Year	2022	
Evaluation Firm	DMI	
Evaluation Engineer	Brian Paonessa	
Senior Engineer	Mickey Bush	

1 EVALUATED SITE SUMMARY AND RESULTS

The evaluated retrofit project was installed at an elementary school. The applicant installed a Runwise controller to automatically control the heating system. The heating system consists of two natural gas hot water boilers. The classrooms each have hot water radiators that modulate temperature via a hot water valve. The Runwise system installation included temperature sensors in 15 classrooms to measure the space temperature and additional sensors to measure the boiler hot water supply and return temperatures.

The applicant classified the measure as a retrofit with single baseline. Based on the information gathered during the site visit, the evaluator adjusted the measure classification to be an add-on with a single baseline. The add-on measure has a single baseline because the boilers are expected to outlast the Runwise system. The site indicated that they had no plans to modify the boilers or hot water system.

The evaluation results are presented in Table 1-1. The evaluator observed that baseline pre-retrofit controller was still present at the site and used as a backup. The evaluator determined that the pre-existing controller has similar energy saving sequences to the Runwise controller. The existing site conditions are discussed in Section 2.4.1. Additionally, the evaluator found that there was no meaningful change in natural gas usage at the site when the controller was installed, as shown in Section 2.4.2.

Table 1-1. Evaluation Results Summary

PA Application ID	Measure Name		Annual Savings (therms)
13242101	Runwise Heating Controls	Tracked	2,457
		Evaluated	0
		Realization Rate	0.0%

1.1 Explanation of Deviations from Tracking

The evaluated savings are 0% of the combined applicant-reported savings. The savings were decreased because the evaluator found that there was an existing controller installed prior to the Runwise installation. The existing controller had similar capabilities as the Runwise controller. Additionally, bill data from the site revealed that the site did not realize any energy savings from the installation of the controller.

1.2 Recommendations for Program Designers & Implementers

The evaluator recommends that the Runwise technology be reviewed to determine if further incentives for installing the technology are warranted. If further incentives are warranted, the evaluator recommends determining a method to repeatably and accurately determine the savings associated with the installation.

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 information available.

The project consisted of the installation of a Runwise controller to control the heating system. The controller has the following functionality:

1. Control of occupied and unoccupied space temperature setpoints
2. Control of the boiler (including the operation and supply water temperature) based on outside air temperature.
3. Cycling of the boilers based on indoor space temperature monitoring. The average of all space temperature sensors, which are installed in 15 classrooms, is monitored and the boilers are cycled to satisfy the occupied and unoccupied setpoints.

2.1 Application Information and Applicant Savings Methodology

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

2.2 Applicant Description of Baseline

The applicant classified the measure as a retrofit with a single baseline. The applicant described the baseline as the existing site conditions. The applicant identified that the boilers comprised a steam heating system. The applicant also stated that “the two boilers have standard outdoor temperature reset, which are the only means of automated control for the system which are offline.” The evaluator disagrees with the existing conditions described by the applicant, as discussed in section 2.4.1.

The applicant determined that the existing site used 23,476 therms/year, from December 2020 through November 2021. When normalized to heating degree days, based on a 65°F base temperature, the applicant determined that the 10-year weather normalized baseline energy use is 24,571 therms/year.

Table 2-1. Application 13242101 baseline summary

Operation Description	Value
Therms/Year (December 2020 – November 2021)	23,476
Therms/Year (Weather Normalized)	24,571
Existing Equipment Controls	Offline outdoor temperature reset controls

2.2.1 Applicant Description of Installed Equipment and Operation

The applicant considered the installed case as the baseline heating system with the Runwise system installed. The installation of the Runwise system includes the following energy saving sequences:

- The occupied period (6AM – 10PM) will maintain a space setpoint of 68°F.
- The unoccupied period (10PM – 6AM) will maintain a space setpoint of 64°F.
- The boilers will operate when the outside air temperature is less than 55°F during the day and 40°F during unoccupied periods and when the room temperature average reads below the target temperature setpoint. The boilers will be cycled off during all other times.
- The hot water temperature will be reset with the outside air temperature. The applicant did not provide a specific sequence of operation, but this appears to be the case based on the Evaluator’s review of the technology in Section 2.3.

2.2.2 Applicant Energy Savings Algorithm

The applicant calculated savings using a bill data analysis. The applicant used bill data from December 2020 through November 2021. The applicant determined the base load, or the non-weather-dependent load, as the load in the summer months between July and September. In cases where the average of the summer months was greater than the billed therms, the entire usage for that month was assumed to be the base load. The applicant also determined the quantity of heating degree days for each billed month based on Providence weather data as well as the average heating degree days over the prior 10-year span. The cutoff for the temperature in the heating degree calculation is unknown.

Table 2-2. Applicant Billed Therms and Heating Degree Day Summary

Bill Month	Billed Therms	Calculated Base Load Therms	Heating Degree Days (Billed Month/Year)	Average Heating Degree Days (Prior 10 Years)
January (2021)	4,675	47	1,015	1,063
February (2021)	4,858	47	913	922
March (2021)	4,114	47	741	785
April (2021)	2,516	47	434	462
May (2021)	1,256	47	193	190
June (2021)	131	47	6	33
July (2021)	75	47	7	1
August (2021)	46	46	1	1
September (2021)	20	20	14	50
October (2021)	177	47	171	285
November (2021)	2,430	47	502	618
December (2020)	3,178	47	894	887
Total	23,476	536	4,891	5,297

Next, the applicant normalized the December 2020 – November 2021 bill data to the 10-year average annual heating degree quantity with the following formula:

$$\text{Therms}_{\text{Normalized}} = (\text{Therms}_{\text{Billed}} - \text{Therms}_{\text{Base Load}}) \times \frac{\text{HDD}_{10-\text{Year}}}{\text{HDD}_{\text{Current}}}$$

Where,

$\text{Therms}_{\text{Normalized}}$ = The heating load therms (controlled by the Runwise system) normalized to the average heating degree days over a 10-year period

$\text{Therms}_{\text{Billed}}$ = The total therms billed each month over the course of the December 2020 – November 2021 period

$\text{Therms}_{\text{Base Load}}$ = The therms each month that were calculated to represent the non-weather-dependent loads not affected by Runwise, including domestic hot water loads or kitchen equipment.

$\text{HDD}_{10-\text{Year}}$ = The average heating degree days each month over the prior 10 years of data

$\text{HDD}_{\text{Current}}$ = The heating degree days in each month and year corresponding to the $\text{Therms}_{\text{Billed}}$ term.

The savings were then determined to be 10% of the monthly $\text{Therms}_{\text{Normalized}}$ quantity, as shown in Table 2-3. The applicant did not offer a basis for the 10% savings number.

Table 2-3. Applicant Savings

Bill Month	Normalized Therms	Savings Percent	Savings Therms
January (2021)	4,845	10%	484
February (2021)	4,857	10%	486
March (2021)	4,311	10%	431
April (2021)	2,628	10%	263
May (2021)	1,188	10%	119
June (2021)	455	10%	46
July (2021)	28*	10%	3
August (2021)	0	10%	0
September (2021)	0	10%	0
October (2021)	217	10%	22
November (2021)	2,935	10%	293
December (2020)	3,108	10%	311
Total	24,571	10%	2,457

*Calculated as the difference between the billed therms and base load therms, not normalized. It is unclear why this month uses a different formula from the rest.

The final savings for the application is 2,457 therms. The applicant documentation suggests that the applicant and the program administrator intended to change the savings factor to 5% to be more conservative, but this change was never reflected in the tracked savings.

2.2.3 Evaluation Assessment of Applicant Methodology

The evaluator agrees with the general approach of using a bill data analysis, but disagrees with simply applying a 10% savings factor to the weather normalized usage. No documentation for the 10% factor was provided. The evaluator's approach involves reviewing the potential sequences of operation for the equipment and verifying sequence changes via a pre- and post-install bill data review.

2.3 On-Site Inspection and Metering

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

2.3.1 Summary of On-site Findings

The evaluator conducted site-visits on February 15, 2024 and May 9, 2024. During the site visits, the evaluator interviewed the site contact, verified the installation of the Runwise system, collected trend data, and installed and picked up meter equipment. A summary of the on-site verification is provided in Table 2-4.

Table 2-4. Measure verification

Measure Name	Verification Method	Verification Result
Runwise Control System	On-site visual inspection & Trend Data	Observed the Runwise controller installed in boiler room. Observed Runwise was operational via computer graphics and trend data.

2.3.2 Measured and Logged Data

The evaluator collected trend data for 2/1/2024 through 4/26/2024 in 15-minute increments. The trend data includes the following relevant points:

- Boiler status (cycled on vs cycled off)
- Supply and return temperature (°F)
- Boilers/Pumps status (on/off for boiler 1 and boiler 2)
- Space temperature for 15 classrooms and the average of all 15.

The data was collected directly from the Runwise system. The data represented the instantaneous measurement at each 15-minute time period, as opposed to the average over the entire increment.

In order to verify the trend data, the evaluator installed HOBO UX100-014M temperature loggers with type K thermocouples on the hot water pump associated with each boiler and on the supply water temperature leaving each boiler. The meters were programmed to record at various increments ranging from 10 seconds to 5 minutes in order to adequately capture any instances where the boiler cycled off and back on. Table 2-5 summarizes the metered data. Temperature was captured on the boiler pumps as a proxy for on/off operation. The length of recorded data varies for each piece of equipment based on when the logger ran out of battery.

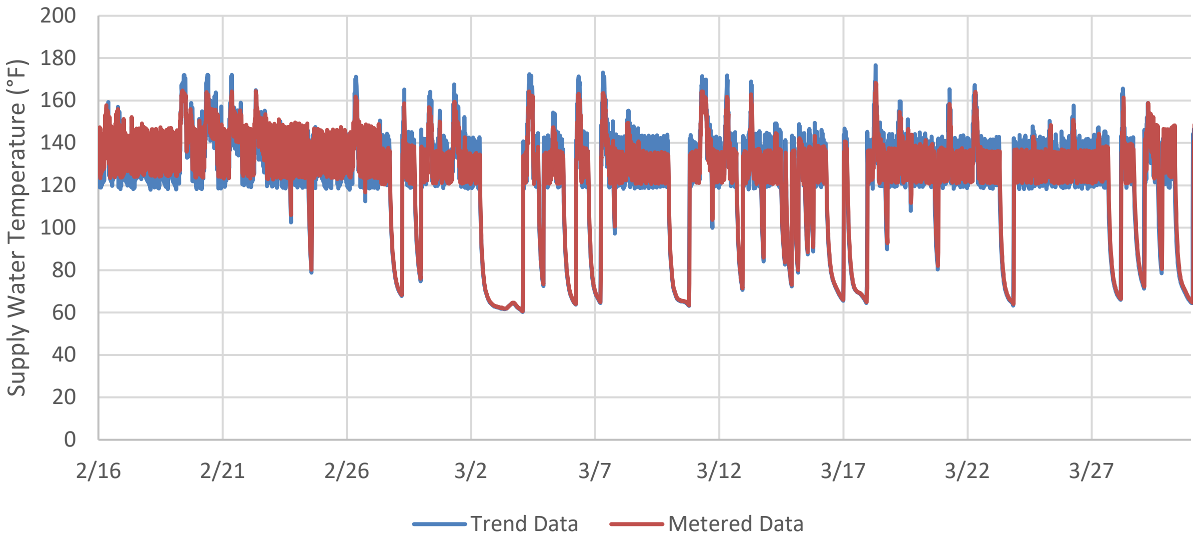
Table 2-5. Metered Data Collection

Metered Parameter	Recording Range	Time Step
Boiler 1 Pump Temperature (°F)	2/16/24-3/17/24	5 minutes
Boiler 1 Supply Water Temperature (°F)*	2/16/24-3/10/24	10 seconds
Boiler 2 Pump Temperature (°F)	2/16/24-3/31/24	5 minutes
Boiler 2 Supply Water Temperature (°F)	2/16/24-3/31/24	30 seconds

*Meter came unattached and did not record reliable data

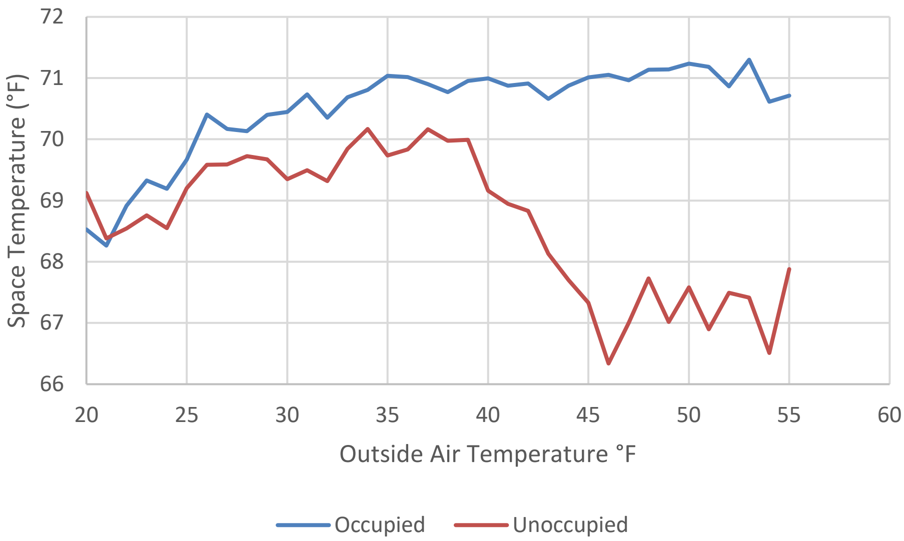
Figure 2-1 shows the trended and metered supply water temperature. The trend and meter data follow each other very closely, which confirms the trend data is accurate. Small differences between the trend and metered values can be attributed to the location of the temperature sensor and the instantaneous nature of the trends vs the metered data that records the average value over each time increment.

Figure 2-1. Trend vs meter data comparison



The average space temperature at each outside air temperature was found and broken into occupied (6AM-10PM, Monday-Friday) and unoccupied periods as shown in Figure 2-2. The evaluator observed that the average space temperature did appear to be set back during unoccupied periods.

Figure 2-2. Space temperature occupied and unoccupied periods



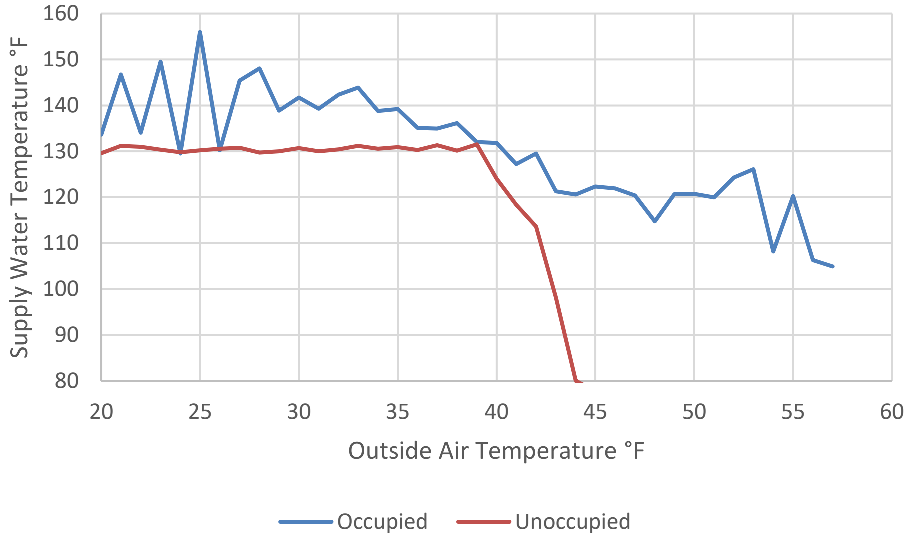
This is further corroborated with a time-of-day analysis, shown in Figure 2-3. It can be inferred that the boilers shut off during unoccupied periods and the temperature is allowed to coast downwards until the space temperature rises again at the start of the subsequent occupied period.

Figure 2-3. Time of day space temperatures (°F)

	Weekday						
Hour	1	2	3	4	5	6	7
0	67.5	69.7	69.7	69.7	70.1	70.4	67.6
1	67.6	69.5	69.6	69.6	69.9	70.2	67.5
2	67.6	69.4	69.5	69.4	69.7	70.1	67.5
3	67.8	69.3	69.4	69.2	69.7	70.0	67.6
4	68.0	69.3	69.3	69.2	69.7	69.8	67.6
5	68.3	69.5	69.4	69.4	69.9	69.7	67.7
6	68.6	70.0	69.7	69.8	70.2	69.7	67.9
7	69.2	70.5	70.2	70.0	70.4	69.6	67.9
8	70.0	70.7	70.8	70.6	70.9	69.6	68.0
9	70.6	70.8	71.2	70.9	70.9	69.5	67.9
10	70.7	70.9	71.4	71.1	71.2	69.3	67.9
11	70.8	70.9	71.4	71.1	71.1	69.0	67.7
12	70.9	70.9	71.5	71.1	71.2	68.8	67.6
13	70.8	71.1	71.5	71.2	71.3	68.7	67.7
14	70.9	71.0	71.5	71.3	71.4	68.5	67.7
15	71.0	71.0	71.6	71.3	71.4	68.5	67.6
16	70.8	70.9	71.4	71.2	71.4	68.3	67.6
17	70.7	70.9	71.3	71.2	71.2	68.2	67.3
18	70.6	70.8	71.1	71.1	71.1	68.1	67.2
19	70.4	70.5	70.9	70.9	71.0	68.0	67.1
20	70.1	70.2	70.7	70.7	70.9	67.9	67.2
21	69.9	70.1	70.4	70.5	70.8	67.8	67.2
22	69.8	69.9	70.1	70.3	70.7	67.7	67.2
23	69.8	69.7	69.8	70.2	70.6	67.6	67.3

The supply water temperature was also observed during occupied and unoccupied periods, as shown in Figure 2-4.

Figure 2-4. Occupied and unoccupied supply water temperatures



During the unoccupied periods, the supply water temperature maintains 130°F through a minimum 40°F outside air temperature. Above 40°F outside air temperature the boilers cycle off during unoccupied mode. It appears that the supply water temperature during occupied periods may reset with outside air temperature, specifically below 40°F as well. The sequences indicate the boilers should shut off during occupied periods with an outside air temperature above 55°F, but trend data was extremely limited during that outside air temperature range.

2.4 Evaluation Methods and Findings

This section describes the evaluator methods and findings.

2.4.1 Evaluation Description of Baseline

The evaluator reviewed the project files and interviewed the site contact to gather information on the baseline. The evaluator determined the control measure to be an add-on with a single baseline as the installed measure life is less than 2/3 of the life of the controlled heating system. The evaluator agrees that the baseline is the pre-existing conditions at the facilities, but disagrees with the pre-existing conditions described by the applicant.

The evaluator first discovered that the heating system was not steam, but hot water. The site indicated that steam used to be present at the facility but was changed-over, and the boilers converted, before the installation of the Runwise system. This ultimately does not impact the savings calculations, since a bill data review was used by the applicant.

Second, the evaluator discovered the existence of a Tekmar boiler controller. The site stated that this controller was operational before the Runwise system was installed, and remains operational as a backup if the Runwise system were to fail. The evaluator reviewed product literature for the Tekmar controller and found that it had the following functionality:

- An occupied and unoccupied temperature setting dial. The Tekmar controller adjusted the indoor air temperature based on the occupied and unoccupied space temperature setpoints, set at the dials.
- An outside air temperature reset. The Tekmar controller measures the outdoor temperature and as the outdoor temperature becomes colder, it balances the heat loss by making the heating supply water hotter.
- Boiler cycling controls. The control will cycle the boiler on and off at the minimum supply temperature to prevent overheating of the classrooms.

2.4.2 Evaluation Calculation Method

The evaluator compared the functionality of the existing Tekmar controller with the installed Runwise controller to identify any potential for savings. A comparison of the controls available between the Tekmar controller and the Runwise controller are shown below in Table 2-6.

Table 2-6. Runwise vs Tekmar controller comparison

Parameter	Tekmar Controller (Existing Baseline)	Runwise Controller (Installed Equipment)
Space Temperature Control	Occupied and unoccupied setpoints controlled via a dial on the controller.	Occupied setpoint is automatically set to a default of 68°F and unoccupied is a default of 64°F. Setpoints are adjustable via online interface.
Outside Air Temperature Reset Control	Supply water temperature is controlled based on outside air temperature.	Unoccupied supply water temperature is a constant 130°F until boilers shut off. Occupied supply water temperature may have some variation with outside air temperature.
Boiler Cycling	Boilers cycle off when at a minimum supply temperature to ensure the space temperature setpoints are not exceeded.	Boilers cycle off to meet the space temperature setpoints.

Based on the functionality of each controller, the evaluator concluded that there was likely no achievable savings from control sequences for installing the Runwise controller instead of continuing to utilize the

Tekmar controller. In addition, the site contact indicated that the Runwise system was installed for monitoring purposes, not direct energy savings.

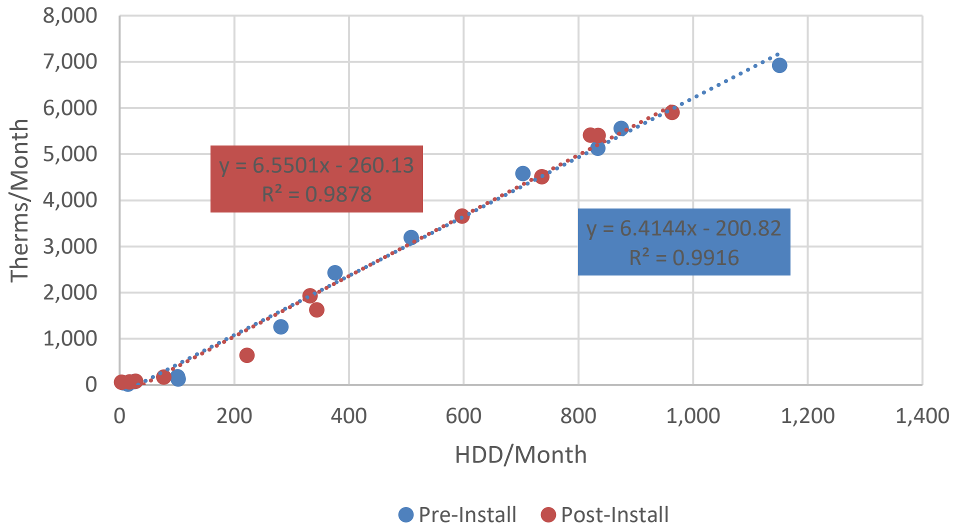
In order to confirm the lack of site savings, the evaluator compared pre- and post-install bill data at the site. The evaluator found the billed therms and heating degree days, based on Providence weather data, for the 12 months immediately preceding and following the installation of the Runwise system. The system was installed in early May 2022, so that month was not counted in either the pre- or post-install data. A 12-month period was chosen to attempt to minimize the affects of varying space loads over a longer time frame, despite the site indicating that there should be no changes to the natural gas use other than the installation of the Runwise system. Table 2-7 summarizes the therms and heating degree days before and after the Runwise installation.

