FINAL

Impact Evaluation of PY2018 Custom Gas Installations in Rhode Island

National Grid

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List of acronyms used in this report

CDA	– comprehensive design assistance
C&I	– commercial and industrial
CI	– confidence interval
DR	– desk review
EFLH	- equivalent full load hours
EMS	– energy monitoring system
HVAC	– heating ventilation and air-conditioning
ISP	– industry standard practice
M&V	– measurement and verification
MBSS	– model-based statistical sampling
PA	– program administrator
PY	- program year
PY2016	– program year 2016
PY2017	– program year 2017
PY2018	– program year 2018
PY2019	– program year 2019
RR	– realization rate
TMY3	– typical meteorological year 3

1 EXECUTIVE SUMMARY

This Executive Summary provides a high-level review of the results for the Rhode Island (RI) Commercial and Industrial (C&I) Impact Evaluation of Program Year (PY) 2018 Custom Gas Installations. In this section, we state the study objectives, summarize the evaluation approach, and present key findings, conclusions, and recommendations. The scope of work of this impact evaluation covered the PY2018 Custom Gas impact category, which included HVAC, EMS, Steam Trap, Insulation, and Other measures. All the measures are commercial retrofit and new construction projects.

The work was completed between 2019 and 2020. DNV GL performed a site-based Measurement and Verification (M&V) impact evaluation to quantify the achieved natural gas energy savings for a sample of custom gas projects completed in Program Year 2018 (PY2018). COVID-19 caused a stop of on-site work during the metering period of the study. Due to the halt in on-site work, two sites were not fully evaluated, which caused DNV GL to adapt the evaluation process by developing a 2-sample inner-year study for PY2018. The remaining 6 sites were fully evaluated, and the study was a success by providing realization rates for PY2018 while surpassing precision targets.

1.1 Study Purpose, Objectives, and Research Questions

The objective of this Impact Evaluation of PY2018 Custom Gas Installations is to provide verification or re-estimation of energy (therms) savings for sampled Custom Gas projects through site-specific inspections, end-use monitoring, and analysis. The site-specific results were aggregated to determine realization rates for National Grid's custom gas installations in RI. Custom gas evaluations for National Grid in RI territory starting from PY2016 are designed to be rolling/staged evaluations. The goal of this approach was to repeat M&V annually as the previous year's tracking data becomes available. This study is considered year-3 of the rolling/staged evaluation with PY2016 and PY2017 as year-1 and year-2 respectively. DNV GL estimates that there are enough sample points by combining RI only results from PY2016, PY2017, and PY2018 to develop independent RI results at the agreed upon precisions (±20% relative precision at 80% confidence) for a gas study.

This study:

- Achieved gross natural gas energy savings for RI custom gas projects, with targeted sampling precision of ±20% at 80% confidence when RI PY2018 results are pooled with RI PY2016 and PY2017 results

1.2 Key Findings and Results

The site-level evaluation results were aggregated using the final adjusted case weights in a 2-sample approach based on adjustment factors collected. The realization rates were calculated and then applied to total tracking savings to determine their total evaluated savings. DNV GL developed realization rates (and associated precision levels) for annual therms savings of the program by combining 3 consecutive custom gas study results (conducted for PYs 2016, 2017, & 2018).

1.2.1 Rolling Statewide Sample: PY2016, PY2017, & 2018

The Rhode Island Piggybacking Diagnostic Study[1] developed guidance on when it is appropriate to "piggyback" or combine RI evaluations efforts with MA studies or adopt MA results as a proxy for RI versus stand-alone RI studies. The "piggybacking" study report recommends which approaches National Grid RI

[1] http://rieermc.ri.gov/wp-content/uploads/2020/09/rhode-island-piggbacking-diagnostic-study-final-final-report-20200114.pdf

should use for C&I measure groups and residential programs. For custom gas, it recommends using a RI Independent Sample approach. Therefore, the rolling statewide evaluation approach was planned to effectively produce independent results for RI by the end of a 3-year rolling cycle if reasonable relative precisions are achieved. The results presented in this report achieved reasonable precisions by combining three program years (PY2016, PY2017, & 2018) as shown in Table 1-1. Overall, the study achieved 84.2% RR with a relative precision (RP) of ±10.1% at an 80% confidence interval. PY2018 RR results were lower than PY2017. PY2018 also has a higher RP range due to the 2-sample approach as discussed in the following section.