Table 2-7. Bill data pre- and post-install comparison

Month	Pre-Install		Post-Install	
	Therms	HDD (65°F)	Therms	HDD (65°F)
January	6,922	1,151	5,407	834
February	5,127	834	5,412	821
March	3,191	509	3,658	597
April	1,256	281	1,628	344
May	131	102	170	77
June	75	25	82	28
July	46	7	57	3
August	20	14	64	17
September	177	101	643	222
October	2,430	375	1,930	332
November	4,577	703	4,509	736
December	5,554	875	5,907	963
Total	29,506	4,976	29,464	4,975

Figure 2-5 shows the therms and heating degree days per month for the pre and post-install data as well as the regression equations for each.

Figure 2-5. Pre and post install therms vs heating degree days



The therms and heating degree days were then normalized to the outside air temperature over a typical year. The evaluator found the heating degree days based on TMY3 weather data in Providence, RI. The regression equations from Figure 2-5 were then used with the TMY3 heating degree days to find the expected therm use over the course of a typical year, as shown in Table 2-8.

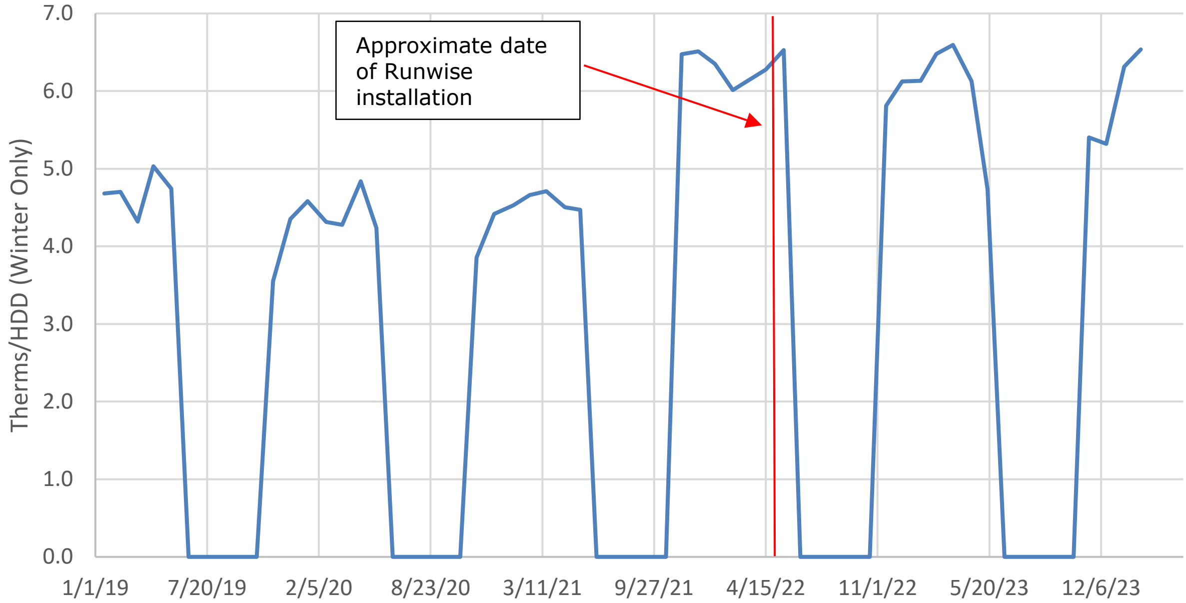
Table 2-8. TMY3 normalized bill data

Month	TMY3 HDD (65°F)	Pre-Install Regressed Therms	Post-Install Regressed Therms	Difference Therms
January	1,151	7,185	7,282	-97
February	1,047	6,514	6,597	-83
March	705	4,320	4,356	-36
April	518	3,122	3,133	-11
May	287	1,641	1,621	20
June	100	440	394	46
July	34	19	0	19
August	43	73	20	54
September	128	619	577	42
October	397	2,346	2,341	5
November	536	3,239	3,252	-13
December	794	4,890	4,938	-48
Total	5,740	34,409	34,512	-102

The bill data analysis reveals that there is a negligible difference between the pre and post-install data, which supports the evaluator's finding that the sequences from the Runwise controller did not provide savings compared to the baseline Tekmar controller.

The pre-install usage found by the evaluator is greater than the pre-install data used by the applicant. The evaluator opted to use bill data from May 2021-April 2022, which encompasses one year of data before the Runwise system was installed. The applicant used bill data from December 2020 through November 2021. In the heating season beginning in the winter of 2021 the natural gas usage, on a therm per heating degree day basis, began to increase. This increase was not fully captured in the applicant's data. Figure 2-5 shows the therms per heating degree days in only the winter months, as well as the approximate date of the Runwise installation. The lower therm usage pre-dates both the Runwise installation and any potential COVID impacts.

Figure 2-1. Winter therms/HDD over time



3 FINAL RESULTS

The application considered the installation of a Runwise system to control the heating systems at an elementary school. The calculated savings are less than the tracked values. Table 3-1 summarizes the key parameters used to calculate the energy savings for the measure.

Table 3-1. Summary of Key Parameters

Parameter	Applicant	Evaluator
Baseline Space Temperature Control	Temperature control from local thermostats.	Temperature control is from Tekmar controller with interior space temperature sensing. Tekmar controller has programmable occupied and unoccupied temperature setpoint.
Baseline Outside Air Temperature Reset Control	Outdoor temperature reset control available from an offline controller	Online Tekmar controller that offers outside air temperature reset control.
Installed Space Temperature Control	Runwise system has interior space temperature sensors and automatically controls the average occupied setpoint to 68°F and the unoccupied setpoint to 64°F.	Runwise system has interior space temperature sensors and automatically controls the average occupied setpoint to 68°F and the unoccupied setpoint to 64°F.
Installed Outside Air Temperature Reset Control	Runwise system cycles the boilers off during unoccupied periods with an outside air temperature above 40°F. The unoccupied supply water temperature, when running, is a constant 130°F, while the occupied supply water temperature resets with outside air temperature.	Runwise system cycles the boilers off during unoccupied periods with an outside air temperature above 40°F. The unoccupied supply water temperature, when running, is a constant 130°F, while the occupied supply water temperature resets with outside air temperature.
1-Year Pre-Installation Weather Normalized Natural Gas Use (Therms)	24,571 (based on December 2020-November 2021 bill data)	34,409 (based on May 2021-April 2022)
1-Year Post-Installation Gas Use (Therms)	22,114 (Assumes a 10% savings factor)	34,512 (based on May 2022-April 2023)
Savings		
Annual natural gas savings (therms)	2,457	0
Natural gas realization rate (%)	0.0%	

3.1 Explanation of Differences

The evaluated savings are less than the applicant savings. Table 3-2 provides a summary of the differences between tracking and evaluated values.

Table 3-2. Summary of Deviations

End-use	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
Baseline	Baseline	Existing heating control equipment	100%	**Decreased Savings:** The evaluator discovered an existing, functional, Tekmar controller that has the same general functionality (OAT reset control, space temperature control), as the installed Runwise controller.

3.2 Lifetime Savings

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

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

where:

LAGI = lifetime adjusted gross impact (therm)

FYS = first year savings (kWh)

EUL = measure life (years)

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

Table 3-3. Measure 13242101 - Lifetime Savings Summary

Factor	Tracking	Evaluator
Lifetime savings (therms)	24,570	0
First year savings (therms)	2,457	0
Measure lifetime (years)	10	10
Measure life reference	Screening Tool	Screening Tool
Measure event type	Retrofit	Add-on
Baseline classification	Single – Pre existing	Single – Pre existing
Measure status (operational or removed)	N/A	Operational

N/A = Not Applicable

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

3.2.1 Ancillary impacts

There were no ancillary impacts associated with the evaluated measure.

RI CUSTOM GAS EVALUATION SITE SPECIFIC MEASUREMENT AND VERIFICATION REPORT

Site ID: 2022RIGN061

Report Date: 08/21/24

Program Administrator	Rhode Island Energy	
Application ID(s)	12697991, 13406021/11705177, 13670467, 13741057	
Project Type	Early Replacement Retrofit	
Program Year	2022	
Evaluation Firm	DNV	
Evaluation Engineer	Indukumar Packirisamy	
Senior Engineer	Shaobo Feng	

1 EVALUATED SITE SUMMARY AND RESULTS

The evaluated project consists of four retrofit measures implemented in a biotech campus, including a biomanufacturing plant and labs.

EEM 1, 12697991, unoccupied setback: This measure consists of an unoccupied temperature setback for five air handling units (AHUs). In the pre-existing condition, heating discharge air temperature (DAT) varied with outdoor air temperature (OAT) throughout the day without accounting for the unoccupied period. This measure is intended to adjust the AHU's DAT to 65°F during unoccupied mode when the OAT is greater than 60°F and to stay in unoccupied mode unless the OAT goes below 50°F. However, upon verification, the evaluator found out that when the OAT is above 50°F during unoccupied periods, the discharge air temperature remains between 58°F and 65°F. Overall, the DAT ranges between 55°F and 70°F for all OATs during unoccupied hours, indicating that the measure is not operating as well as intended and producing much lower savings than estimated. Savings result from lower DAT setpoints during unoccupied periods. The annual tracking gas savings for this measure is 4,256 therms.

EEM 2, 13406021/11705177, boiler sequencing: This measure consists of the installation of a new boiler control system to optimize boiler modulation and sequencing. There are four boilers rated at 1,500 HP. Pre-existing controls were outdated and would call on the lag boiler prematurely and keep it running based on continuous cycling. The lag boiler (third boiler in rotation) would be maintained in stand-by, but boiler cycling would be reduced by lowering the steam pressure header standby setpoints and minimizing lag boiler run time. The annual tracking gas savings for this measure is 13,517 therms.

EEM 3, 13670467, preheat temperature reset: This measure consists of resetting the pre-heat temperature of a lab AHU. The preheat setpoint of the impacted unit was originally fixed at 70°F. This measure resets the preheat coil temperature setpoint from 50°F to 65°F based on the OAT between 45°F and 0°F. Savings are achieved by lowering the preheat temperature, which also reduces the cooling requirement. The annual tracking gas savings for this measure is 6,752 therms.

EEM 4, 13741057, simultaneous heating and cooling: The AHU that serves the north and south labs supplies both heating and cooling at the same time. This measure consists of repairing the leaking three-way heating valves to avoid overcooling. The annual tracking gas savings for this measure is 123,937 therms.

During the site visit, the site contact mentioned that additional measures were installed on other systems after the implementation of EEM 1, 2, 3, and 4. These subsequent installations will also impact consumption, making it difficult to accurately isolate the effects of EEM 1, 2, 3, and 4 if a billing analysis were conducted. Furthermore, production has increased over the years, and due to confidentiality concerns, the evaluator was unable to obtain the production data. As a result, the evaluator decided against using a billing analysis approach. The applicant created different Excel-based weather bin calculation workbooks, using inputs from design documents, trend data, operational information from the customer, and load assumptions informed by an energy audit to calculate savings. The evaluator used a similar methodology and updated input parameters based on site visit findings and collected trend data.

The total tracking savings for this project is 148,462 therms. The total evaluated savings for this project are 185,923 therms. The evaluation results are presented in Table 1-1.

Table 1-1. Evaluation results summary

PA application ID	Measure name		Annual savings (therms)
12697991	EEM 1: Unoccupied setback	Tracked	4,256
		Evaluated	1,726
		Realization rate	41%
13406021/11705177	EEM2: Boiler sequencing	Tracked	13,517
		Evaluated	17,704
		Realization rate	131%
13670467	EEM3: Preheat temperature reset	Tracked	6,752
		Evaluated	8,037
		Realization rate	119%
13741057	EEM4: Simultaneous heating and cooling	Tracked	123,937
		Evaluated	158,132
		Realization rate	128%
Total		**Tracked**	**148,462**
		Evaluated	**185,599**
		Project realization rate	**125%**

1.1 Explanation of deviations from tracking

The evaluated total first-year savings are 25% higher than the applicant-reported savings. The main factor contributing to this discrepancy is the increase in savings for EEM 4. For this measure, as well as for EEM-1 and EEM-3, the evaluator accounted for system losses by dividing the savings by the boiler efficiency whereas the TA had not included boiler efficiency in the tracking calculation, implicitly assuming 100%. Further details regarding deviations from the tracking savings are presented in Section 3.

1.2 Recommendations for program designers and implementers

The evaluator recommends the implementor to adjust the energy savings as appropriate if post-retrofit trend data is different than expected.

1.3 Customer alert

There are no customer alerts.

2 EVALUATED MEASURES

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

The evaluated project involved four measures. Application 12697991, 13670467, and 13741057 consisted of updating the control strategy for their HVAC systems, and application 13406021/11705177 consisted of installing a new boiler control system for four of their boilers at the facility.

2.1 Application information and applicant savings methodology

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

2.1.1 Applicant description of baseline

A vendor conducted an energy audit and collected pre-existing trend data to estimate the baseline sequence of operation for measures 1, 3, and 4. For the boiler measure, the vendor used nameplate information along with data from the site contact to describe baseline conditions. The applicant classified the installed measures as retrofits and characterized the baseline as the pre-existing conditions. EEMs 1, 3, and 4 involve updating control strategies of AHUs. Table 2-1 summarizes the critical applicant baseline parameters for each application. Three of the four measures involve AHUs. For reference, an example schematic is included in Figure 2-1.

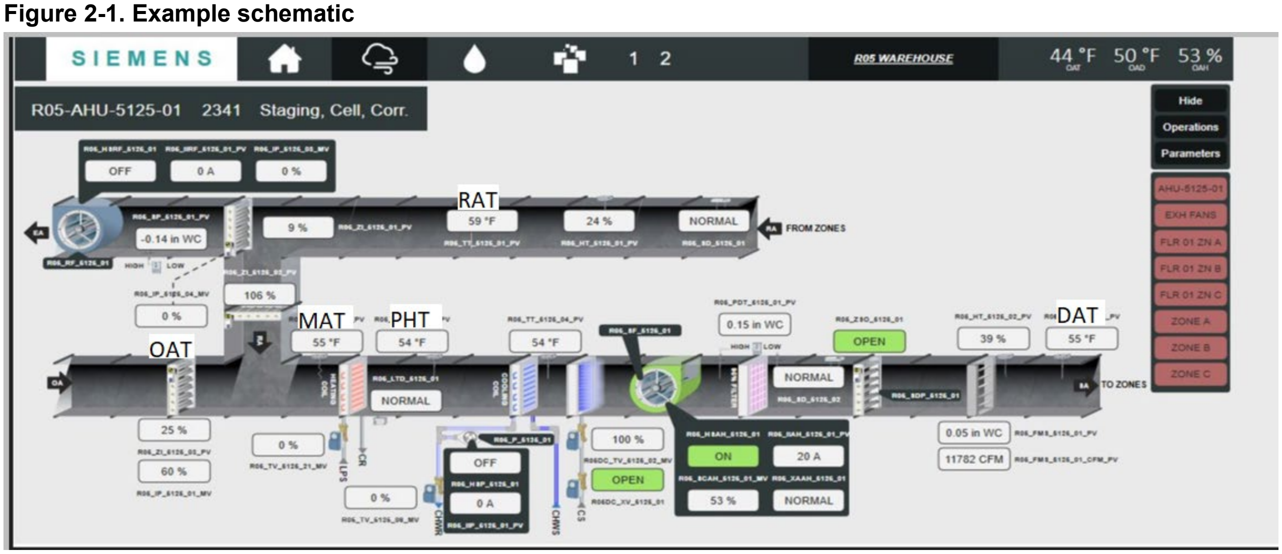
Table 2-1. Applicant baseline key parameters[1]

Measure	Control strategy	Parameter	BASELINE Value(s)	Unit	Source of parameter value
EEM 1: Unoccupied setback	DAT resets between 62°F and 68°F linearly based on the OAT between 65°F and 35°F, without accounting for unoccupied hours.	Supply air	3,200-28,007	Cubic feet per minute	Applicant calculation spreadsheet
		Mixed air temperature	39-82	Fahrenheit	
		Return air temperature	69-74	Fahrenheit	
		Preheat temperature	58-90	Fahrenheit	
		Discharge temperature	**58-65**	Fahrenheit	
		Reheat air temperature	70	Fahrenheit	
		Bin hours	8760	Hours	
EEM 2: Boiler Controls	Set a lead-lag-standby configuration. The old controller called on the lag boiler prematurely and keep it running based on cycling.	**Cycles/Day**	**6**		Applicant calculation spreadsheet
		Firing Time per cycle	4.75	Minutes	
		Average Firing rate	242.745	Scfm	
		Operating days	360	Days	

[1] Values which are intentionally changed from pre to post are highlighted in **Bold**.

Measure	Control strategy	Parameter	BASELINE Value(s)	Unit	Source of parameter value
		Boiler Efficiency	83.29%		
		Supply air	17,000	Cubic feet per minute	
		Preheat temperature	**58-97.5**	Fahrenheit	
		Return Air temperature	69	Fahrenheit	
		Mixed Air temperature	61-80	Fahrenheit	
		Discharge temperature	54-56	Fahrenheit	
		Reheat air temperature	70	Fahrenheit	
EEM 3: Preheat temperature reset	Set preheat setpoint to 70°F for 24/7	Bin hours	8760	Hours	Applicant calculation spreadsheet
		Supply Air	42,890-49,285	Cubic feet per minute	
		Heat Recovery temperature	40-84	Fahrenheit	
		Preheat temperature	**79.5-84**	Fahrenheit	
		Discharge temperature	54-58	Fahrenheit	
		Reheat Air temperature	70	Fahrenheit	
EEM 4: Simultaneous heating and cooling	Preheat setpoint temperature of 80°F	Bin hours	8760	Hours	Applicant calculation spreadsheet

Figure 2-1. Example schematic



2.1.2 Applicant description of installed equipment and operation

The applicant described the installed measures and their operation in Table 2-2.

Table 2-2. Application proposed key parameters[2]

Measure	Control strategy	Parameter	INSTALLED Value(s)	Unit	Source of parameter value
EEM 1: Unoccupied setback	DAT adjusts to 65°F during unoccupied mode when OAT is above 60°F and stays in unoccupied mode unless OAT goes below 50°F.	Supply air	3,200-28,007	Cubic feet per minute	Applicant calculation spreadsheet
		Mixed air temperature	40-90	Fahrenheit	
		Return air temperature	67-80	Fahrenheit	
		Preheat temperature	56-90	Fahrenheit	
		Discharge temperature	**62-70**	Fahrenheit	
		Reheat air temperature	70	Fahrenheit	
		Bin hours	8760	Hours	
EEM 2: Boiler Controls	Set a lead-lag-standby configuration. The new controller set the cycle based on steam pressure header standby setpoint.	**Cycles/Day**	**3**		Applicant calculation spreadsheet
		Firing Time per cycle	4.75	Minutes	
		Average Firing rate	242.745	Scfm	
		Operating days	360	Days	
		Boiler Efficiency	83.29%		
EEM 3: Preheat temperature reset	Reset the preheat coil temperature setpoint from 50°F to 65°F on an OAT of 45 °F to 0 °F.	Supply air CFM	17,000	Cubic feet per minute	Applicant calculation spreadsheet
		Preheat temperature	**4097.5**	Fahrenheit	
		Return Air temperature	69	Fahrenheit	
		Mixed Air temperature	62-80	Fahrenheit	
		Discharge temperature	54.5-56	Fahrenheit	
		Reheat air temperature	70	Fahrenheit	
		Bin hours	8760	Hours	

[2] Values which are intentionally changed from pre to post are highlighted in **Bold**.

Measure	Control strategy	Parameter	INSTALLED Value(s)	Unit	Source of parameter value
EEM 4: Simultaneous heating and cooling	Reduced and varying preheat temperature setpoints based on OAT	Supply Air CFM	42,890-49,285	Cubic feet per minute	Applicant calculation spreadsheet
		Heat Recovery temperature	27-87	Fahrenheit	
		Preheat temperature	**56-87**	Fahrenheit	
		Discharge temperature	54-58	Fahrenheit	
		Reheat Air temperature	70	Fahrenheit	
		Bin hours	8760	Hours	

2.1.3 Applicant energy savings algorithm

Two vendors developed different Excel-based weather bin calculation workbooks, based on inputs from design documents, trend data, operational information from the customer, and load assumptions informed by an energy audit. The formulas below show the savings algorithms used by the vendors for each measure:

12697991, unoccupied setback:

$$Gas\ savings = Baseline\ heating\ consumption - Proposed\ heating\ consumption$$

$$Heating\ consumption = AHU001 + AHU002 + AHU003 + AHU026B + AHU007$$

For each unit bin profile:

$$Heating\ Consumption = \frac{Therms}{hour} \times bin\ hours$$

$$\frac{Therms}{hour} = 1.08 \times Supply\ air\ \times \frac{PAT - MAT}{100000} + 1.08 \times Supply\ air \times \frac{ReHEAT - DAT}{100000}$$

Where,

$bin\ hours$ = five-degree interval temperature data, developed by using BinMaker Pro, based on the local TMY3 weather data for “normal” weather from 1978-2005.

$Supply\ Air$ = AHU supply fan airflow in Cubic feet per minute (CFM), based on the data collected from site contact.

PAT = Average preheat coil air temperature for each temperature bin, based on the pre (for baseline) and post (for installed) trend data

MAT = Average mix air temperature for each temperature bin, based on the pre (for baseline) and post (for installed) trend data

$ReHEAT$ = Average reheat coil air temperature for each temperature bin, consistent at 70°F

DAT = Average discharge air temperature for each temperature bin, based on the pre (for baseline) and post (for installed) trend data

13406021/11705177, boiler sequencing:

$$Gas\ Savings = Cycling\ loss\ reduction + Purge\ loss\ reduction$$

$$Cycling\ loss\ reduction = (Pre\ cycles\ per\ day - Post\ cycles\ per\ day) \times \frac{Firing\ minutes\ per\ cycle}{60\ min/hour} \times FR \times Operation\ Days$$

$$Purge\ loss\ reduction = Purge\ loss \times (Pre\ cycles\ per\ day - Post\ cycles\ per\ day) \times Operation\ days \div Boiler\ efficiency$$

$$Purge\ loss = Boiler\ heating\ surface \times (Internal\ boiler\ surface\ temperature - Combustion\ air\ temperature) \times h \times Purge\ duration \div 60\ min/hour$$

Where,

$Cycles\ per\ Day$ = number of sequencing switch for third boiler per day. The applicant assumed six cycles for baseline, based on one day of trend data, and assumed three cycles in the installed case.

$Firing\ minutes\ per\ Cycle$ = Firing duration to maintain standby temperature, the applicant used 4.75 minutes based on one day of pre-trend data

$FR = Gas\ flow \times Gas\ heat\ density$ Gas flow was based on the trend data, and assumed natural gas higher heating value (HHV) of 1028 Btu/CF

$Operation\ days$ = 360 days/year

$Boiler\ Heating\ surface$ = 5,353.86 ft^2

$Internal\ boiler\ surface\ temperature$ = 350°F

$Combustion\ air\ temperature$ = 80°F

h = convective heat transfer coefficient, 1.8311683 btu/(hr ×ft^2)°F

$Purge\ duration$ = 1.25 mins

13670467, preheat temperature reset:

$$Gas\ savings = Baseline\ heating\ consumption - Proposed\ heating\ consumption$$

For each bin profile:

$$Heating\ consumption = \frac{Therms}{hour} \times bin\ hours$$

$$\frac{Therms}{hour} = 1.08 \times Outside\ air\ \times \frac{PAT - OAT}{100000} + 1.08 \times Supply\ Air\ \times 20\% \times \frac{ReHEAT - DAT}{100000}$$

Where,

$bin\ hours$ = five-degree interval temperature data, developed by using BinMaker Pro, based on the local TMY3 weather data

$Outside\ air$ = outside air airflow in cubic feet per minute (CFM), assumed constant 7,000 cfm as a control set

OAT = outside air temperature, based on local TMY3 data

PAT = preheat coil air temperature, based on the pre (for baseline) and post (for installed) trend data

$Supply\ air$ = AHU supply fan airflow in cubic feet per minute (CFM), based on the data collected from site contact

20% = the amount of supply air needed to be reheated

$ReHEAT$ = reheat coil air temperature, consistent at 70°F

DAT = discharge air temperature, based on the pre (for baseline) and post (for installed) trend data

13741057, simultaneous heating and cooling:

$$Gas\ Savings = Total\ baseline\ heating\ consumption - Total\ proposed\ heating\ consumption$$

$$Total\ heating\ consumption = AHU\_South + AHU\_North$$

For each bin profile:

$$Heating\ consumption = \frac{Therms}{hour} \times bin\ hours$$

$$\frac{Therms}{hour} = 1.08 \times Supply\ Air\ \times \frac{PAT - HRC}{100000} + 1.08 \times Supply\ Air\ \times 10\% \times \frac{ReHEAT - DAT}{100000}$$

Where,

$bin\ hours$ = five-degree interval temperature data, developed by using BinMaker Pro, based on the local TMY3 weather data

$Supply\ air\ cfm = Design\ air\ flow \times Supply\ air\ fan\ speed\%$ AHU supply fan airflow in cubic feet per minute (CFM). The design airflow was from AHU specs, and supply air fan speed percentage was based on the pre (for baseline) and post (for installed) trend data.

PAT = preheat coil air temperature, based on the pre (for baseline) and post (for installed) trend data

HRC = air temperature leaving the heat recovery wheel, based on the pre (for baseline) and post (for installed) trend data

$ReHEAT$ = reheat coil air temperature, consistent at 70°F

DAT = discharge air temperature, based on the pre (for baseline) and post (for installed) trend data

2.1.4 Evaluation assessment of applicant methodology

The applicant did not consider the boiler efficiency to include for the system losses for the unoccupied setback, preheat temperature reset, and simultaneous heating and cooling measures. The evaluator calculated the final savings for each measure with the consideration of boiler efficiency to account for system losses.

12697991, unoccupied setback:

In calculating the therm/hr for each bin, the applicant considered the heat exchange at the preheat coil and the heating coil at the zone level. However, since the measure only updates the DAT during unoccupied hours, to accurately calculate its impact the evaluator has focused on heat exchange at the heating coil in the zone level. The current DAT varies between 58°F and 70°F for all OATs during unoccupied hrs.

The evaluator updated the bin hours for each temperature bin by filtering the TMY weather data for the unoccupied hours and updated the therms/hour equation by removing the preheat coil heat exchange component.

13406021/11705177, boiler sequencing:

The applicant only calculated the savings for boiler 3, instead of the whole boiler plant. In addition, the applicant only collected and used one day of pre-trend data to estimate the number of cycles per day and the gas flow rate.

The evaluator collected six months of 1-min interval data of both pre and post periods, for all three boilers. Instead of assuming the number of cycles per day and the firing time per cycle, the evaluator calculated the total firing time, and the average firing during the cycling status, for both baseline and installed cases to estimate the savings.

13670467, preheat temperature reset:

The measure directly impacts the heat exchange at the preheat coil, but the applicant has considered the heat exchange at the pre-heat coil and the heating coil at the zone level. To accurately evaluate the impact of this measure the evaluator will focus on the heat exchange at the pre-heat coil and will remove the heating coil heat exchange component from the therms/hr equation.

13741057, simultaneous heating and cooling: The applicant has calculated the energy changes of the entire AHU system even though the faulty three-way valve only affects the heating and pre-heat coil. To evaluate the measure's accurate impact, the evaluator will focus on the heat exchanges at the heating coil and pre-heat coil.

Overall, the evaluator used the same calculator but revised the formula and updated non-operational and operational parameters based on evaluation findings and trend data.

2.2 On-site inspection and metering

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

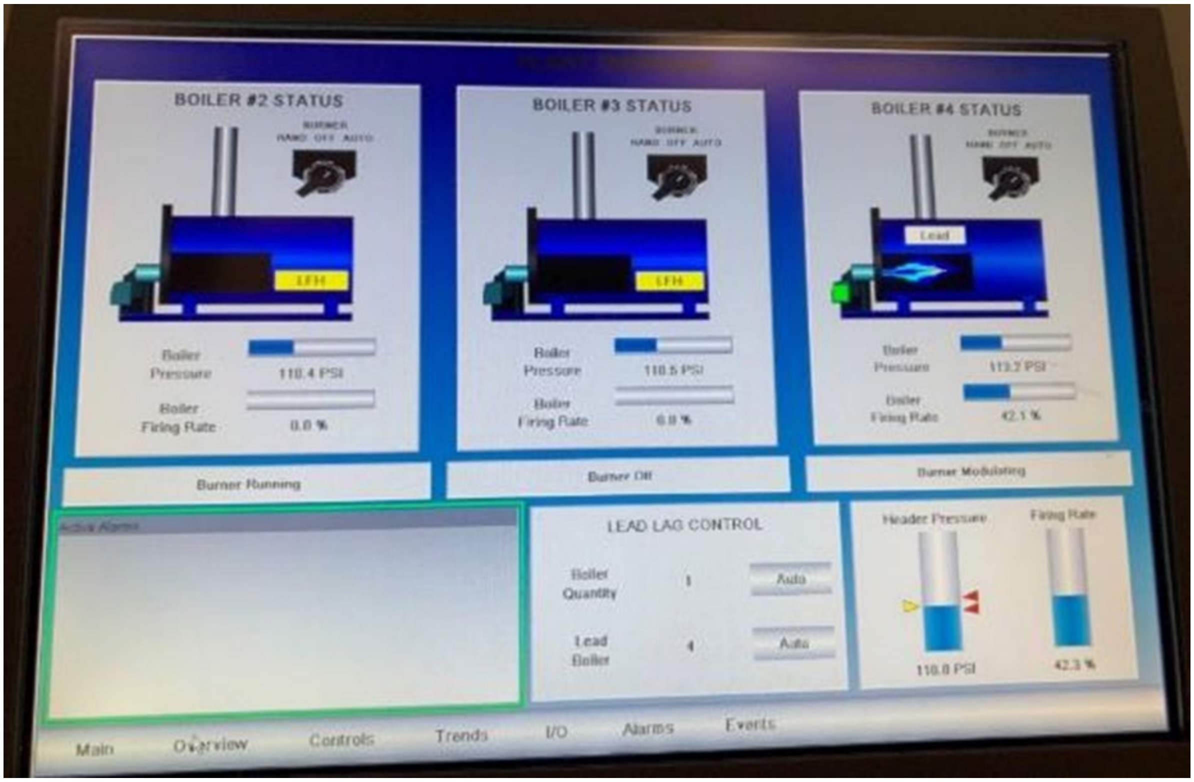
2.2.1 Summary of on-site findings

The evaluator conducted a site visit to the facility on March 12, 2024. During the site visit, the evaluator met with the site contact and discussed the nature of the project. The evaluator also interviewed the site contact and identified the available trend data. Since the facility manufactures biotech products, the site contact did not allow the installation of loggers but provided six months of trend data on the affected AHUs and boilers. Table 2-3 summarizes how the measures were verified during the site visit. Figure 2-2 shows the newly installed boiler controller interface showing the real-time boiler operating status. It shows the boiler firing rate and the steam pressure reading, indicating the proposed controller is operating as intended.

Table 2-3. Measure verification summary

Measure name	Verification method	Verification result
12697991, unoccupied setback	Collected EMS trend data for six months from one of the affected AHUs and a picture of their EMS	The AHU does not operate as expected
13406021/11705177, boiler sequencing	Visual verification of the new boiler controls and pictures of their EMS	The boiler systems are operating as intended.
13670467, preheat temperature reset	Collected EMS trend data for six months from the affected AHU and a picture of their EMS	The measure reduces preheat energy more than the applicant predicted
13741057, simultaneous heating and cooling	Collected EMS trend data for six months from the affected AHUs and a picture of their EMS	The measure is operating as intended

Figure 2-2. The installed boiler control system with interface



2.2.2 Measured and logged data

Due to safety and health concerns, this facility does not permit the deployment of temperature sensors in the AHU or the installation of kW loggers in the electric panel. However, the site contact mentioned that their building automation system (BAS) has trending capabilities and provided a list of available data points. Based on the list of trends of input parameters utilized by the applicant to develop the savings calculation workbook and the list shared by the site contact, the evaluator requested the last six months of trend data for most of these variables. The site contact sent this data after the visit. For Application 12697991, EEM-1: unoccupied setback measure, the evaluator was able to collect the trends for only one of the five affected AHUs (AHU-007), which contributes 82% savings from this measure. This is summarized in Table 2-4.

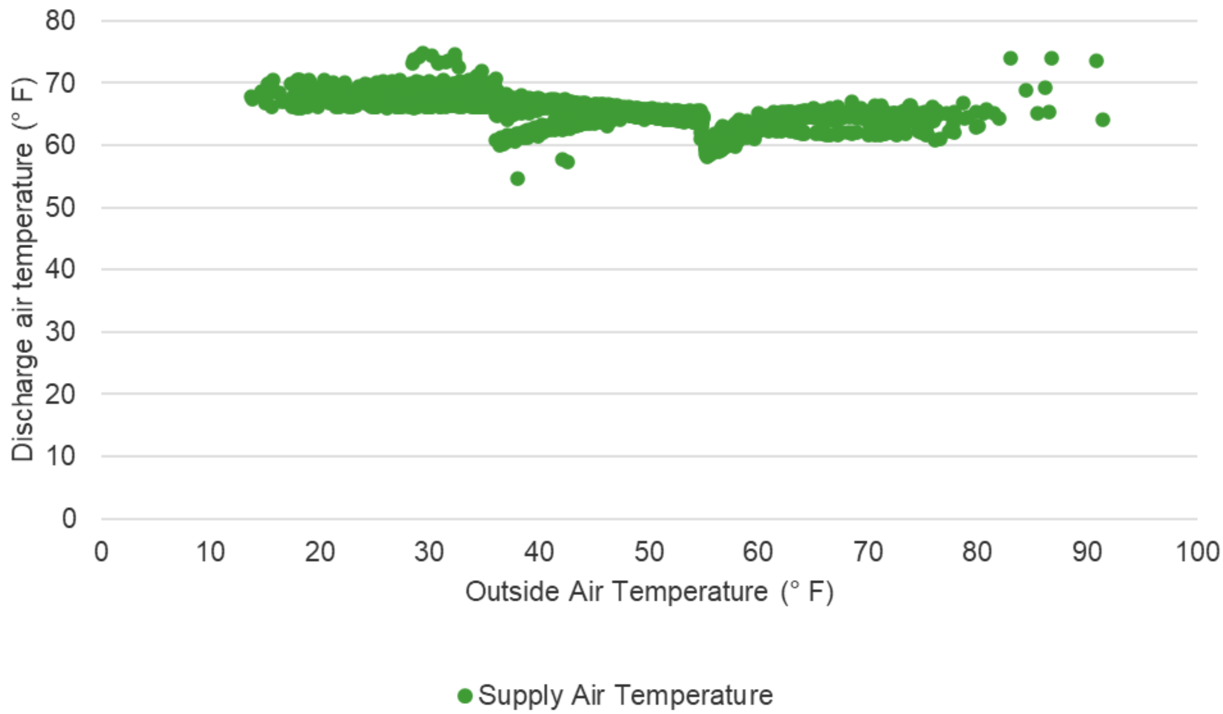
Table 2-4. Evaluator collected data

EEM	Source	Unit name	Parameter	Interval	Duration
			Outside air temperature		
			Preheat air temperature		
1		AHU-22-007	Discharge air temperature	1-hour	09/07/2023-03/07/2024
			Outside air temperature		Pre: 11/01/2020-04/29/2020
			Runtime hrs. of boilers		
2		Boilers 2, 3 & 4	Natural gas flow of boilers	1-min	Post: 11/01/2023-04/29/2024
			Outside air temperature		
			Discharge airflow		
3	EMS	AHU-5115	Outside air damper position	1-hour	09/07/23-03/07/24

EEM	Source	Unit name	Parameter	Interval	Duration
			Return air temperature		
			Mixed air temperature		
			Preheat air temperature		
			Discharge air temperature		
			Outside air temperature		
			Heat recovery temperature		
			Heat recovery valve position		
			Heating valve position		
			Heating coil temperature		
			Discharge air temperature	15 Minutes	
4		AHU-North & AHU-South	Fan speed (%)		09/07/23-03/07/24

12697991, EEM-1: unoccupied setback: The evaluator used post-installation data from September 2023 to March 2024 to generate Figure 2-3. Pre-retrofit data is shown below in Figure 2-3.

Figure 2-3. Unoccupied post-installation OAT and DAT for AHU-22-007



Although the applicant described the measure as adjusting DAT to 65°F during unoccupied mode when the OAT is greater than 60°F and staying in unoccupied mode unless the OAT goes below 50°F, the post-install trend data analysis shows that the measure is having an effect and saving energy, though not exactly as expected. In verification, the evaluator found that when the OAT is above 60°F during unoccupied periods, the DAT remains between 60.5°F and 75.9°F. When the OAT is less than 60°F, the DAT ranges between 48.6°F and 74.5°F with an average of 65.9°F, indicating that the measure is not operating as well as intended, producing much lower savings than expected.

Figure 2-4 (Outside air temperature vs. Discharge air temperature) below represents the pre-install trend data for AHU-22-007, filtered to show the Discharge Air Temperature (DAT) and Outside Air Temperature (OAT) only during unoccupied periods.

Figure 2-4. Unoccupied pre-installation OAT and DAT for AHU-22-007

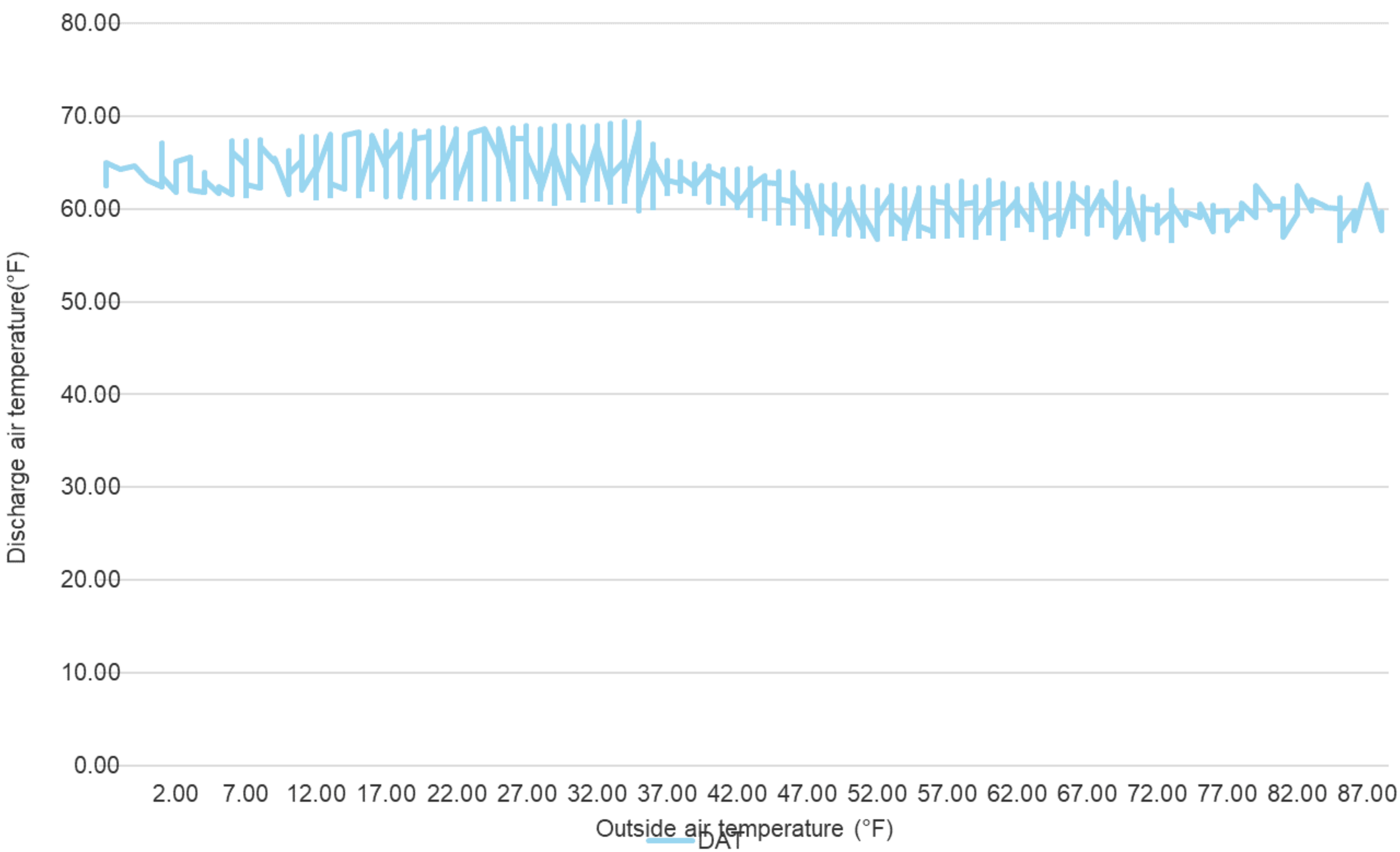


Figure 2-4 illustrates that the DAT ranges between 57°F and 68°F for all OATs during unoccupied hours in the pre-install period.

13406021/11705177, EEM-2: boiler sequencing: Figure 2-5 and Figure 2-6 show the gas flow reading for boilers 2, 3 and 4 (boiler 1 was decommissioned) during the baseline and installed period. Both figures indicate that three boilers were switching lead-lag-standby status equally, which matched the customer statement and applicant proposed sequence of operation. The evaluator added a red box in both figures to identify the "idle" status for each boiler when it was in cycling mode. The comparison of two boxes shows the records for cycling mode in the installed case is sparser and more scattered, indicating the amount of cycling was reduced. This proves the proposed measure was installed and operated as intended. On the other hand, the overall post firing rate during the cycling mode for each boiler was higher than the base case. This explains the logic of the new controller: It reduces the cycling time but slightly increases the firing rate to maintain the boiler standby status. In the evaluated approach, the evaluator determined different gas flow rates for different boiler during the pre and post cases, to estimate the annual cycling time and average standby firing rate, respectively.

In addition, the evaluator noticed that boiler 4 (green line) operated for a significantly less time with a gas flow rate below 160 CFM in the post-upgrade period, comparing to the pre-existing period. The site contact stated it could be due to the maintenance on that boiler or the manually boiler rotation setting. Since either of two cases is not directly related to the proposed measure, the evaluator did not consider the impact when gas flow was below a certain cfm for each boiler in pre and pose cases.