Table 1-1: Yearly RI Specific Results and Pooled Results

Parameter	PY2016	PY2017	PY2018	PYs 2016+2017 +2018
Tracking Savings	1,114,770	1,948,383	2,350,739	5,413,892
Sample Size	8	6	6[2]	20
Realization Rate (RR)	71%	92%	83.3%	84.2%
Relative Precision @ 80% CI (%)	±10.6%	±2.3%	±22.6%	±10.1%

CI = confidence interval

1.2.2 2-Sample Ratio Estimation within 2018 Program Year

Due to the COVID-19 pandemic, all fieldwork in RI was shut down in March 2020. DNV GL had already completed the first site visit for 7 out of 8 sampled sites and acquired trending information for the 8th site to verify the installation of technology and quantities. Therefore, all the non-operational adjustments (see Table 1-2) were calculated for 8 sites using the in-depth desk review and the 1st site-visits.

Table 1-2. Adjustment Factors for Evaluation

	Adjustment Factors						
Ratio Name:	**Non-Operational Adjustments**					**Operational Adjustments**	
Obtained:	**In-depth desk review**			**1st site-visit**		**logger pickup**	
Factor:	Baseline	Methodology	Tracking & Admin	Technology	Quantity	Operational	HVAC Interactive

In August, National Grid had agreed to fieldwork on a conditional basis, allowing logger pickup for the custom gas study sites and additional attempts to conduct on-site work at the remaining two sites. DNV GL was able to collect operational data for 6 out of the 8 sites and the remaining two sites were non-responsive. Of the 6 sites for which DNV GL collected operational data, three sites had loggers installed and 2 sites provided trending data. One site did not have the measure installed so loggers and trending data were not necessary. No operational data was available for the site-level analysis for the two sites that were non-responsive. DNV GL developed a 2-sample ratio estimation method which essentially uses two sets of case weights to calculate the realization rate (RR) for PY2018. These case weights were based on the six sites that have both non-operational and operational adjustments (1st set), and the eight sites that include non-operational adjustments only (2nd set).

2 The minimum of the two inner-year samples (8 through only non-operational adjustments and 6 through operational adjustments) dictates sample size

The calculated RR for PY2018 was then combined with both sets of sites to calculate the overall rolled-up program RR, as shown in Table 1-3.

Table 1-3. PY2018 Realization Rate Calculation

Site ID	Unweighted Tracking Savings (therms)	Non-Operational			Operational		
		Weight (-)	Weighted Tracking Savings (therms)	Weighted Evaluated Savings (therms)	Weight (-)	Weighted Tracking Savings (therms)	Weighted Evaluated Savings (therms)
2018RIG78	17,625	4.50	79,313	0	9.00	0	0
2018RIG26	1,349	20.33	27,430	27,430	30.50	41,145	0
2018RIG27	8,011	20.33	162,890	17,103	30.50	25,655	0
2018RIG64	3,687	20.33	74,969	74,969	N.A.	N.A.	N.A.
2018RIG43	691,953	1.00	691,953	691,953	1.00	691,953	694,942
2018RIG55	207,347	4.50	933,062	933,062	N.A.	N.A.	N.A.
2018RIG19	8,730	8.00	69,840	69,840	8.00	69,840	83,640
2018RIG58	18,863	8.00	150,904	150,904	8.00	150,904	131,096
		Total	**2,190,360**	**1,965,261**		**979,497**	**909,678**
		Non-Operational RR		**89.7%**		**Operational RR**	**92.9%**
						Overall 2018 RR	**83.3%**

1.3 Conclusions, Recommendations and Considerations

This section presents the conclusions, recommendations, and of the impact evaluation study.