Figure 2-5. Gas flow reading for each boiler, baseline period

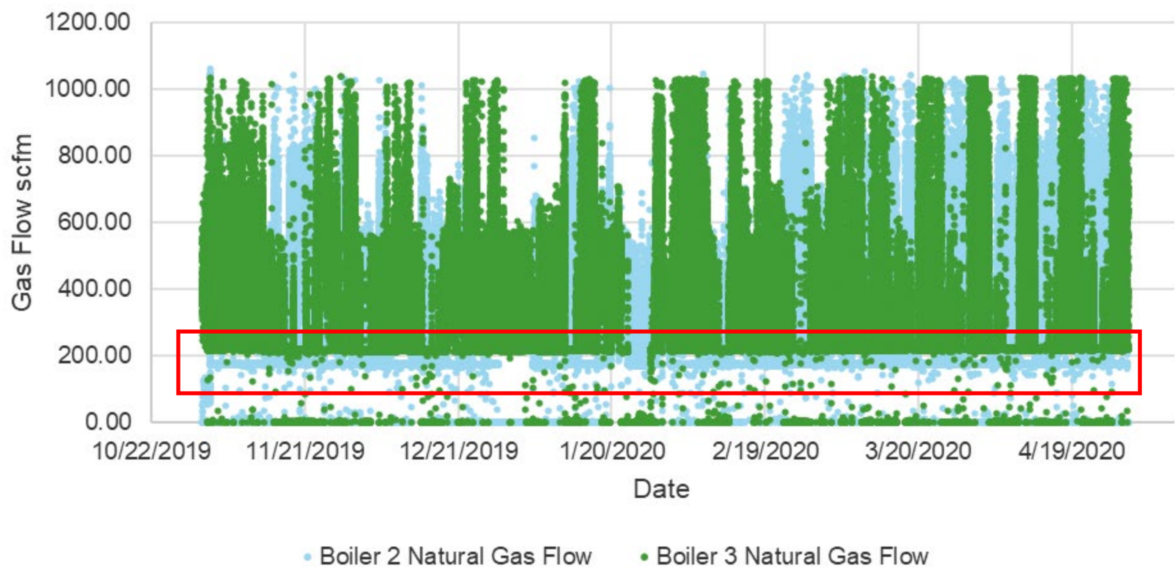
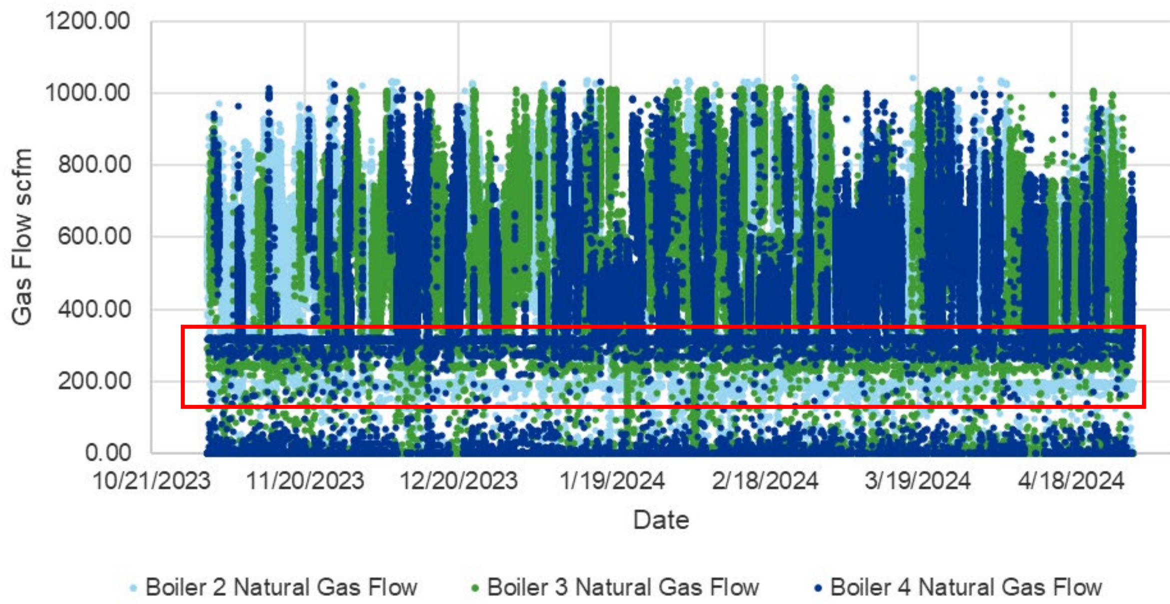
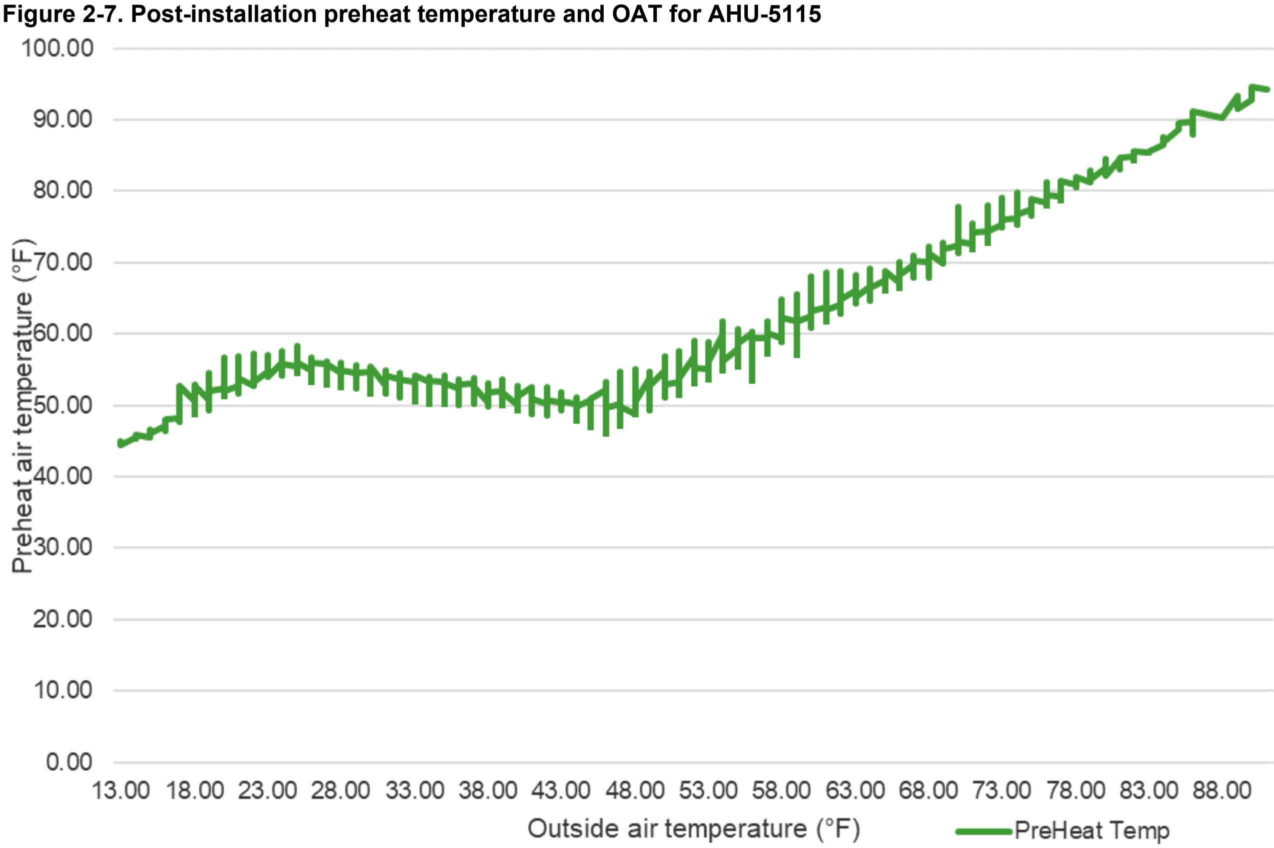


Figure 2-6. Gas flow reading for each boiler, installed period



13670467, EEM-3: preheat temperature reset: The evaluator used post-installation data from September 2023 to March 2024 to generate Figure 2-7.

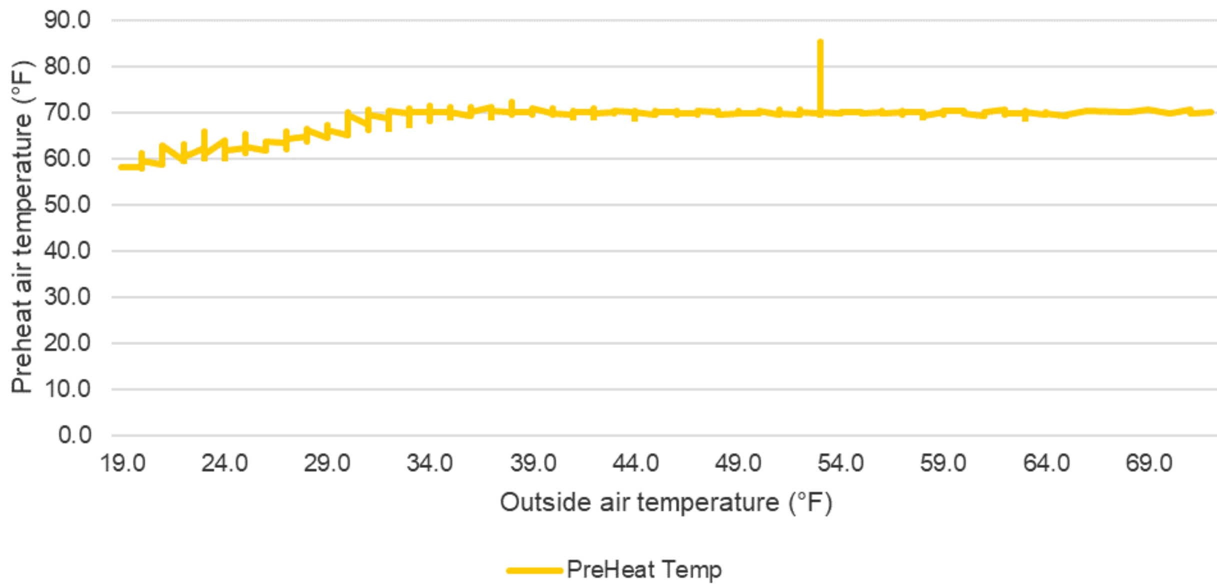
Figure 2-7. Post-installation preheat temperature and OAT for AHU-5115



Although the applicant described the measure as resetting the preheat coil temperature setpoint from 50 °F to 65 °F on an OAT of 45°F to 0°F, Figure 2-7 shows that the preheat temperature varies between 45°F and 56 °F when the OAT is below 45°F. When the OAT is above 45°F, the preheat temperature is approximately equal to the OAT, indicating little or no pre-heating, as expected. The measure reduces preheat energy more than the applicant predicted, increasing energy savings.

The evaluator used the pre-install data to generate Figure 2-8.

Figure 2-8. Pre-installation preheat temperature and OAT for AHU-5115



Although the applicant described the pre-install conditions as maintaining the preheat temperature at 70°F continuously, 24/7, Figure 2-8 shows that the preheat temperature ranges from 59°F to 70°F for OATs between 20°F and 32°F. For OATs greater than 32°F, the preheat temperature remains constant at 70°F.

13741057, EEM-4: simultaneous heating and cooling: The evaluator used the trend data from September 2023 to March 2024 to generate Figure 2-9.

Figure 2-9. Post-installation heating temperature, heating valve position, and OAT for AHU-North

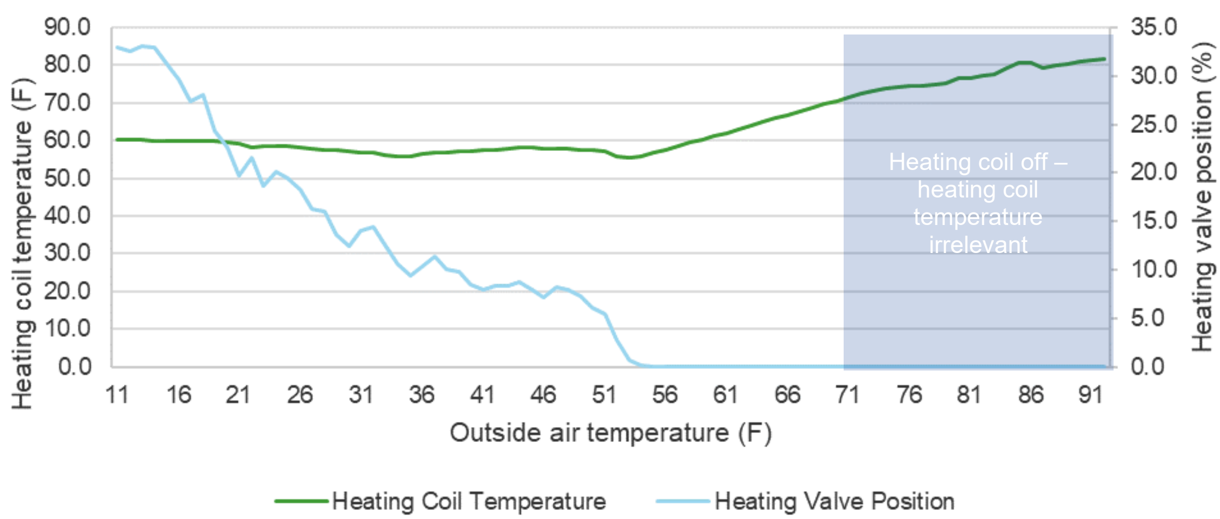


Figure 2-9 shows that the heating valve position constantly changes from 0% to 32% for OATs between 60°F to 11°F. Also, the reduced heating coil temperature changes from 60°F to 80°F for OATs between 11°F to 90°F. These observations indicate that the heating valve was repaired, and the measure is operating as intended.

The evaluator used the pre-install data to generate Figure 2-10.

Figure 2-10. Pre-installation heating temperature, heating valve position, and OAT for AHU-North

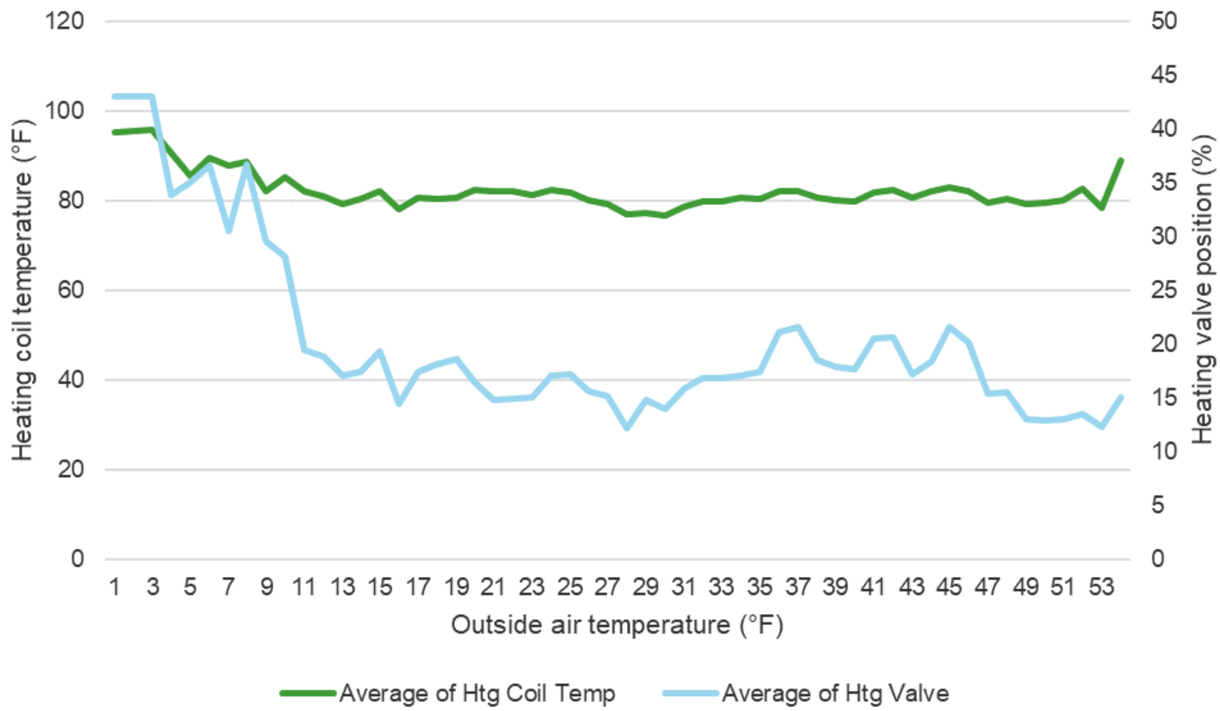


Figure 2-10 shows that the heating coil temperature ranges from 80°F to 100°F for lower OATs, specifically between 1°F and 13°F, while it remains constant at 80°F for all other OATs. Additionally, the heating valve position varies between 40% and 15% for lower OATs from 1°F to 15°F and then stabilizes around 15% for higher OATs, appearing rather random or stuck rather than modulating with OAT as one would normally expect.

2.3 Evaluation methods and findings

This section describes the evaluator's 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 evaluator has classified all measures as add-ons with a single baseline. The baseline is single because the measure with the longest measure life (10 years) is less than two-thirds of the life of the impacted heating system equipment (25 years). The baseline is the pre-existing conditions for all the measures. Detailed descriptions of the baseline for individual measures are given below.

12697991, EEM-1: unoccupied setback: The baseline is the pre-existing conditions in which the DAT for the AHU-22-007 with the highest savings varied between 55°F and 70°F as the OAT varied between -3°F and 95°F during unoccupied hours. There is potential for saving heating energy if DAT is higher.

13406021/11705177, EEM-2: boiler sequencing: The evaluated baseline for this measure is the evaluator's estimated standby/cycling time and the average firing rate during the standby/cycling time, based on the collected pre-trend data discussed above**.**

13670467, EEM-3: preheat temperature reset: During the baseline period, AHU-5115's preheat temperature ranged from 59°F to 70°F for lower OATs, specifically between 20°F and 32°F. After this range, the preheat temperature remained constant at 70°F for OATs below 70°F. No heating is required for OATs above 70°F.

13741057, EEM-4: simultaneous heating and cooling: In the baseline condition all the AHU's heating coil temperature ranges from 80°F to 100°F for lower OATs, specifically between 1°F and 13°F, and it remains constant at 80°F for all other OATs. Pre-retrofit data indicates an average pre-heating temperature of 80°F. Additionally, the heating valve position varies between 40% and 15% for lower OATs from 1°F to 15°F and then stabilizes around 40% for higher OATs.

2.3.2 Evaluation calculation method

The evaluator agrees with the overall analysis methodology used by the applicant and has used the same workbook with current trend data and updated input parameters to calculate savings.

The evaluator analyzed the current trend data and verified that the preheat temperature reset (EEM 3) and simultaneous heating & cooling (EEM 4) measures were functioning as intended. However, while the unoccupied setback measure (EEM 1) is saving energy, it is not performing exactly as expected. During the site visit, the evaluator also inspected the newly installed control panel for the boiler sequencing measure (EEM 2) and confirmed its proper installation.

The calculation method, evaluation process, and analysis for each of the measures are as follows:

12697991, EEM-1: unoccupied setback: The installed measure is to adjust the Supply air/Discharge air temperature (DAT) to 65°F during unoccupied hrs. Since the measure only impacts the DAT, the evaluator removed the energy impacts at the preheat coil from the Therms/hr equation. Figure 2-11 is an example of the calculation workbook screenshot.

Figure 2-11. Screenshot of the calculation table for AHU-22-007

AHU ID:	AHU-22-007					
	Old CFM	New CFM	Average Airflow	28,007.0	estimate based on data provided
AHU CFM:	28,007	28,007	SF_TSP_DESIGN	5.0	estimate
% of Air rehe	10%	10%	DAP EXT OPERATING	0.8	from screenshot
kWh Savings:	(17,852)		SF FAN eff	0.7	estimate
Demand (kW) Savings:	(2.6)		SF Motor eff	0.95	estimate
Therms Savings:	768		RAT	72.0	estimate
			BTU/HR_HP	2,544.4	constant
				6,356.0	constant

PHT DAT is max MAT or actual value for calculations

% OA is estimated based on final DAT | MAT minimum=40F | PHT DAT min = 60F | DAT min = 60F

Pre Conditions

Providence Bin Data				Supply Air		Mixed Air/OA Properties		RA		Preheat		Supply Fan				Final Discharge		Reheat Air	Cooling Load		Total Electric		Total Gas Consumption	
DB Mid Point (F)	Hours	Enthalpy (BTU/lb)	Dewpoint (F)	CFM	% OA	Temperature (F)*	h (BTU/lb)	Temperature (F)	h (BTU/lb)	Temperature (F)	h (BTU/lb)	DAP (in wg)	DAP Total (in wg)	SF BHP	Temperature Rise (F)	Temperature (F)	h (BTU/lb)	DAT (F)	kW/Ton	Load (Tons)	Demand (kW)	kWh	Therm/Hr	Therms
97.5	-	35	56.9	28,007.0	4.7%	73.2	24.9	72.0	24.4	73.2	24.9	0.8	5.0	31.5	2.6	57.3	23.0	70.0	0.77	46.7	59.2	-	0.4	-
92.5	10	37	65.5	28,007.0	4.7%	73.0	24.9	72.0	24.3	73.0	24.9	0.8	5.0	31.5	2.6	57.8	22.7	70.0	0.74	44.9	56.5	564.9	0.4	3.7
87.5	37	36	65.6	28,007.0	4.7%	72.7	24.8	72.0	24.2	72.7	24.8	0.8	5.0	31.5	2.6	58.2	22.5	70.0	0.71	43.2	53.9	1,994.9	0.4	13.2
82.5	162	34	63.0	28,007.0	4.7%	72.5	24.6	72.0	24.1	72.5	24.6	0.8	5.0	31.5	2.6	58.7	22.2	70.0	0.68	41.4	51.4	8,333.9	0.3	55.4
77.5	333	33	63.6	28,007.0	4.7%	72.3	24.4	72.0	24.0	72.3	24.4	0.8	5.0	31.5	2.6	59.2	22.0	70.0	0.65	39.7	49.1	16,342.1	0.3	109.2
72.5	433	31	62.7	28,007.0	4.7%	72.0	24.3	72.0	23.9	72.0	24.3	0.8	5.0	31.5	2.6	59.6	21.7	70.0	0.62	37.9	46.8	20,269.4	0.3	135.9
67.5	660	29	60.1	28,007.0	4.7%	71.8	24.1	72.0	23.8	71.8	24.1	0.8	5.0	31.5	2.6	62.5	21.5	70.0	0.59	30.0	41.0	27,085.7	0.2	149.1
62.5	715	25	54.3	28,007.0	4.7%	71.6	23.8	72.0	23.7	71.6	23.8	0.8	5.0	31.5	2.6	60.2	21.2	70.0	0.56	35.4	43.1	30,818.4	0.3	212.4
57.5	499	22	48.0	28,007.0	80.0%	60.4	22.1	72.0	23.6	69.1	22.1	0.8	5.0	31.5	2.6	59.9	21.0	70.0	0.53	29.9	39.2	19,547.3	0.3	152.6
52.5	24	3	(4.1)	28,007.0	60.0%	60.3	11.0	72.0	23.5	66.4	11.0	0.8	5.0	31.5	2.6	59.5	11.0	70.0	0.51	24.2	35.8	859.1	0.3	7.6
47.5	605	19	42.8	28,007.0	50.0%	59.8	21.3	72.0	23.4	65.5	21.3	0.8	5.0	31.5	2.6	60.4	10.8	70.0	0.51	19.4	33.4	20,194.6	0.3	175.4
42.5	512	17	38.1	28,007.0	40.0%	60.2	20.7	72.0	23.3	63.1	20.7	0.8	5.0	31.5	2.6	62.6	10.5	70.0	0.51	7.9	27.5	14,093.3	0.2	115.3
37.5	636	15	33.8	28,007.0	30.0%	61.7	20.7	72.0	23.2	67.4	20.7	0.8	5.0	31.5	2.6	63.5	10.3	70.0	0.51	16.5	31.9	20,283.6	0.2	125.0
32.5	742	13	28.6	28,007.0	25.0%	62.1	20.5	72.0	23.1	85.7	20.5	0.8	5.0	31.5	2.6	64.6	10.0	70.0	0.51	60.0	54.1	40,137.2	0.2	121.7
27.5	652	11	22.6	28,007.0	20.0%	63.1	20.5	72.0	23.0	83.8	20.5	0.8	5.0	31.5	2.6	64.6	9.8	70.0	0.51	55.1	51.6	33,620.3	0.2	105.7
22.5	316	9	15.9	28,007.0	15.0%	64.6	20.8	72.0	22.9	82.0	20.8	0.8	5.0	31.5	2.6	64.5	9.5	70.0	0.51	50.9	49.5	15,629.7	0.2	53.0
17.5	326	7	11.2	28,007.0	15.0%	63.8	20.5	72.0	22.8	79.9	20.5	0.8	5.0	31.5	2.6	64.6	9.3	70.0	0.51	45.3	46.6	15,189.4	0.2	53.2
12.5	188	6	6.0	28,007.0	15.0%	63.1	20.2	72.0	22.7	77.5	20.2	0.8	5.0	31.5	2.6	64.4	9.0	70.0	0.51	39.7	43.8	8,225.0	0.2	32.0
7.5	89	4	(1.0)	28,007.0	4.7%	69.0	21.8	72.0	22.6	65.0	21.8	0.8	5.0	31.5	2.6	65.6	8.8	70.0	0.51	-	23.5	2,089.7	0.1	11.9
2.5	1	2	(0.0)	28,007.0	4.7%	68.8	21.6	72.0	22.5	65.0	21.6	0.8	5.0	31.5	2.6	66.0	8.5	70.0	0.51	-	23.5	23.5	0.1	0.1
																					Total kWh:	295,302	Annual Therms:	1,632.4
																					avg kW (ref only):	43		

$$Gas\ Savings = \frac{(Baseline\ Heating\ Consumption - Proposed\ Heating\ Consumption)}{Boiler\ efficiency}$$

$$Heating\ Consumption = AHU001 + AHU002 + AHU003 + AHU026B + AHU007$$

For each unit bin profile:

$$Heating\ Consumption = \frac{Therms}{hour} \times bin\ hours$$

$$\frac{Therms}{hour} = 1.08 \times Supply\ Air\ cfm \times \frac{ReHEAT - DAT}{100{,}000}$$

Where,

$bin\ hours$ = five-degree interval temperature data, developed by using BinMaker Pro, based on the local TMY3 weather data for 1976-2005

$Supply\ Air\ cfm$ = AHU supply fan airflow, based on the pre (for baseline) and post (for installed) trend data

$ReHEAT$ = Average reheat coil air temperature for each temperature bin, consistent at 70°F

DAT = discharge air temperature for each temperature bin, based on the pre (for baseline) and post (for installed) trend data

$Boiler\ efficiency$ = 83.29%

The evaluator used outside air temperature data provided by the facility in their analysis. The temperature data was then filtered to reflect dry bulb temperatures during unoccupied hours of an AHU. The evaluator then used pivot tables to group the temperatures ranging from 0-95°F into bins of five and calculated the count of unoccupied hours and average dry bulb temperatures of each of the temperature bins. The process described above was repeated for all five affected AHUs. The evaluator used the TMY3 data only to calculate the hours of each temperature bin.

The respective AHUs are programmed to be in unoccupied mode during the hours below.

AHU-22-001 : 4 pm to 6 am
AHU-22-002 : 11pm to 6 am
AHU-22-003 : 4 pm to 6 am
AHU-22-026B : 4 pm to 6 am
AHU-22-007 : 2 pm to 7 am

The evaluator then updated the bin hours of each temperature bin with the newly calculated hours during unoccupied periods for each of the AHUs.

The evaluator gathered the latest temperature data from the facility for only one of the AHUs (AHU-22-007), which accounts for 82% of the total measure savings. For the other AHUs, the evaluator did not receive updated post-install trend data but did have and use post-install trend data from 2018 provided by the applicant. The evaluator then filtered the existing baseline, post-installation, and newly updated post-installation data for all AHUs to reflect only temperature readings during unoccupied hours. Subsequently, the evaluator created a pivot table and updated the average OAT, reheat temperature, and DAT for each temperature bin to calculate savings. Additionally, the evaluator adjusted the final gas savings by dividing the savings by the boiler efficiency to account for system losses. The boiler efficiency value was derived from the applicant's workbook for the boiler measure, where the efficiency was calculated based on the system's performance at different loads. The evaluator was able to collect the current temperature data for only one of the AHUs (AHU-22-007) and replaced the existing post-install data with the current data. The evaluator then filtered the existing baseline, post-install and newly updated post-install data to reflect only temperature readings during unoccupied hrs.

13406021, EEM-2: Boiler sequencing:

Based on the collected trend data in Figure 2-5 and Figure 2-6, the evaluator determined different particular gas flow rates in baseline and installed periods to define the “idle” standby status and calculate the total cycling time during the trending period, for each boiler. Similarly, the evaluator used the average gas flow value during the “idle” standby status as the evaluated firing rate for each boiler. Finally, the evaluator extrapolated the trend period into the annual operating profile by assuming 360 days of operating per year, which is same as applicant estimated.

The formulas are below:

$$Gas\ Savings = Cycling\ Loss\ Reduction + Purge\ Loss\ Reduction$$

$$Cycling\ Loss\ Reduction = \sum Boiler\ Baseline\ Cycling\ Consumption - \sum Boiler\ Installed\ Cycling\ Consumption$$

$$Boiler\ Cycling\ Consumption = Total\ Cycling\ Hour \times FR \div Total\ Trend\ days\ \times Operation\ Days$$

Where,

$Total\ Cycling\ Hour$ = Total cycling hours for each boiler, during the trending period.

$FR = Gas\ Flow \times Gas\ Heat\ Density$ Gas flow was based on the trend data, and natural gas heat density is 1028 Btu/CF

$Total\ Trend\ days$ = 181 days

$Operation\ Days$ = 360 days/year

For Purge loss reduction, it refers to the energy loss that occurs when the combustion chamber of a boiler is purged with air to remove any unburned fuel or combustible gases before ignition or between firing cycles. The applicant collected single day of boiler operation data in the pre situation to count six cycles in that day, and assumed the number of cycles would be reduced from six per day to three per day. However, the evaluator's trend data showed that the overall daily number of cycles in the post-situation was higher than in the pre-situation, therefore the evaluator determined that this measure did not have a positive impact on purge loss reduction. Since the evaluator's data was collected over a long-term period, making it difficult to count the exact number of cycles due to fluctuations in gas flow readings, this purge loss reduction was not included in the evaluated savings.

13670467, EEM-3: preheat temperature reset: According to the pre-install data, the maximum preheat temperature is 70°F and the heating valve is closed for OATs above 70°F. In the most recent post-install data, the preheat temperature varies between 45°F and 56°F when the OAT is below 45°F and the heating valve is closed for OATs above 45°F. Since no heat is added in the baseline for OATs above 70°F, the evaluator removed from the erroneous analysis the therm/hour consumption for all temperature bins above 70°F.

Also, the measure is to reset the preheat coil temperature setpoint so the evaluator focuses on the heat exchange in the preheating coil and has removed the heating coil heat exchange component from the Therms/hr equation in both the baseline and post-install cases. Additionally, the evaluator adjusted the final gas savings by dividing by the boiler efficiency to account for system losses. The boiler efficiency value was derived from the applicant's workbook for the boiler measure, where the efficiency was calculated based on the system's performance at different loads. Figure 2-12 is an example of the calculation workbook screenshot.

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Figure 2-12. Screenshot of calculation table for AHU-5115

AHU ID:	AHU-5115					
	Old CFM	New CFM		Design Supply Airflow	17,000.0	based on drawing from Amgen
AHU CFM:	17,000	17,000	design	SF_TSP_DESIGN	5.0	estimate
OA flow	7,000	7,000	based on drawing, not OA damper signal	DAP EXT OPERATING	1.0	estimate
% of Air reheated	20%	20%		SF FAN eff	0.7	estimate
kWh Savings:	32,193			SF Motor eff	0.95	estimate
nand (kW) Savings:	4			BTU/HR_HP	2,544.4	constant
Therms Savings:	6,694				6,356.0	constant

Max preheat setpoint is 70 F and no heating when OAT is above 70F.

Assumed RAH based on ~50% RH | Mixed air is combined Return air and heated OA | CC DAT is DAF final - FTR

Pre Conditions

Providence Bin Data			Supply Air			PHT Properties		Return Air		Mixed Air		CC	
DB Mid Point (F)	Hours	Enthalpy (BTU/lb)	OA CFM	CFM	% OA	Temperature (F)	h (BTU/lb)	Temperature (F)	h (BTU/lb)	Temperature (F)	h (BTU/lb)	Temperature (F)	h (BTU/lb)
97.5	3	35	7,000	17,009	41%	97.5	34.7	68.9	24.8	80.7	28.9	56.4	23.1
92.5	41	38	7,000	17,008	41%	92.5	37.5	68.9	24.8	78.6	30.0	56.1	22.9
87.5	76	36	7,000	17,006	41%	87.5	36.3	68.9	24.8	76.5	29.5	55.8	22.6
82.5	298	34	7,000	17,005	41%	82.5	33.6	68.9	24.8	74.5	28.4	55.5	22.4
77.5	475	32	7,000	17,004	41%	77.5	32.3	68.9	24.8	72.4	27.9	54.2	22.1
72.5	556	31	7,000	17,019	41%	70.1	30.6	69.0	24.3	70.3	26.9	57.1	21.9
67.5	813	28	7,000	16,969	41%	70.0	28.2	68.9	23.8	69.0	25.6	55.0	21.6
62.5	904	25	7,000	17,005	41%	70.0	24.5	68.9	23.3	69.9	23.8	54.5	21.4
57.5	647	21	7,000	16,993	41%	70.0	21.4	68.7	22.8	71.1	22.2	52.5	21.1
52.5	758	19	7,000	17,005	41%	70.2	18.9	68.8	22.3	71.1	20.9	53.0	18.9
47.5	616	17	7,000	16,999	41%	70.0	16.7	68.7	21.8	70.0	19.7	53.0	16.7
42.5	740	15	7,000	16,994	41%	70.0	14.7	68.7	21.3	69.0	18.6	52.5	14.7
37.5	921	13	7,000	16,985	41%	70.1	12.5	68.7	20.8	68.3	17.4	52.3	12.5
32.5	805	11	7,000	17,000	41%	68.7	10.6	68.8	20.3	67.2	16.3	52.3	10.6
27.5	387	9	7,000	16,998	41%	64.4	8.7	68.8	19.8	64.8	15.2	52.5	8.7
22.5	375	7	7,000	16,997	41%	61.0	7.0	68.8	19.3	63.0	14.2	52.4	7.0
17.5	224	5	7,000	16,965	41%	58.3	5.4	68.7	18.8	61.7	13.3	53.4	5.4
12.5	96	4	7,000	16,985	41%	61.9	3.9	68.7	18.3	65.9	12.4	51.5	3.9
7.5	24	3	7,000	16,983	41%	61.0	2.5	68.7	17.8	65.5	11.5	51.2	2.5
2.5	1	1	7,000	16,982	41%	60.1	1.4	68.7	17.3	65.2	10.7	50.9	1.4

	Supply Fan				Final Discharge		Reheat Air	Cooling Load		Total Electric		Total Gas Consumption	
DB Mid Point (F)	DAP (in wg)	DAP Total (in wg)	SF BHP	Temperature Rise (F)	Temperature (F)	h (BTU/lb)	DAT (F)	kW/Ton	Load (Tons)	Demand (kW)	kWh	Therm/Hr	Therms
97.5	1.0	5.0	19.1	2.6	59.0	23.1	70.0	0.77	36.8	42.4	127.3		-
92.5	1.0	5.0	19.1	2.6	58.7	22.9	70.0	0.74	45.8	47.9	1,964.5		-
87.5	1.0	5.0	19.1	2.6	58.4	22.6	70.0	0.71	44.2	45.4	3,453.4		-
82.5	1.0	5.0	19.1	2.6	58.1	22.4	70.0	0.68	38.7	40.4	12,039.6		-
77.5	1.0	5.0	19.1	2.6	56.8	22.1	70.0	0.65	36.9	38.1	18,079.7		-
72.5	1.0	5.0	19.2	2.7	59.7	21.9	70.0	0.62	32.2	34.1	18,948.8		-
67.5	1.0	5.0	19.0	2.6	57.6	21.6	70.0	0.59	25.5	29.1	23,682.6	0.2	152.2
62.5	1.0	5.0	19.1	2.6	57.1	21.4	70.0	0.56	15.6	22.9	20,712.3	0.6	510.2
57.5	1.0	5.0	19.1	2.6	55.2	21.1	70.0	0.53	7.2	18.0	11,643.1	0.9	611.5
52.5	1.0	5.0	19.1	2.6	55.6	18.9	70.0	0.51	12.8	20.8	15,743.2	1.3	1,012.6
47.5	1.0	5.0	19.1	2.6	55.6	16.7	70.0	0.51	19.1	24.0	14,785.0	1.7	1,046.8
42.5	1.0	5.0	19.1	2.6	55.1	14.7	70.0	0.51	24.7	26.9	19,872.5	2.1	1,539.3
37.5	1.0	5.0	19.1	2.6	55.0	12.5	70.0	0.51	31.1	30.1	27,693.2	2.5	2,270.3
32.5	1.0	5.0	19.1	2.6	55.0	10.6	70.0	0.51	36.4	32.8	26,408.0	2.7	2,205.7
27.5	1.0	5.0	19.1	2.6	55.1	8.7	70.0	0.51	41.6	35.5	13,728.2	2.8	1,079.5
22.5	1.0	5.0	19.1	2.6	55.0	7.0	70.0	0.51	46.1	37.8	14,160.2	2.9	1,090.4
17.5	1.0	5.0	19.0	2.6	56.0	5.4	70.0	0.51	50.1	39.7	8,896.0	3.1	690.7
12.5	1.0	5.0	19.1	2.6	54.2	3.9	70.0	0.51	53.9	41.7	4,004.7	3.7	358.5
7.5	1.0	5.0	19.1	2.6	53.9	2.5	70.0	0.51	57.3	43.4	1,042.3	4.0	97.1
2.5	1.0	5.0	19.1	2.6	53.6	1.4	70.0	0.51	59.5	44.6	44.6	4.4	4.4
										Total kWh:	257,029	ual Therms:	12,669.1
										avg kW (ref only):	29		

The formulas for the savings calculations are below:

$$Gas\ Savings = \frac{(Baseline\ Heating\ Consumption - Proposed\ Heating\ Consumption)}{Boiler\ Efficiency}$$

For each bin profile:

$$Heating\ Consumption = \frac{Therms}{hour} \times bin\ hours$$

$$\frac{Therms}{hour} = 1.08 \times Outside\ Air\ cfm \times \frac{PAT - OAT}{100000}$$

Where,

$bin\ hours$ = five-degree interval temperature data, developed by using BinMaker Pro, based on the local TMY3 weather data for 1976-2005

$Outside\ Air\ cfm$ = outside air airflow, assumed constant 7,000 cfm as the control set

OAT = outside air temperature, based on local TMY3 data

PAT = preheat coil air temperature, based on the pre (for baseline) and post (for installed) trend data

$Boiler\ Efficiency$ =83.29%

13741057, EEM-4: simultaneous heating and cooling: Since the measure was to repair the broken valve that modulates the heating temperature based on OAT, the evaluator will focus on the heat exchange component of the heating coil for both AHU-South and AHU-North. Additionally, the evaluator adjusted the final gas savings by dividing by the boiler efficiency to account for system losses. The boiler efficiency value was derived from the applicant's workbook for the boiler measure, where the efficiency was calculated based on the system's performance at different loads. Figure 2-13: is an example of the calculation workbook screenshot.

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Figure 2-13. Screenshot of calculation table for AHU-north

AHU ID:	AHU-North					
	Old CFM	New CFM		Design Supply Airflow	68,000.0	based on email from Amgen
AHU CFM:	68,000	68,000	design	SF_TSP_DESIGN	7.0	estimate
% OA	100%	100%		DAP EXT OPERATING	1.4	from data
ction above 50F OAT	100%	100%		SF FAN eff	0.7	estimate
% of Air reheated	10%	10%		SF Motor eff	0.95	estimate
kWh Savings:	287,090			RAT		estimate
Demand (kW) Savings:	32.8			BTU/HR_HP	2,544.4	constant
Therms Savings:	66,310				6,356.0	constant

min HR DAT allowed in calc = 40; using post HR properties at high OATs; max preheat temp allowed in calcs = 80; using post data for final discharge temperature to not double count, min

Pre Conditions

Providence Bin Data			Supply Air			HR Properties	PHT Properties	CC	Supply Fan				Final Discharge	Reheat Air	Cooling Load		Total Electric		Total Gas Consumption	
DB Mid Point (F)	Hours	Enthalpy (BTU/lb)	Supply Fan Signal %	CFM	% OA	Temperature (F)*	Temperature (F)*	Temperature (F)	DAP (in wg)	DAP Total (in wg)	SF BHP	Temperature Rise (F)	Temperature (F)	DAT (F)	kW/Ton	Load (Tons)	Demand (kW)	kWh	Therm/Hr	Therms
97.5	3	35	65.2%	44,306.0	100%	89.6	89.6	50.8	1.4	3.8	37.6	2.0	52.8	70.0	0.77	154.8				
92.5	41	38	66.7%	45,382.3	100%	83.4	83.4	50.7	1.4	3.9	39.7	2.1	52.8	70.0	0.74	133.6				
87.5	76	36	61.8%	42,043.4	100%	82.6	82.6	50.9	1.4	3.6	33.6	1.9	52.8	70.0	0.71	120.0				
82.5	298	34	62.7%	42,648.3	100%	79.2	80.0	51.6	1.4	3.6	34.6	1.9	53.5	70.0	0.68	109.1				
77.5	475	32	65.1%	44,249.1	100%	76.4	80.0	51.7	1.4	3.8	37.5	2.0	53.7	70.0	0.65	112.8				
72.5	556	31	65.9%	44,781.1	100%	73.8	80.0	51.6	1.4	3.8	38.5	2.0	53.7	70.0	0.62	114.1				
67.5	813	28	66.0%	44,854.9	100%	68.9	79.9	52.2	1.4	3.8	38.7	2.0	54.3	70.0	0.59	111.8				
62.5	904	25	65.8%	44,765.7	100%	63.6	79.9	53.0	1.4	3.8	38.5	2.0	55.0	70.0	0.56	108.5	89.0	80,422.2	7.9	7,148.1
57.5	647	21	65.8%	44,772.0	100%	58.8	79.9	53.0	1.4	3.8	38.5	2.0	55.0	70.0	0.53	108.2	85.6	55,357.6	10.2	6,590.3
52.5	758	19	65.2%	44,363.2	100%	53.8	80.0	52.0	1.4	3.8	37.7	2.0	54.0	70.0	0.51	111.8	85.2	64,544.4	12.6	9,513.2
47.5	616	17	65.0%	44,194.4	100%	51.3	80.0	52.3	1.4	3.8	37.4	2.0	54.3	70.0	0.51	110.3	84.1	51,834.2	13.7	8,447.6
42.5	740	15	64.9%	44,139.9	100%	51.0	80.0	52.8	1.4	3.8	37.3	2.0	54.8	70.0	0.51	107.9	82.9	61,322.6	13.8	10,221.6
37.5	921	13	64.7%	44,024.6	100%	49.7	80.0	53.4	1.4	3.7	37.1	2.0	55.3	70.0	0.51	105.6	81.5	75,068.0	14.4	13,285.8
32.5	805	11	64.4%	43,805.7	100%	47.5	79.3	54.0	1.4	3.7	36.7	2.0	56.0	70.0	0.51	99.7	78.2	62,967.5	15.1	12,139.3
27.5	387	9	64.1%	43,586.7	100%	44.4	78.2	54.7	1.4	3.7	36.3	2.0	56.6	70.0	0.51	92.3	74.1	28,692.8	15.9	6,167.9
22.5	375	7	63.6%	43,216.6	100%	41.0	80.0	55.3	1.4	3.7	35.6	1.9	57.2	70.0	0.51	96.1	75.5	28,321.0	18.2	6,827.9
17.5	224	5	63.8%	43,360.9	100%	32.1	80.0	55.7	1.4	3.7	35.8	1.9	57.7	70.0	0.51	94.8	75.1	16,813.8	22.4	5,019.7
12.5	96	4	63.8%	43,363.6	100%	23.6	80.0	56.1	1.4	3.7	35.8	1.9	58.0	70.0	0.51	93.4	74.4	7,138.9	26.4	2,535.2
7.5	24	3	64.2%	43,638.3	100%	26.9	79.6	56.2	1.4	3.7	36.4	2.0	58.1	70.0	0.51	91.9	74.0	1,775.7	24.8	596.4
2.5	1	1	64.2%	43,683.8	100%	23.5	79.5	56.4	1.4	3.7	36.4	2.0	58.4	70.0	0.51	91.0	73.6	73.6	26.5	26.5
																	Total kWh:	534,332	Total Annual Therms:	88,519.4
																	avg kW (ref only):	61		

$$Gas\ Savings = \frac{(Total\ Baseline\ Heating\ Consumption - Total\ Proposed\ Heating\ Consumption)}{Boiler\ Efficiency}$$

$$Total\ Heating\ Consumption = AHU\_South + AHU\_North$$

For each bin profile:

$$Heating\ Consumption = \frac{Therms}{hour} \times bin\ hours$$

$$\frac{Therms}{hour} = 1.08 \times Supply\ Air\ cfm \times \frac{PAT - HRC}{100000}$$

Where,

$bin\ hours$ = five-degree interval temperature data, developed by using BinMaker Pro, based on the local TMY3 weather data for 1976-2005

$Supply\ Air\ cfm = Design\ air\ flow \times Supply\ Air\ Fan\ speed\%$ AHU supply fan airflow. The design airflow was from AHU specs, and supply air fan speed percentage was based on the pre (for baseline) and post (for installed) trend data.

PAT = preheat coil air temperature, based on the pre (for baseline) and post (for installed) trend data

HRC = air temperature leaving the heat recovery wheel, based on the pre (for baseline) and post (for installed) trend data

DNV

3 FINAL RESULTS

This section summarizes the evaluation results determined in the analysis above. Both the applicant and evaluation savings are based on trend data. The applicant used a custom spreadsheet-based analysis to calculate the project savings. The evaluator used the applicant's spreadsheet with current trend data to update savings. Table 3-1 summarizes the key tracking and evaluated parameters.

Table 3-1. Summary of key parameters

EEM	Parameter	BASELINE Tracking Value(s)	BASELINE Evaluation Value(s)	PROPOSED / INSTALLED Tracking Value(s)	PROPOSED / INSTALLED Evaluation Value(s)
1	Supply air CFM	3,200-28,007	3,200-28,007	3,200-28,007	3,200-28,007
	Mixed air temperature °F	39-82	Not used	40-90	Not used
	Return air temperature °F	69-74	Not used	67-80	Not used
	Preheat temperature °F	58-90	Not used	56-90	Not used
	Discharge temperature °F	58-65	59-66	62-70	60-74
	Reheat air temperature °F	70	70	70	70
	Annual operation hours	8760	4,600-6,940	8760	4,600-6,940
	Boiler efficiency	Not used	83.29%	Not used	83.29%
2	Cycling Status, annual number of hours	6 cycles per day and 4.75 mins per cycle, equivalent to 171 hours per year for boiler 3 only	Boiler 2: 388 hours Boiler 3: 367 hours Boiler 4: 240 hours	3 cycles per day and 4.75 mins per cycle, equivalent to 85.5 hours per year for boiler 3 only	Boiler 2: 329 hours Boiler 3: 238 hours Boiler 4: 170 hours
	Average Firing rate, cfm	242.745	Boiler 2: 183 Boiler 3: 220 Boiler 4: 225	242.745	Boiler 2: 189 Boiler 3: 268 Boiler 4: 300
3	Supply air CFM	17,000	17,000	17,000	17,000
	Preheat temperature °F	58-97.5	58-70	54-97.5	40-69.5
	Return Air temperature °F	69	Not used	69	Not used
	Mixed Air temperature °F	61-80	Not used	62-80	Not used
	Discharge temperature °F	54-56	Not used	54.5-56	Not used
	Reheat air temperature °F	70	Not used	70	Not used
	Annual operation hours	8760	8,760	8760	8,760
	Boiler efficiency	Not used	83.29%	Not used	83.29%

EEM	Parameter	BASELINE Tracking Value(s)	BASELINE Evaluation Value(s)	PROPOSED / INSTALLED Tracking Value(s)	PROPOSED / INSTALLED Evaluation Value(s)
4	Supply Air CFM	42,890-49,285	42,890-49,285	42,890-49,285	42,890-49,285
	Heat Recovery temperature °F	40-84	22.3-63.6	27-87	23.1-63.6
	Preheat temperature °F	79.5-84	79.5-80	56-87	56.4-62.9
	Discharge temperature °F	54-58	Not used	54-58	Not used
	Reheat Air temperature °F	70	N/A	70	N/A
	Annual operation hours	8760	8760	8760	8760
	Boiler efficiency	Not used	83.29%	Not used	83.29%

3.1 Explanation of differences

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

Table 3-2. Summary of deviations

End-use	Discrepancy	Parameter	Impact of deviation	Discussion of deviations
Space heating	Operational	EEM 1: Bin hrs.	-1.9%	Decrease in savings - The actual unoccupied hours of each temperature bin used by the evaluator was less than those used by the applicant.
Space heating	Operational	EEM 1: DAT	-10.6%	Decrease in savings - The DAT calculated by the evaluator for each temperature bin based on the trend data was higher than those used by the applicant.
Space heating	Methodology	EEM 1: Therms/hr. estimation	-10.5%	Decrease in savings - The Therms/hr. for each temperature bin calculated by the evaluator was less than those used by the applicant because the evaluator removed the preheat coil heat exchange component from the Therms/hr equation. This resulted in lower savings.
Space heating	Efficiency	EEM 1: Boiler efficiency	0.2%	Increase in savings - The evaluator adjusted the final gas savings by including the boiler efficiency to account for system losses.
Production load	Operational	EEM 2: Boiler control	2.8%	Increase in savings - The evaluator calculated cycling reduction for the boiler plant is higher than applicant assumed.

End-use	Discrepancy	Parameter	Impact of deviation	Discussion of deviations
Space heating	Methodology	EEM 3: Therms/hr estimation	0.8%	Increase in savings - The Therms/hr. for each temperature bin calculated by the evaluator was more than those used by the applicant because the evaluator removed the heating coil heat exchange component from the Therms/hr. This resulted in higher savings.
Space heating	Methodology	EEM 3: Preheat temperature	-1.0%	Decrease in savings - The Preheat temperature calculated by the evaluator for each temperature bin based on the trend data was lower than those used by the applicant.
Space heating	Efficiency	EEM 3: Boiler efficiency	0.9%	Increase in savings - The evaluator adjusted the final gas savings by including the boiler efficiency to account for system losses.
Space heating	Methodology	EEM 3: Temperature bins	0.2%	Increase in savings- The evaluator determined that there is no heat added above 70°F. The evaluator removed the temperature bins above 70°F whereas the applicant included them.
Space heating	Methodology	EEM 4: Preheat temperature	5.0%	Increase in savings - The Preheat temperature calculated by the evaluator for each OAT bin based on the trend data was low than those used by the applicant.
Space heating	Efficiency	EEM 4: Boiler efficiency	17.8%	Increase in savings - The evaluator adjusted the final gas savings by including the boiler efficiency to account for system losses.
Total			**25%**	

3.2 Lifetime savings

Both the measures installed were deemed by evaluators to be add-on measures with single baselines. Evaluators calculated applicant and evaluated lifetime savings values using the following formula:

$$LAGI = FYS \times EUL$$

where,

LAGI = lifetime adjusted gross impact (therm)

FYS = first year savings (kWh)

EUL = measure life (years)

The evaluated lifetime savings differ from the tracking lifetime savings for three out of the four measures because the evaluated first-year savings are different from the tracking first-year savings for these measures. Table 3-3 provides a summary of the savings values for the whole project.

Table 3-3. Project- lifetime savings summary

EEM	Factor	Tracking	Application	Evaluator
1	Lifetime savings	21,280	21,280	8,630
	First-year savings	4,256	4,256	1,726
	Measure lifetime	5	5	5
	Baseline classification	Retrofit	Retrofit	Add-on
2	Lifetime savings	135,170	135,170	177,041
	First-year savings	13,517	13,517	17,704
	Measure lifetime	10	10	10
	Baseline classification	Retrofit	Retrofit	Add-on
3	Lifetime savings	33,760	33,760	40,185
	First-year savings	6,752	6,752	8,037
	Measure lifetime	5	5	5
	Baseline classification	Retrofit	Retrofit	Add-on
4	Lifetime savings	247,874	247,874	316,264
	First-year savings	123,937	123,937	158,132
	Measure lifetime	2	2	2
	Baseline classification	Retrofit	Retrofit	Add-on
Total project lifetime savings	Lifetime savings	438,084	438,084	542,120
	First-year savings	148,462	148,462	185,599
	Measure lifetime	2.95	2.95	2.92
	Baseline classification	Retrofit	Retrofit	Add-on

3.3 Ancillary impacts

This section explains the ancillary impacts associated with electric savings. The original tracking analysis calculated annual electric savings of 148,462 kWh. Evaluators calculated the annual electric savings to be 164,407 kWh.

RI CUSTOM GAS EVALUATION SITE SPECIFIC MEASUREMENT AND VERIFICATION REPORT

Site ID: RIG22N012

Report Date: 6/17/24

Program Administrator	National Grid	
Application ID(s)	12891673	
Project Type	Add-on	
Program Year	2022	
Evaluation Firm	DNV	
Evaluation Engineer	Matthew Piana	
Senior Engineer	Shaobo Feng	

1 EVALUATED SITE SUMMARY AND RESULTS

The evaluated project was installed at an elementary school and consisted of the installation of removable insulating jackets and linear pipe insulation on bare fittings, valves, tanks, and pipes. The uninsulated system components are part of a steam distribution system that is utilized for space heating purposes. Gas savings result from the reduction in heat loss from the hot pipes to the unconditioned boiler room space, which in turn reduces the gas consumption of the boiler.

The evaluation results are presented in Table 1-1. The tracking analysis included a spreadsheet that models the heat loss rates of bare and insulated pipes, fittings, and valves. The evaluator metered the temperature of a sample of insulated components in order to update the applicant savings spreadsheet. The evaluated first-year savings are 23% greater than the applicant estimated savings value.

Table 1-1. Evaluation results summary

PA application ID	Measure name		Annual savings (therms)
12891673	Pipe insulation	Tracked	2,880
		Evaluated	3,534
		Realization Rate	123%

1.1 Explanation of deviations from tracking

The evaluated first-year savings are 23% more than the applicant-reported savings. The main factor making the evaluated savings greater than the applicant savings is the metered temperature difference between the boiler room ambient temperature and the pipe surface temperatures. The evaluator-observed temperature differences are greater than the applicant-estimated temperature differences, which resulted in more heat loss reduction. Further details regarding deviations from the tracking savings are presented in Section 3.

1.2 Recommendations for program designers and implementers

There are no recommendations at this time.

1.3 Customer alert

There are no customer alerts.

2 EVALUATED MEASURES

The following sections present the evaluation procedure, including the findings from an in-depth review of the supplied applicant calculations and the evaluation methodology determined to be the best fit for the site and information available. The evaluated project consisted of adding removable insulating jackets and insulation to fittings, valves, tanks, and pipes in an elementary school.

2.1 Application information and applicant savings methodology

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

2.2 Applicant description of baseline

A vendor conducted a scoping audit in which they identified uninsulated fittings, valves, tanks, and pipes. These bare components are part of a steam distribution system that is used for space heating purposes. These bare components were allowing excess heat to escape to the unconditioned boiler room space and reducing the performance of the steam boiler system. The vendor took surface temperature readings of the uninsulated surfaces, collected surface areas, and determined the hours of operation for the steam system.

The applicant classified the measure as a retrofit with the pre-existing bare pipe conditions as the baseline. The baseline consisted of 161 ft^2 of uninsulated fittings, valves, and tanks, and a total of 460 linear feet of uninsulated pipes in an unconditioned boiler room. Table 2-1 summarizes the critical applicant baseline parameters.

Table 2-1. Applicant baseline key parameters

Measure	Parameter	BASELINE	
		Value(s)	Source of parameter value
Pipe insulation	Operating hours	2,190	Applicant assumed
Pipe insulation	Ambient space temperature	80°F	Applicant spot measurement
Pipe insulation	Steam-side pipe temperature	227°F	Applicant spot measurement
Pipe insulation	Condensate-side pipe temperature	180°F	Applicant spot measurement
Pipe insulation	Total therm losses uninsulated components	3,233 therms/year	Applicant savings calculation
Pipe insulation	Boiler efficiency	80%	Applicant assumed

2.2.1 Applicant description of installed equipment and operation

Table 2-2 summarizes the key proposed applicant parameters with the installed insulation.

Table 2-2. Applicant proposed key parameters

Measure	Parameter	BASELINE	
		Value(s)	Source of parameter value
Pipe insulation	Operating hours	2,190	Applicant assumed
Pipe insulation	Ambient space temperature	80°F	Applicant spot measurement
Pipe insulation	Steam-side pipe temperature	227°F	Applicant spot measurement
Pipe insulation	Condensate-side pipe temperature	180°F	Applicant spot measurement
Pipe insulation	Total therm losses uninsulated components	353 therms/year	Applicant savings calculation
Pipe insulation	Boiler efficiency	80%	Applicant assumed

2.2.2 Applicant energy savings algorithm

The applicant model used heat loss equations to calculate bare and insulated surface heat loss rates. The applicant savings calculation included an original savings estimate that was done by the insulation contractor. However, a TA vendor was hired to check the original savings estimate. The TA vendor updated the original savings estimate based on their on-site findings that savings value is the tracking savings value for this project. Savings were calculated for the pipe insulation measure by summing the avoided heat loss of each insulated component according to the following algorithms:

$$Savings = \sum_{1}^{n}(Q_b - Q_i)$$

where:

Q_b= annual therm loss of bare component
Q_i= annual therm loss of insulated component

The applicant calculated the therm loss for bare components according to the following algorithm based on heat loss per square foot:

$$Q_b = \frac{A \times h \times \dot{Q}_c}{100{,}000 \times \eta}$$

where:

A= area of component (ft^2)
h= energized annual hours of component (2,190 hours all components)
$\dot{Q}_c$= heat loss rate of bare component (BTU/hour/ft^2)
100,000= BTU to therm conversion factor
η= boiler efficiency (80%)

The applicant calculated the therm loss for components fitted with insulating jackets according to the following algorithm:

$$Q_i = \frac{A \times h \times \dot{Q}_c}{100{,}000 \times \eta}$$

where:

A= area of component (ft^2)
h= energized annual hours of component (2,190 hours all components)
$\dot{Q}_c$= heat loss rate of insulated component (BTU/hour/ft^2)
100,000= BTU to therm conversion factor
η= boiler efficiency (80%)

For linear pipes, the applicant calculated the therm loss for bare pipes according to the following algorithm based on heat loss per linear foot:

$$Q_b = \frac{l \times h \times \dot{Q}_c}{100{,}000 \times \eta}$$

where:

l= length of component (ft)
h= energized annual hours of component (2,190 hours all components)
$\dot{Q}_c$= heat loss rate of bare component (BTU/hour/ft)
100,000= BTU to therm conversion factor
η= boiler efficiency (80%)

The applicant calculated the therm loss for linear pipes according to the following algorithm:

$$Q_i = \frac{l \times h \times \dot{Q}_c}{100{,}000 \times \eta}$$

where:

l= length of component (ft)
h= energized annual hours of component (2,190 hours all components)
$\dot{Q}_c$= heat loss rate of insulated component (BTU/hour/ft)
100,000= BTU to therm conversion factor
η= boiler efficiency (80%)

The applicant calculated Q_b and Q_i using 3EPlus, assuming an ambient boiler room temperature of 80°F and component surface temperatures of 180°F and 227°F. Figure 2-1 shows a screenshot of the applicant savings calculation spreadsheet.

Figure 2-1. Applicant savings calculation spreadsheet

Item	Description	Nominal D (in.)	Op. Temp (°F)	Amb. Temp (°F)	Surface Area (sqft)	Op. Hrs	Insul. Thickness	Insul. Benefit %	Bare Btu/hr/sqft, linear lost	Insulated Btu/hr/sqft, linear foot lost	Insulated Touch Temp (°F)	Boiler Efficiency	Pre Therms	Post Therms	Therms Saved Per Year
200	6" Hard Pipe Insulation x1' 2"	6.00	227	80	1.57	2190	2"	100%	598.60	43.09	93	80%	16.39	1.18	15.21
210	6" Hard Pipe Insulation x1' 2"	6.00	180	80	4.99	2190	2"	100%	364.60	27.62	88	80%	23.85	1.81	22.05
208	4" Hard Pipe Insulation x1' 1 1/2"	4.00	180	80	10.40	2190	1.5"	100%	252.90	24.76	90	80%	68.75	6.73	62.02
202	4" Hard Pipe Insulation x1' 2"	4.00	227	80	12.27	2190	2"	100%	414.80	31.84	92	80%	132.97	10.21	122.76
216	1.25" Hard Pipe Insulation x1' 1 1/2"	1.25	227	80	4.33	2190	1.5"	100%	0.00	0.00	92	80%	0.00	0.00	0.00
203	1.5" Hard Pipe Insulation x1' 1.5"	1.50	180	80	7.82	2190	1.5"	100%	113.80	13.61	88	80%	62.49	7.47	55.02
211	0.5" Hard Pipe Insulation x1' 1.5"	0.50	180	80	3.99	2190	1.5"	100%	55.14	8.56	86	80%	47.06	7.31	39.76
201	8" Hard Pipe Insulation x1' 2"	8.00	227	80	79.58	2190	2"	100%	770.20	53.19	94	80%	801.20	55.33	745.87
207	2.5" Hard Pipe Insulation x1' 1 1/2"	2.50	180	80	28.74	2190	1.5"	100%	166.50	15.95	87	80%	200.14	19.17	180.97
206	1" Hard Pipe Insulation x1' 1 1/2"	1.00	180	80	13.23	2190	1.5"	100%	81.72	10.77	87	80%	113.98	15.02	98.96
209	2" Hard Pipe Insulation x1' 1 1/2"	2.00	180	80	37.64	2190	1.5"	100%	139.60	15.54	88	80%	274.73	30.58	244.15
205	1.25" Hard Pipe Insulation x1' 1 1/2"	1.25	180	80	28.19	2190	1.5"	100%	100.70	12.03	87	80%	238.86	28.54	210.33
204	0.75" Hard Pipe Insulation x1' 1 1/2"	0.75	180	80	17.89	2190	1.5"	100%	66.98	9.92	87	80%	168.91	25.02	143.89
7	Front Boiler Door	-	227	80	21.66	2190	1"	100%	327.00	38.36	107	80%	193.89	22.75	171.15
9	Front Boiler Door	-	227	80	5.12	2190	1"	100%	327.00	38.36	107	80%	45.83	5.38	40.46
10	Heat Exchanger Head	-	227	80	3.50	2190	1"	100%	327.00	38.36	107	80%	31.33	3.68	27.66
13	Heat Exchanger Head	-	227	80	3.50	2190	1"	100%	327.00	38.36	107	80%	31.33	3.68	27.66
15	Back Boiler Door	-	227	80	2.47	2190	1"	100%	327.00	38.36	107	80%	22.11	2.59	19.52
213	Boiler Exhaust	-	227	80	85.55	2190	1"	100%	0.00	0.00	107	80%	0.00	0.00	0.00
14	4 Flange 125/150 (0-299°F) 1"	4.00	227	80	1.57	2190	1"	100%	327.00	38.36	103	80%	14.05	1.65	12.41
1	6 Flange 125/150 (0-299°F) 1"	6.00	227	80	1.92	2190	1"	100%	327.00	38.36	106	80%	17.19	2.02	15.17
2	6 Bonnet - Gate 125/150 (0-299°F) 1"	6.00	227	80	2.52	2190	1"	100%	327.00	38.36	106	80%	22.56	2.65	19.91
3	6 Gate Valve 125/150 (0-299°F) 1"	6.00	227	80	5.04	2190	1"	100%	327.00	38.36	106	80%	45.12	5.29	39.82
8	6 Gate Valve 125/150 (0-299°F) 1"	6.00	227	80	5.04	2190	1"	100%	327.00	38.36	106	80%	45.12	5.29	39.82
11	8 Gate Valve 125/150 (0-299°F) 1"	8.00	227	80	6.77	2190	1"	100%	327.00	38.36	105	80%	60.60	7.11	53.49
17	0.75 Armstrong Condensate Pump NPT 1" (0°-299°F)	0.75	180	80	4.23	2190	1"	100%	198.60	24.50	92	80%	23.00	2.84	20.16
18	0.75 Armstrong Condensate Pump NPT 1" (0°-299°F)	0.75	180	80	4.23	2190	1"	100%	198.60	24.50	92	80%	23.00	2.84	20.16

2.2.3 Evaluation assessment of applicant methodology

The evaluator found the applicant evaluation methodology to be appropriate.

2.3 On-site inspection and metering

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

2.3.1 Summary of on-site findings

During the site visit, the evaluator verified that the bare components were insulated per the scope of the project. The evaluator used a measuring tape to measure the linear feet of insulated pipe. The evaluator found that the 460 linear feet of insulated pipe outlined in the project documentation to be accurate based on these measurements. The evaluator counted the number of insulated jackets in the boiler room and found the count to match the project documentation. While installing thermocouples on the insulated pipes, the evaluator verified insulation thicknesses using a measuring tape. To verify the ambient temperature of the space, the evaluator deployed one temperature sensor in the middle of the room. The evaluator installed five HOBO loggers with thermocouples to a sample set of insulated pipes in order to verify the steam operating temperature of the system. Table 2-3 summarizes the evaluator measure verification.

Table 2-3. Measure verification

Measure Name	Verification Method	Verification Result
Pipe insulation	Visual verification and data logging using Hobo loggers with thermal couples	All uninsulated components were insulated per the project scope.

2.3.2 Measured and logged data

The evaluator deployed data loggers to characterize the performance of the insulation from March 12, 2024. through May 8, 2024. Table 2-4 presents the logger deployment details. The evaluator deployed six HOBO loggers with thermocouples in total. Five loggers were installed on insulated pipes on the steam side of the boiler system and one logger was installed in the middle of the boiler room to measure the ambient space temperature. These five loggers were installed underneath the insulation. No loggers were installed on the condensate side of the system.

During the site visit, the site contact informed the evaluator that the elementary school was decommissioned for use as a school at the end of the 2022/2023 school year. Based on this information from the site contact and the project files, the evaluator confirmed that the pipe insulation was installed and working for one normal winter heating season before the school was decommissioned. The site contact informed the evaluator that the school heating system now operated to maintain the facility at 60°F to prevent any damage to the building from cold weather, and the future occupancy and use of the school had not been determined. It is unclear whether the school will be used again in the future in the same capacity it was before the pipe insulation measure was installed. Therefore, the evaluator calculated the first-year savings normally and applied a correction factor to the remainder of the measure life. A detailed explanation of this adjustment is described in Section 3.2.

Table 2-4. Evaluation data collection

Source	Parameter	Number of loggers	Interval	Duration
HOBO thermocouple	Temperature of steam pipe 1″ insulation	3	15-minute	8 weeks
HOBO thermocouple	Temperature of steam pipe 1.5″ insulation	1	15-minute	8 weeks
HOBO thermocouple	Temperature of steam pipe 2″ insulation	1	15-minute	8 weeks
HOBO thermocouple	Boiler room ambient temperature	1	15-minute	8 weeks

Figure 2-2 shows the logged temperature of the insulated pipes during the metering period.

Figure 2-2. Metered steam pipe temperatures

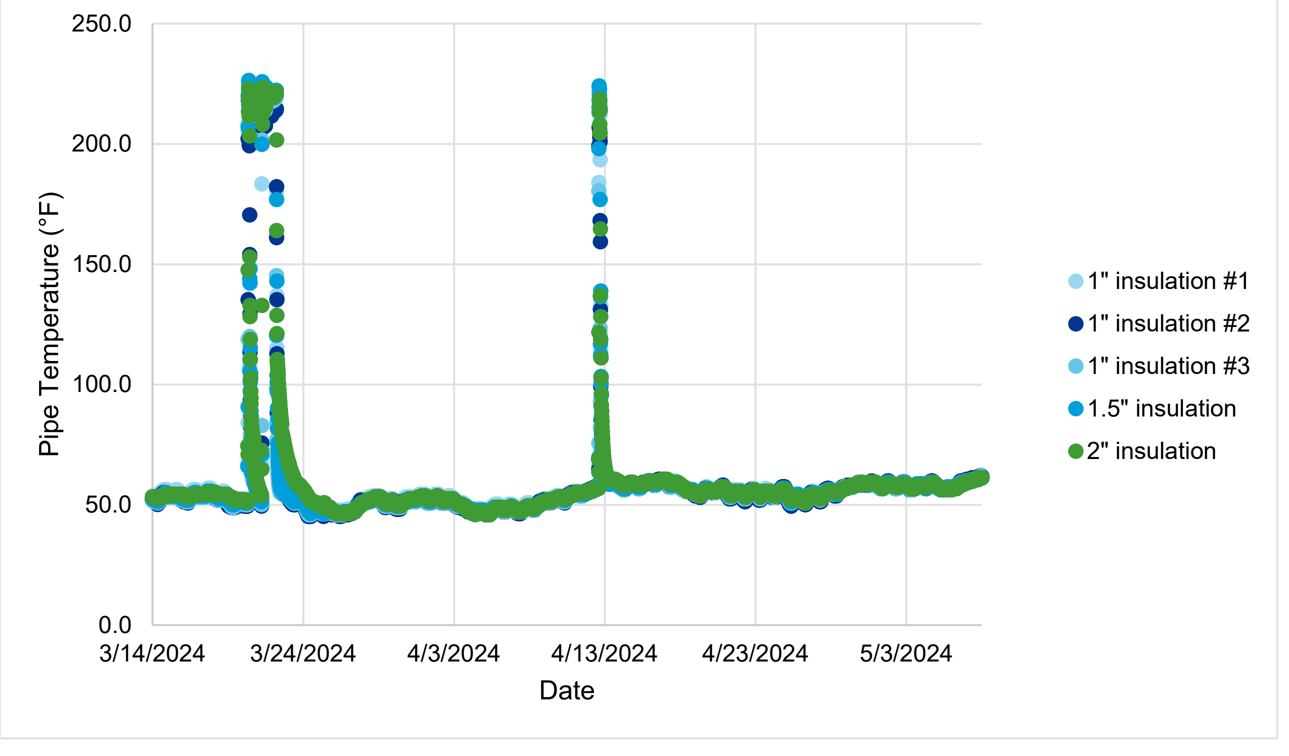
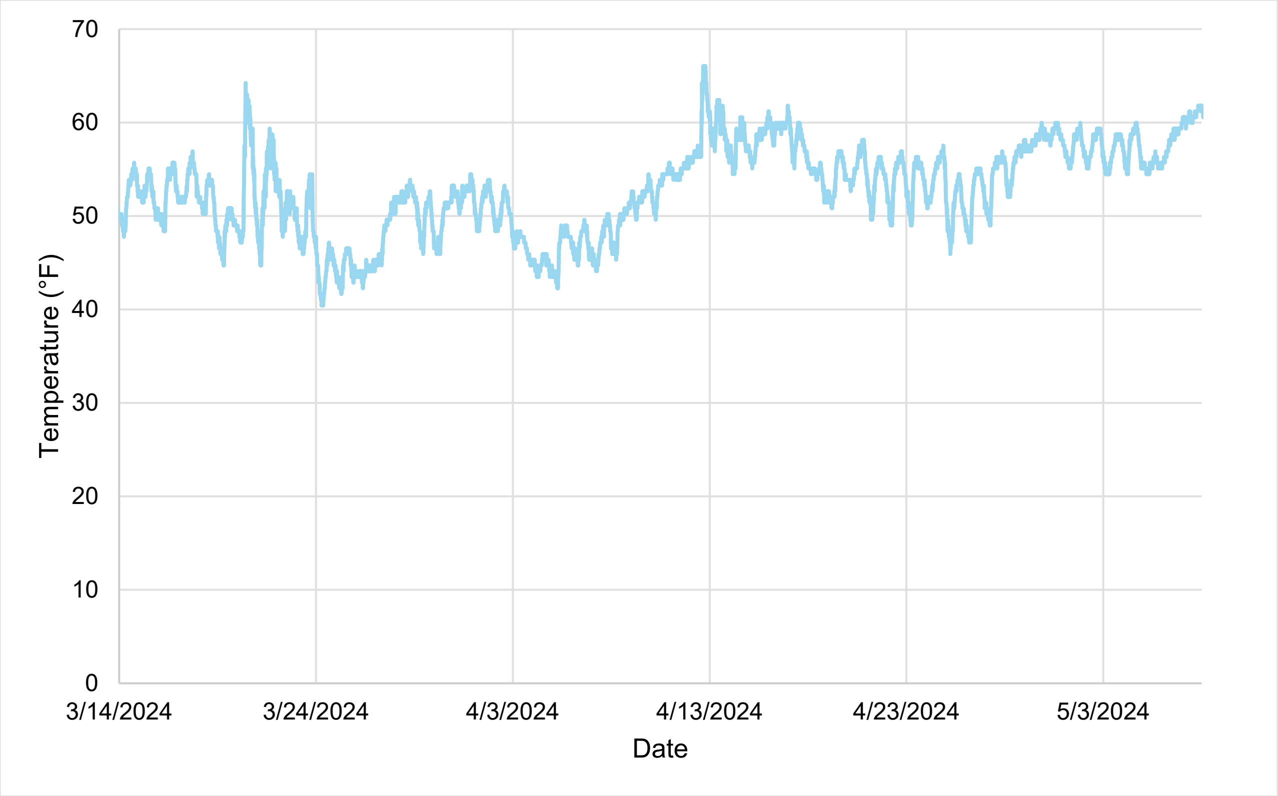


Figure 2-2 shows that the steam heating system was de-energized for the majority of the metering period. In total, the boiler system was energized 2% of the time during the metering period which did include some warmer weather when the boiler was not likely needed if the school had still been operating. This observation was in alignment with the heating system operation the site contact described (operating only to prevent damage to the building). The evaluator observed an average pipe surface temperature of 219°F while the system was energized. The evaluator did not obtain metered data for the condensate side of the system and therefore kept the applicant estimated condensate-side temperature of 180°F in the savings analysis. Figure 2-3 shows the metered boiler room ambient temperature during the metering period.

Figure 2-3. Metered boiler room ambient temperature



The average boiler room ambient temperature was observed to be 55°F while the boiler system was energized. This 55°F was much lower than the applicant value of 80°F but is in line with the school being decommissioned.

2.4 Evaluation methods and findings

This section describes the evaluator methods and findings.

2.4.1 Evaluation description of baseline

The evaluator reviewed the project files and interviewed the site contact to gather information on the baseline. The baseline is the pre-existing conditions, which consisted of 161 ft^2 of uninsulated fittings, valves, and tanks and a total of 460 linear feet of uninsulated pipes that were energized during the winter heating season. The evaluator classified the measure as an add-on with a single baseline. The baseline is single because the insulation measure life of 15 years is less than two-thirds the heating equipment measure life of 25 years.

2.4.2 Evaluation calculation method

The evaluator updated the applicant savings calculation spreadsheet based on the data gathered during the metering period. The evaluator used the metered steam pipe temperatures and metered boiler room ambient temperature to calculate heat transfer rates using 3EPlus. The evaluator only used temperatures that were metered while the boiler was operational. The evaluator updated the applicant savings calculation spreadsheet using these metering-based heat transfer rates. The evaluator used the following algorithms to calculate the savings for this project.

$$Savings = \sum_{1}^{n} (Q_b - Q_i)$$

where:

Q_b= annual therm loss of bare component
Q_i= annual therm loss of insulated component

The evaluator calculated the therm loss for bare components according to the following algorithm based on heat loss per square foot:

$$Q_b = \frac{A \times h \times \dot{Q}_c}{100{,}000 \times \eta}$$

where:

A= area of component (ft^2)
h= energized annual hours of component (2,190 hours all components)
$\dot{Q}_c$= heat loss rate of bare component (BTU/hour/ft^2)
100,000= BTU to therm conversion factor
η= boiler efficiency (81%)

The evaluator calculated the therm loss for components fitted with insulating jackets according to the following algorithm:

$$Q_i = \frac{A \times h \times \dot{Q}_c}{100{,}000 \times \eta}$$

where:

A= area of component
h= energized annual hours of component (2,190 hours all components)
$\dot{Q}_c$= heat loss rate of insulated component (BTU/hour/ft^2)
100,000= BTU to therm conversion factor
η= boiler efficiency (81%)

For linear pipes, the evaluator calculated the therm loss for bare pipes according to the following algorithm based on heat loss per linear foot:

$$Q_b = \frac{l \times h \times \dot{Q}_c}{100{,}000 \times \eta}$$

where:

l= length of component (ft)
h= energized annual hours of component (2,190 hours all components)
$\dot{Q}_c$= heat loss rate of bare component (BTU/hour/ft)
100,000= BTU to therm conversion factor
η= boiler efficiency (81%)

The evaluator calculated the therm loss for linear pipes according to the following algorithm:

$$Q_i = \frac{l \times h \times \dot{Q}_c}{100{,}000 \times \eta}$$

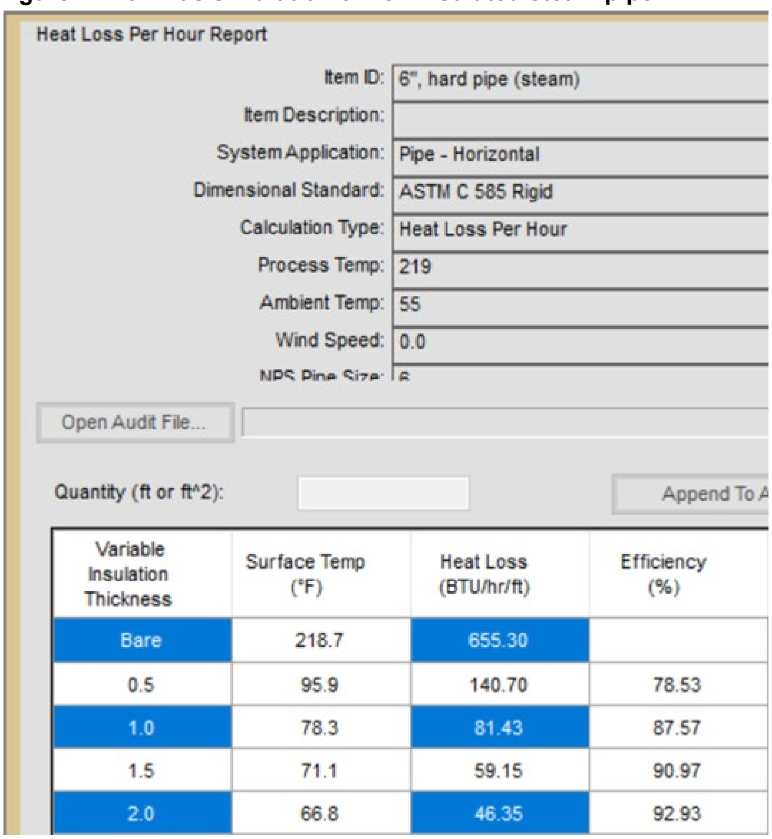
where:

l= length of component (ft)
h= energized annual hours of component (2,190 hours all components)
$\dot{Q}_c$= heat loss rate of insulated component (BTU/hour/ft)
100,000= BTU to therm conversion factor
η= boiler efficiency (81%)

The evaluator calculated Q_b and Q_i using 3EPlus, assuming an ambient boiler room temperature of 55°F and component surface temperatures of 180°F and 219°F. The ambient boiler room temperature was 55°F during the boiler's operation. The evaluator deemed this value to be representative of the boiler room's typical operational state due to the room's layout. With a large cubic volume, wall of single-paned windows, and a large, empty side room, the evaluator found the 55°F metered ambient temperature to be representative of the boiler room's typical operational state. The evaluator updated the applicant savings spreadsheet based on the metered pipe temperatures, ambient temperature, and calculated 3EPlus heat transfer rates. Because the facility was decommissioned during the site visit and metering period, the evaluator deemed that the applicant annual operation hours value of 2,190 hours was accurate based on the interview with the site contact. For this reason, the evaluator also used 2,190 hours for the annual hours of operation.

Figure 2-4 and Figure 2-5 are screenshots of evaluator 3EPlus simulations that were used to calculate savings for this project. Figure 2-4 shows the heat transfer rates calculated for a six-inch steam-side pipe and Figure 2-5 shows the heat transfer rates calculated for a six-inch condensate-side pipe.

Figure 2-4. 3EPlus simulation 6-inch insulated steam pipe


Heat Loss Per Hour Report

Item ID: 6", hard pipe (steam)
Item Description:
System Application: Pipe - Horizontal
Dimensional Standard: ASTM C 585 Rigid
Calculation Type: Heat Loss Per Hour
Process Temp: 219
Ambient Temp: 55
Wind Speed: 0.0
NPS Pipe Size: 6

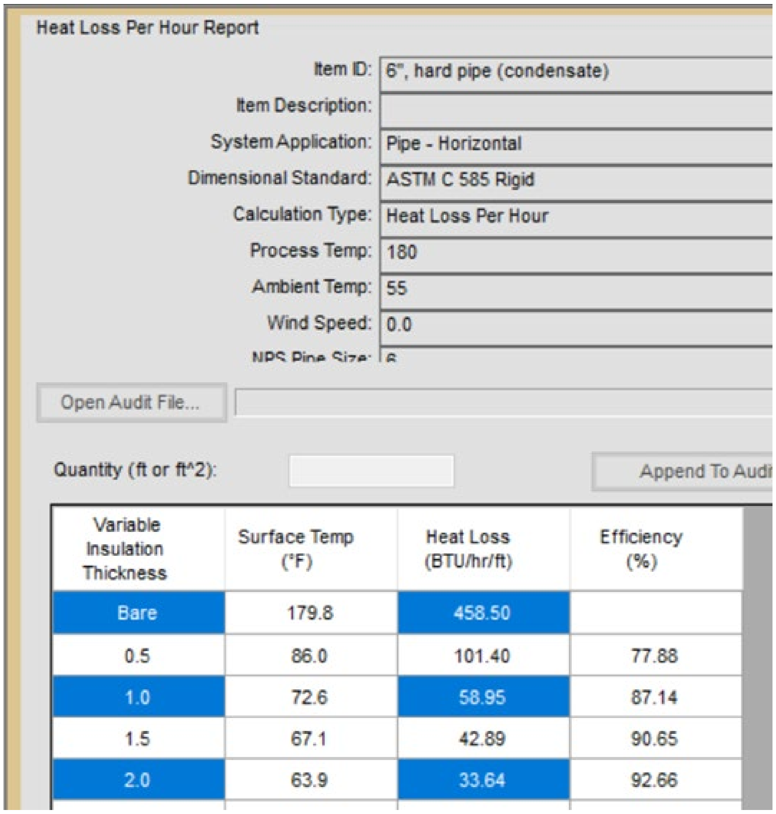
Open Audit File...

Quantity (ft or ft^2):

Append To A

Variable Insulation Thickness	Surface Temp (°F)	Heat Loss (BTU/hr/ft)	Efficiency (%)
Bare	218.7	655.30	
0.5	95.9	140.70	78.53
1.0	78.3	81.43	87.57
1.5	71.1	59.15	90.97
2.0	66.8	46.35	92.93

Figure 2-5. 3EPlus simulation 6-inch insulated condensate pipe



Variable Insulation Thickness	Surface Temp (°F)	Heat Loss (BTU/hr/ft)	Efficiency (%)
Bare	179.8	458.50	
0.5	86.0	101.40	77.88
1.0	72.6	58.95	87.14
1.5	67.1	42.89	90.65
2.0	63.9	33.64	92.66

The evaluator updated the boiler efficiency value from 80% to 81% based on Table 5-1 from the 2022 Steam Traps and Boiler Efficiency Research – Phase II report[1] for boilers of capacity 0-99 HP with linkage controls. Table 5-1 from the 2022 report is shown in Figure 2-6.

[1] 2022 Steam Traps and Boiler Efficiency Research – Phase II report

Figure 2-6. Table 5-1 from the 2022 Steam traps and boiler efficiency research – phase II report

Boiler output	Boiler Capacity (HP)	Steam Pressure (psig)	Boiler Controls	AHPE (%)
Hot water	All capacities	Not applicable	Linkage	84%
			Advanced	85%
Steam	0 – 99	All pressures	Linkage	81%
			Advanced	84%
	100 - 499	All pressures	Linkage	84%
			Advanced	84%
	500 and larger	0 - 99	Linkage	85%
			Advanced	83%
		99 and larger	Linkage	80%
			Advanced	82%

Because the school has been decommissioned since the measure was installed and the future use of the facility is unknown, the evaluator applied a 50% reduction savings correction factor to the calculated lifetime savings according to the following algorithm.

$$LAGI = FYS + (EUL - 1) * FYS * 50\%$$

3 FINAL RESULTS

This section summarizes the evaluation results determined in the analysis above. Both the applicant and evaluation savings are based on heat transfer rates calculated using 3EPlus. The evaluator found a larger temperature difference between the hot pipes and the ambient temperature of the boiler room, which increased savings. The evaluator also adjusted the boiler efficiency value, which slightly reduced the savings. The evaluator did not change the annual operating hours based on the site interview. Table 3-1 is a summary of key applicant and evaluated parameters.

Table 3-1. Summary of key parameters

Parameter	BASELINE		PROPOSED / INSTALLED	
	Tracking Value(s)	Evaluation Value(s)	Tracking Value(s)	Evaluation Value(s)
Operating hours	2,190	2,190	2,190	2,190
Ambient space temperature	80°F	55°F	80°F	55°F
Steam operating temperature	227°F	219°F	227°F	219°F
Condensate operating temperature	180°F	180°F	180°F	180°F
Boiler efficiency	80%	81%	80%	81%
Total therm losses all components	3,233 therms/year	3,966 therms/year	353 therms/year	432 therms/year

3.1 Explanation of differences

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

Table 3-2. Summary of deviations

End-use	Discrepancy	Parameter	Impact of deviation	Discussion of deviations
Space heating	Operational	Steam-side operational temperature and boiler room ambient temperature	+24%	The evaluated temperature difference between steam-side pipes and boiler room ambient temperature is higher than the applicant estimated, causing an increase in heat loss reduction and higher savings.
Space heating	Efficiency	Boiler efficiency	-1%	The evaluated boiler efficiency is higher than applicant assumed, which slightly reduced the savings.

3.2 Lifetime savings

The evaluator classified the measure as an add-on with a single baseline. The baseline is single because the insulation measure life of 15 years is less than 2/3 the heating equipment measure life of 25 years.

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

$$LAGI = FYS + (EUL - 1) * FYS * 50\%$$

where:

$LAGI$ = lifetime adjusted gross impact (therm)

FYS = first year savings (kWh)

EUL = measure life (years)

The evaluated lifetime savings are smaller than the tracking lifetime savings because the evaluator applied a 50% reduction factor for the final 14 years of the 15-year measure life. The evaluator applied this savings correction factor because the school operated normally with the insulation measure installed for the first year of its measure life. After the first year of operation with the measure installed, the school was decommissioned, and its future occupancy is uncertain. For this reason, the evaluator applied a 50% savings reduction factor to the final 14 years of the 15-year measure life to represent a 50% probability that the school will return to its original occupancy. For this reason, the evaluated lifetime savings are less than the tracking lifetime savings. Table 3-3 provides a summary of key factors that influence the lifetime savings.

Table 3-3. Measure 12891673 - lifetime savings summary

Factor	Tracking	Application	Evaluator
Lifetime savings	37,440 therms	43,200 therms	28,272 therms
First year savings	2,880 therms	2,880 therms	3,534 therms
Measure lifetime	13 years	15 years	15 years
Baseline classification	Retrofit	Retrofit	Add-on single

The evaluation uses the same 15-year measure life as the applicant. The evaluator first-year savings are greater than the applicant and tracking savings value. With the 50% savings-reduction factor, the evaluator lifetime savings are less than both the tracking and applicant savings values.

3.3 Ancillary impacts

There are no ancillary impacts associated with this project.

RI CUSTOM GAS EVALUATION SITE SPECIFIC MEASUREMENT AND VERIFICATION REPORT

Site ID: RIG22N079

Report Date: 6/26/2024

Program Administrator	Rhode Island Energy	
Application ID(s)	13140161	
Project Type	Retrofit	
Program Year	2022	
Evaluation Firm	DMI	
Evaluation Engineer	Brian Paonessa	
Senior Engineer	Mickey Bush	

1 EVALUATED SITE SUMMARY AND RESULTS

The evaluated retrofit project was installed at an elementary school. The applicant installed a Runwise controller to automatically control the heating system. The heating system consists of two natural gas steam boilers. The classrooms each have steam unit ventilators that modulate temperature via a control valve. The Runwise system installation included temperature sensors in nine classrooms to measure the space temperature and additional sensors to measure the boiler supply and return temperatures.

The applicant classified the measure as a retrofit with single baseline. Based on the information gathered during the site visit, the evaluator adjusted the measure classification to be an add-on with a single baseline. The add-on measure has a single baseline because the boilers are expected to outlast the Runwise system. The site indicated that they had no plans to modify the boilers or the steam system.

The evaluation results are presented in Table 1-1. The evaluator determined that no site savings are being realized for this measure because the Runwise system has very similar control capabilities as the existing baseline system. The Runwise system was not operational during the metering period, but is also not expected to have produced any appreciable savings if it was fully functional. This is supported by a billing analysis that does not show any site-level savings over a multi-year period when the system was reportedly operational.

Table 1-1. Evaluation Results Summary

PA Application ID	Measure Name		Annual Savings (therms)
13140161	Runwise Heating Controls	Tracked	7,246
		Evaluated	0
		Realization Rate	0.0%

1.1 Explanation of Deviations from Tracking

The evaluated savings are 0% of the combined applicant-reported savings. The savings were decreased because the evaluator found that the expected Runwise sequence of operations did not yield any natural gas savings when compared to the pre-existing outside air reset controller and original boiler sequence of operations. Additionally, bill data from the site revealed that the site did not realize any energy savings from the installation of the controller.

1.2 Recommendations for Program Designers & Implementers

The evaluator recommends that the Runwise technology be reviewed to determine if further incentives for installing the technology are warranted. If further incentives are warranted, the evaluator recommends determining a method to repeatably and accurately determine the savings associated with the installation.

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 information available.

The project consisted of the installation of a Runwise controller to control the steam heating system. The controller has the following functionality:

1. Control of occupied and unoccupied space temperature setpoints
2. Control of the boiler operation (cycling) based on outside air temperature. The steam pressure is not expected to be controlled.
3. Cycling of the boilers based on indoor space temperature monitoring. The average of all nine space temperature sensors is monitored and the boilers are cycled to satisfy the occupied and unoccupied setpoints.

2.1 Application Information and Applicant Savings Methodology

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

2.2 Applicant Description of Baseline

The applicant classified the measure as a retrofit with a single baseline. The applicant described the baseline as the existing site conditions. The applicant identified that the boilers comprised a steam heating system. The applicant also stated that the “boilers have a standard outdoor temperature reset, which is the only means of automated control for the system.” It is unclear exactly what this outdoor reset sequence of operations entails since it was not specified by the applicant and the site was not aware. The evaluators believe that it is unlikely that steam pressure was being reset, but that the boilers were cycling based on outside air temperature.

The applicant determined that the total existing site usage was 48,308 therms/year based on a 3-year average. The applicant did not state what time period this usage corresponded with, but it is assumed to be from ~2019-2021. The applicant did not adjust this average to account for weather-normalization effects.

Table 2-1. Application 13242101 baseline summary

Operation Description	Value
Therms/Year (Annual Average, ~2019-2021)	48,308
Existing Equipment Controls	Outdoor temperature reset (cycling) controls

2.2.1 Applicant Description of Installed Equipment and Operation

The applicant considered the installed case as the baseline heating system with the Runwise system installed. The installation of the Runwise system includes the following energy saving sequences:

- The occupied period (6AM – 10PM) will maintain a space setpoint of 68°F.
- The unoccupied period (10PM – 6AM) will maintain a space setpoint of 64°F.
- The boilers will operate when the outside air temperature is less than 55°F during the day and 40°F during unoccupied periods and when the room temperature average reads below the target temperature setpoint. The boilers will be cycled off during all other times.
- The boilers will cycle based on the outside air temperature. The applicant did not provide a specific sequence of operation, but this appears to be the case based on the Evaluator's review of the technology in Section 2.3.

2.2.2 Applicant Energy Savings Algorithm

The applicant calculated savings using a bill data analysis. The applicant did not provide a source for when the bill data is taken from, but the evaluator expects that it is a 3-year average from ~2019-2021. The applicant determined that the average natural gas use at the facility is 48,308 therms per year. The applicant did not provide usage on a monthly basis or normalize the usage to TMY3 weather data.

To determine the savings, the applicant simply multiplied the pre-existing usage by 15%, which equals the tracked savings of 7,246 therms. The 15% savings appears to be based on the pre-existing school energy use intensity (EUI). The applicant indicates the pre-existing natural gas EUI is 128.4 kBTU/ft²/year. The target EUI after the Runwise installation is 109.1 kBTU/ft²/year based on the 15% savings factor.

2.2.3 Evaluation Assessment of Applicant Methodology

The evaluator agrees with the general approach of using a bill data analysis, but disagrees with simply applying a 15% savings factor to the average 3-year annual usage. The evaluator's approach involves reviewing the potential sequences of operation for the equipment and verifying sequence changes via a pre- and post-install bill data review that includes normalizing the usage for weather effects.

2.3 On-Site Inspection and Metering

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

2.3.1 Summary of On-site Findings

The evaluator conducted site-visits on April 2, 2024 and May 9, 2024. During the site visits, the evaluator interviewed the site contact, verified the installation of the Runwise system, and installed and picked up meter equipment. A summary of the on-site verification is provided in Table 2-2.

Table 2-2. Measure verification

Measure Name	Verification Method	Verification Result
Runwise Control System	On-site visual inspection & Trend Data	Observed the Runwise controller was installed in the boiler room; however the evaluator found that the controller was not operational during the initial or return site visits.

During the site visit, the evaluator visually observed and confirmed with the site contact that the Runwise system was not operational. Figure 2-1 shows the Runwise controller with the switch set to "old control" and the screen indicating the system is operating in manual fallback mode.

Figure 2-1. Runwise controller observed conditions

The evaluator learned from speaking to the site contact that that site was aware of the issue and that the controller was switched to manual override shortly before the evaluator's first site visit due to maintenance needs. At the time of the return site visit in early May, the controller was still in manual fallback mode. It is expected to be operational again for the following heating season.

2.3.2 Measured and Logged Data

The evaluator installed four HOBO UX100-014M temperature loggers with type K thermocouples. One temperature logger was installed on the face of each boiler and two loggers were installed on the return piping. The evaluator also installed one HOBO UX90-004M motor on/off loggers on the combustion fan associated with each boiler (two in total). The meters were programmed to record in 10-second increments in order to adequately capture any instances where the boiler cycled off and back on. Table 2-3 summarizes the metered data. The length of recorded data varies for each piece of equipment based on when the logger ran out of battery.

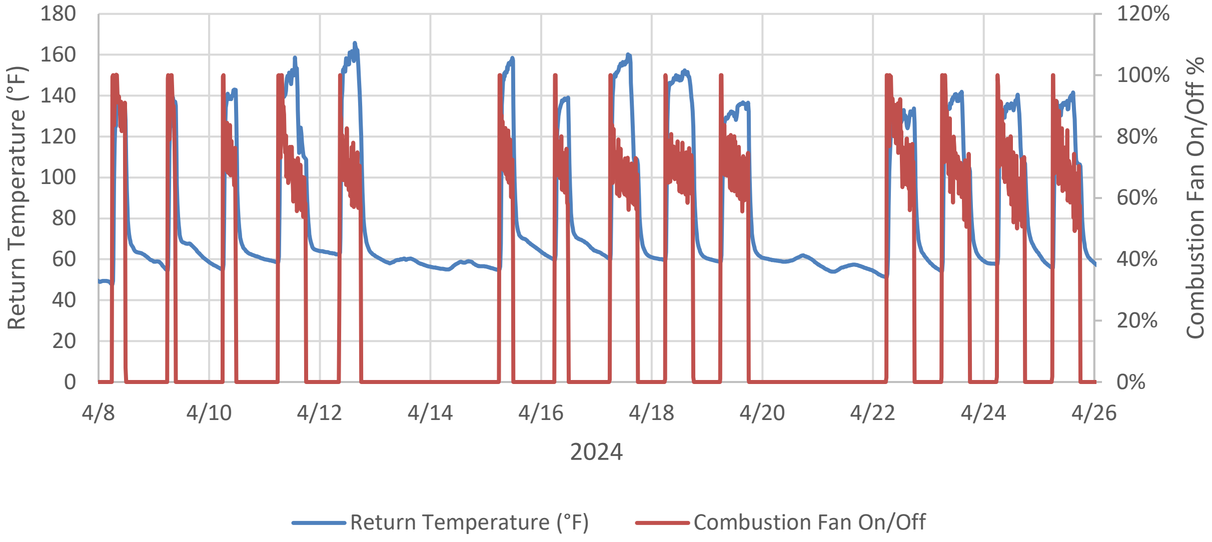
Table 2-3. Metered Data Collection

Metered Parameter	Recording Range	Time Step
Boiler 1 Face	4/2/24-4/26/24	10 seconds
Boiler 2 Face	4/2/24-4/17/24	10 seconds
Return Piping 1	4/2/24-4/26/24	10 seconds
Return Piping 2*	4/2/24-4/26/24	10 seconds
Boiler 1 Combustion Fan	4/2/24-5/9/24	Change of Value
Boiler 2 Combustion Fan	4/2/24-5/9/24	10 seconds

*Meter came unattached and did not record reliable data

Since the Runwise system was non-operational, the meter data represents the system operation not controlled by the Runwise controller. This operation may vary slightly from the pre-existing baseline operation, since the pre-existing outside air reset controller is no longer installed at the site. However, it is expected to be largely representative. Figure 2-2 shows the return temperature and the boiler combustion fan operation. The combustion fan operation is summed such that if both boiler fans were on simultaneously over the entire period, it would yield 200%. The boilers appear to only ever operate one at a time.

Figure 2-2. Return temperature and combustion fan operation over time



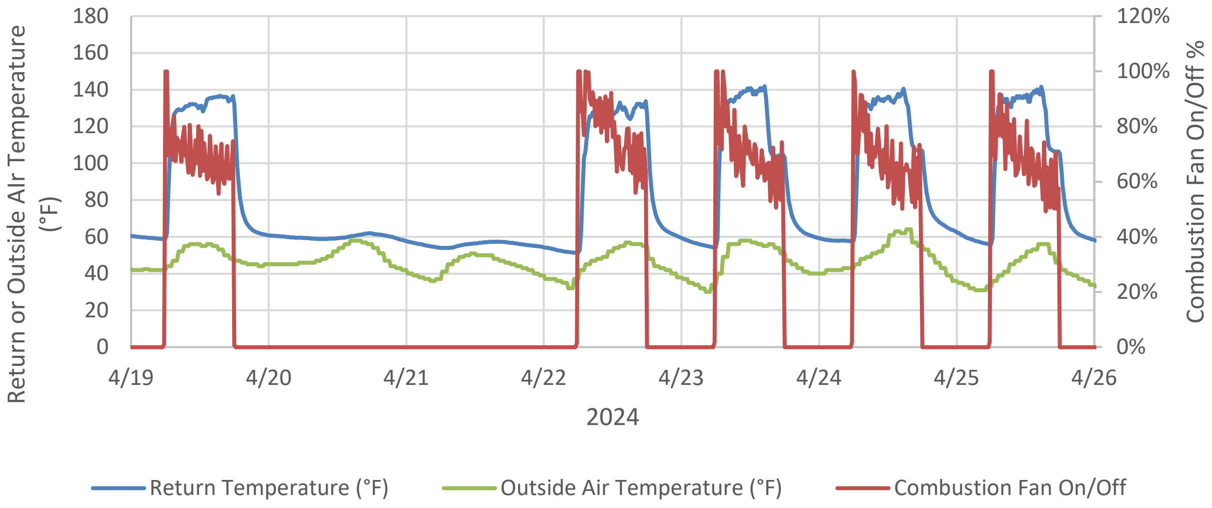
The return temperature and boiler fan follow each other very closely. Figure 2-2 also shows a clear time of day dependency even without the Runwise controller being operational, further shown in Figure 2-3.

Figure 2-3. Combustion fan operating % weekly analysis

	Day Of Week						
Hour	1	2	3	4	5	6	7
0	0%	0%	0%	0%	0%	0%	0%
1	0%	0%	0%	0%	0%	0%	0%
2	0%	0%	0%	0%	0%	0%	0%
3	0%	0%	0%	0%	0%	0%	0%
4	0%	0%	0%	0%	0%	0%	0%
5	0%	0%	0%	0%	0%	0%	0%
6	93%	87%	73%	71%	68%	0%	0%
7	87%	81%	64%	69%	65%	0%	0%
8	82%	75%	62%	80%	68%	0%	0%
9	79%	59%	59%	75%	76%	0%	0%
10	71%	50%	57%	71%	72%	0%	0%
11	56%	35%	53%	73%	72%	0%	0%
12	22%	24%	43%	69%	71%	0%	0%
13	14%	23%	42%	67%	68%	0%	0%
14	15%	22%	42%	64%	62%	0%	0%
15	14%	22%	43%	63%	63%	0%	0%
16	13%	22%	42%	60%	63%	0%	0%
17	14%	22%	42%	62%	63%	0%	0%
18	0%	0%	0%	0%	0%	0%	0%
19	0%	0%	0%	0%	0%	0%	0%
20	0%	0%	0%	0%	0%	0%	0%
21	0%	0%	0%	0%	0%	0%	0%
22	0%	0%	0%	0%	0%	0%	0%
23	0%	0%	0%	0%	0%	0%	0%

During unoccupied periods the boilers are observed to completely shut off. The Runwise system sequence of operation indicates the boilers would shut off during unoccupied periods with an outside air temperature above 40°F. There was limited data below 40°F outside air temperature in the metered period, but when the outside air temperature did drop below 40°F the boilers are observed to stay off, as shown in Figure 2-4. The sequence without Runwise could possibly save energy compared to the Runwise sequence since the boilers may cycle on less during unoccupied periods.

Figure 2-4. Return temperature and combustion fan operation with OAT



The metered data was also reviewed for an outside air dependence. Figure 2-5 shows that the return temperature does not change with outside air temperature, but Figure 2-6 shows that the boilers cycle off more frequently during warmer outside air temperatures. Both Figure 2-5 and Figure 2-6 consider the average return temperature and combustion fan % at each outside air temperature, and each only consider the occupied time periods.

Figure 2-5. Return temperature (occupied time periods only) vs outside air temperature

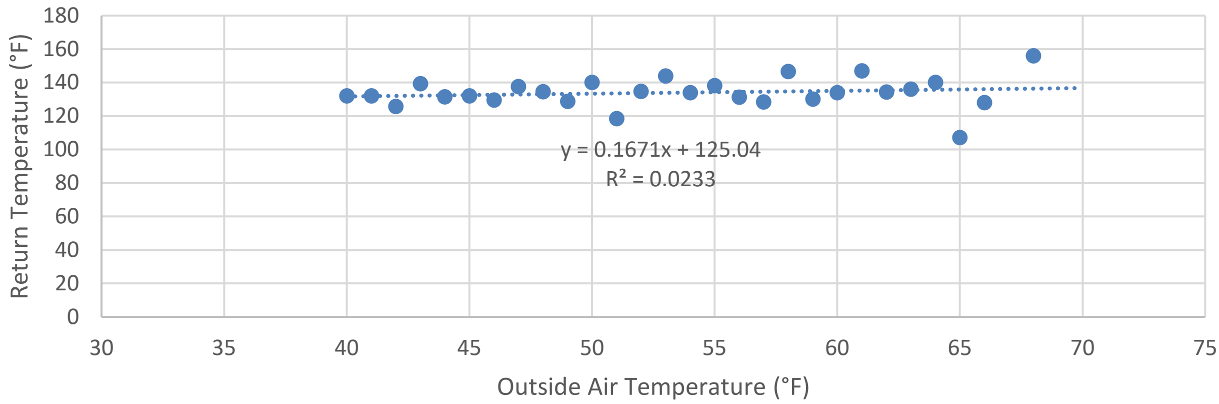
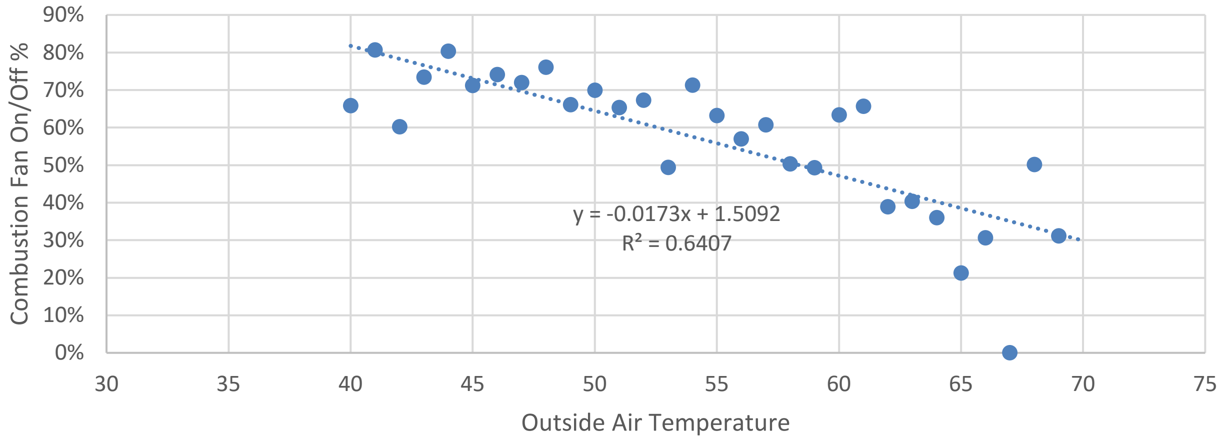


Figure 2-6. Combustion fan operation (occupied time periods only) vs outside air temperature



2.4 Evaluation Methods and Findings

This section describes the evaluator methods and findings.

2.4.1 Evaluation Description of Baseline

The evaluator reviewed the project files and interviewed the site contact to gather information on the baseline. The evaluator determined the control measure to be an add-on with a single baseline as the installed measure life is less than 2/3 of the life of the controlled heating system. The evaluator agrees that the baseline is the pre-existing conditions at the facilities.

The applicant indicated that there was a pre-existing controller with outside air reset control. This controller was no longer installed on-site and the site contact was not fully familiar with the pre-existing conditions, but the site did not give a reason to doubt that the pre-existing controller used to be there. Since the controller is no longer there it is not represented in the metered data shown in Section 2.3.2.

The remaining pre-existing baseline conditions are what is observed in Section 2.3.2 since the Runwise controller was not operational. Specifically, the boilers have a strict time-of-day dependent schedule and shut down overnight and on the weekends. Additionally, the boilers cycle off as the outside air temperature rises while the steam pressure and temperature remain similar. The evaluator does not have visibility into the classroom space temperatures, but since the combustion fans cycle a varying amount throughout the day the sequence of operations is assumed to be related to maintaining an interior space temperature setpoint. Without the Runwise system, interior space temperature setpoints are determined at the classroom thermostats.

2.4.2 Evaluation Calculation Method

The evaluator compared the functionality of the installed Runwise controller with the observed baseline sequence to identify any potential for savings if the Runwise controller ran as intended, which it did not during the limited metering period. A comparison of the controls available between baseline sequence of operations and the Runwise controller are shown below in Table 2-4.

Table 2-4. Runwise controller vs baseline sequences comparison

Parameter	Existing Baseline Controls	Runwise Controller (Installed Equipment)
Space Temperature Control	Occupied space temperature setpoint determined at local thermostats. Boilers shut off during unoccupied periods.	Occupied setpoint is automatically set to a default of 68°F and unoccupied is a default of 64°F. Setpoints are adjustable via online interface.
Outside Air Temperature Control	Steam pressure does not vary with outside air temperature. Boilers cycle off as outside air temperature rises. Unclear sequence of operation from pre-existing outside air reset controller (now removed).	Specific sequence not specified. Boilers are expected to cycle off as outside air temperature rises.
Boiler Cycling	Boilers cycle off during unoccupied periods and during occupied periods to ensure the space temperature setpoints are not exceeded.	Boilers cycle off to meet the space temperature setpoints.

Based on the functionality of the Runwise controller versus the pre-existing sequence of operations, the evaluator concluded that there was likely little to no achievable savings from the installation of the Runwise controller even if it was operational. In addition, the site contact indicated that although the system was installed partially for energy savings benefits and partly for monitoring, he was doubtful that energy savings were actually being realized.

In order to confirm the lack of site savings, the evaluator compared pre- and post-install bill data at the site. The evaluator found the billed therms and heating degree days based on Providence weather data. Available bill data spans from 12/19/2018 through 2/20/2024. Based on the applicant documentation the system was expected to be installed in June 2022. Figure 2-7 shows the therms per heating degree days during only the winter months. The evaluator observed that there was no significant pre- and post-install difference that could be attributed to a change in space load or COVID affects, so the entirety of the available pre and post bill data was used in the analysis.

Figure 2-7. Therms per heating degree hour over time

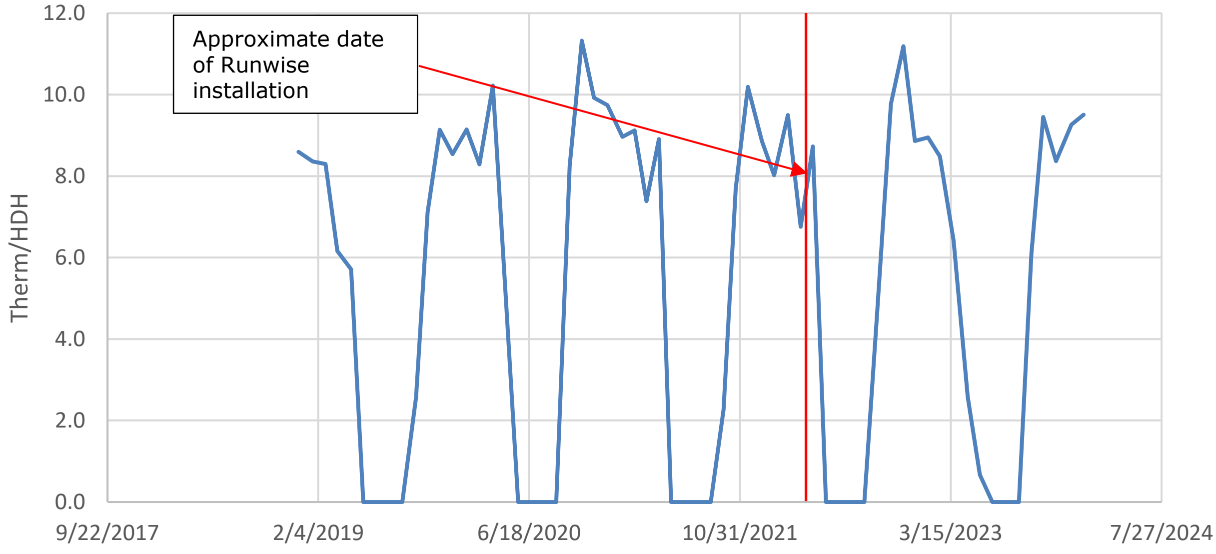
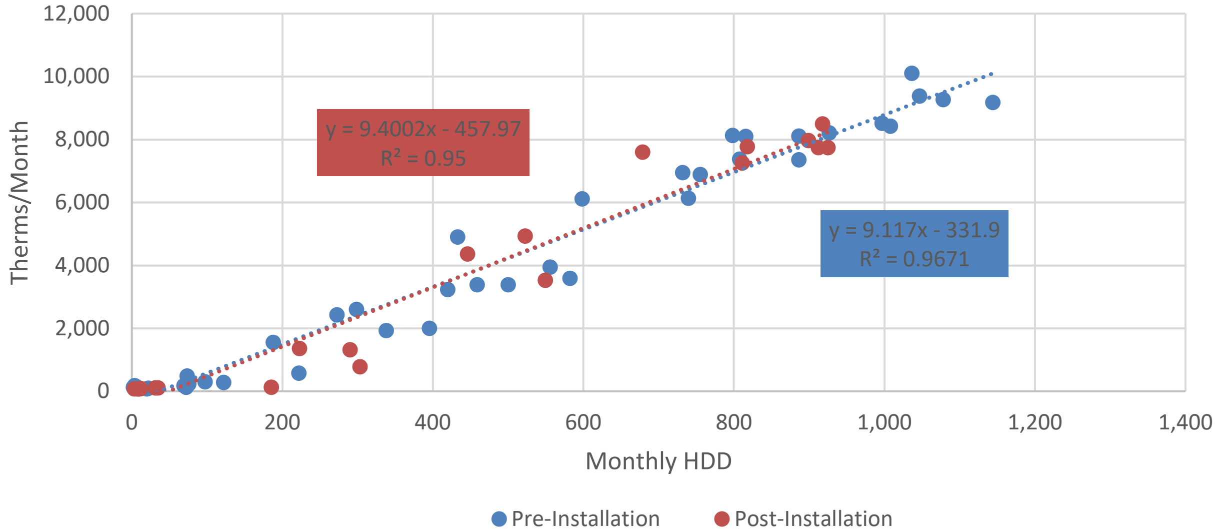


Figure 2-8 shows the therms and heating degree days per month for the pre and post-install data as well as the regression equations for each. The pre-install data includes 42 months of data and the post install includes 20 months.

Figure 2-8. Pre and post install therms vs heating degree days



The therms and heating degree days were then normalized to the outside air temperature over a typical year using the heating degree days based on TMY3 weather data in Providence, RI. The regression equations from Figure 2-8 were then used with the TMY3 heating degree days to find the expected therm use over the course of a typical year, as shown in Table 2-5.

Table 2-5. TMY3 normalized bill data

Month	TMY3 HDD (65°F)	Pre-Install Regressed Therms	Post-Install Regressed Therms	Difference Therms
January	1,112	9,804	9,993	-189
February	917	8,027	8,160	-134
March	811	7,059	7,162	-103
April	535	4,542	4,567	-25
May	260	2,039	1,987	52
June	85	443	341	102
July	18	0	0	0
August	27	0	0	0
September	107	645	550	96
October	379	3,126	3,108	19
November	675	5,818	5,883	-65
December	1,051	9,249	9,421	-171
Total	5,976	50,753	51,171	-419

The bill data analysis reveals that there is a negligible difference between the pre and post-install data, which supports the evaluator's finding that the Runwise controller did not provide savings compared to the baseline sequences, even if the Runwise controller was running during most of the post-install billing period which the site indicated it was.

3 FINAL RESULTS

The application considered the installation of a Runwise system to control the heating systems at an elementary school. The calculated savings are less than the tracked values. Table 3-1 summarizes the key parameters used to calculate the energy savings for the measure.

Table 3-1. Summary of Key Parameters

Parameter	Applicant	Evaluator
Baseline Space Temperature Control	Temperature control from local thermostats.	Temperature control is from local thermostats. Boilers cycle to maintain an occupied space temperature setpoint and shut off during unoccupied periods.
Baseline Outside Air Temperature Reset Control	Outdoor temperature reset control available from a controller. Exact sequence of operations is unknown.	Outdoor temperature reset controller was installed but sequence of operations is not known. Boiler sequences without Runwise cycle off as outside air temperature increase. Boiler pressure and temperature do not vary with outside air temperature.
Installed Space Temperature Control	Runwise system has interior space temperature sensors and automatically controls the average occupied setpoint to 68°F and the unoccupied setpoint to 64°F.	Runwise system has interior space temperature sensors and automatically controls the average occupied setpoint to 68°F and the unoccupied setpoint to 64°F.
Installed Outside Air Temperature Reset Control	Runwise system cycles the boilers off during unoccupied periods with an outside air temperature above 40°F.	Runwise system cycles the boilers off during unoccupied periods with an outside air temperature above 40°F.
Pre-Installation Annual Natural Gas Use (Therms)	48,308 (based on 3-year average, not weather normalized.)	50,753 (based on December 2018 through May 2022. Weather normalized.)
Post-Installation Gas Use (Therms)	41,062 (Assumes a 15% savings factor.)	51,171 (based on July 2022-February 2024. Weather normalized.)
Savings		
Annual natural gas savings (therms)	7,246	0
Natural gas realization rate (%)	0.0%	

3.1 Explanation of Differences

The evaluated savings are less than the applicant savings. Table 3-2 provides a summary of the differences between tracking and evaluated values.

Table 3-2. Summary of Deviations

End-use	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
Baseline	Baseline	Existing heating sequence of operations	100%	**Decreased Savings:** The Runwise controls were not operational at the time of the visit and the evaluator discovered that the pre-existing heating control sequence of operations yields the same energy use as the installed Runwise controller would have. This finding is supported by a pre/post bill analysis showing no savings

3.2 Lifetime Savings

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

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

where:

LAGI = lifetime adjusted gross impact (therm)

FYS = first year savings (kWh)

EUL = measure life (years)

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

Table 3-3. Measure 13140161 - Lifetime Savings Summary

Factor	Tracking	Evaluator
Lifetime savings (therms)	72,460	0
First year savings (therms)	7,246	0
Measure lifetime (years)	10	10
Measure life reference	Screening Tool	Screening Tool
Measure event type	Retrofit	Add-On
Baseline classification	Single – Pre existing	Single – Pre existing
Measure status (operational or removed)	N/A	Operational

N/A = Not Applicable

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

3.2.1 Ancillary impacts

There were no ancillary impacts associated with the evaluated measure.

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