1.3.1 Conclusions

PY2018 Performance. The program continues to generate significant natural gas savings. In RI, the PY2018 custom gas projects saved an estimated 2.35 million therms (adjusted gross savings) annually with 83.3% of the savings realized based on the evaluation sample for RI PY2018 sites. Combined over the 3-year rolling sampling period, the program realized 5.4 million therms with 84.2% of savings realized.

DNV GL will continue to work with National Grid to finalize the remaining two full site reports should the sites continue with the evaluation. However, the current results are accurate within state and regulatory standards and provide adequate planning and program reporting savings estimations. Should the sites finish the evaluations, DNV GL does not expect a large deviation from current results.

Site-specific sample weights are shown in APPENDIX A. More details on the PY2018 results are presented in the section below, and in each site-report included in APPENDIX B.

1.3.2 Recommendations

DNV GL reviewed project files, conducted detailed analyses of the information provided in the files, and quantified discrepancies to make the recommendations presented below.

1.3.2.1 R1: Realization Rate

DNV GL recommends National Grid to use the PY2016, PY2017, & PY2018 combined RR of 84.2% for planning and program reporting, starting with PY2021 and continuing to subsequent years until new impact evaluation study results are available. The applicable RRs are noted in Table 1-1. This recommendation was based on the following factors:

- When PY2016 (71%), PY2017 (92%), & PY2018 (83.3%) results are pooled, the study produced state-wide results that met precision targets of ±20% relative precision at 80% confidence (actual: ±10.1% at 80% confidence level).

Based on the results listed for PY2018, an Error Ratio Target of 0.55 has been recommended for 2019 RI Custom Gas Impact Evaluation to achieve the next 3-year rolling savings evaluation precision targets.

1.3.2.2 R2: EMS/Control Calculation Method and Commissioning

EMS and Control measure projects (2) evaluated in the PY2018 sample resulted in 0 savings. EMS systems are difficult at best to achieve an accurate savings estimate without prior system behavior monitoring, and the deemed savings calculator is inadequate for these types of projects. Additionally, several checks were not performed at the sites to ensure proper EMS programming was completed or if the system could perform at the levels necessary to ensure savings were achieved. DNV GL recommends the following items to improve EMS and Control based measures to improve the current process:

a) For all EMS/Control based projects, including smaller projects, consider adding certain levels of verification such as: 1) verify trend data demonstrates controls are operating as designed, 2) capture screenshots of the new interface that contains setpoints, or 3) some other meaningful form of documentation to ensure control based claimed savings are operational and achieving savings
b) Update the energy management system (EMS) savings calculator or require custom savings calculators from vendors with better post-installation verification to better document energy savings
c) Document pre-installation site conditions, pre-installation trend data, pre-installation operating protocols, and pertinent information for evaluators to compare baseline conditions to new operation with the overall intent of verifying system changes and evaluating savings

2018RIG26 and 2018RIG27: Pre-existing control sequences determine the energy savings associated with implementing simple control sequences, such as the ones considered for this project, but there is solely anecdotal information available about the pre-existing system operation. The custom express EMS program does not require documentation to inform baseline system assumptions for the energy savings calculations, so a comparative pre-condition is missing for energy savings calculations. The evaluation finding indicates the EMS custom express tool does not adequately consider pre-existing system control sequences to allow for accurate energy saving calculations. In addition, the evaluator found that the sequences claimed for savings are not implemented as expected. Optimal start/stop is not implemented, HW reset is not working properly, and there is very little difference between occupied and unoccupied operation although there is an occupancy schedule. Both sites resulted in 0% RRs.

1.3.2.3 R3: Post Inspection Verification for Large Projects

A smaller project, discussed below, had its commissioning combined with a larger CDA project at the same site, which resulted in not observing a measure that was not installed. DNV GL recommends that National Grid examines the system in place for post-commissioning and post-inspecting to determine how the error was caused and to place mitigation efforts to improve future practices. For example, invoice quantities can verify amounts purchased for the measures especially when there are multiple applications for a specific location.

2018RIG78: The project, installation of high efficiency washing machines, was completed at the same time as a larger CDA project for the hotel that was included in a separate Parent/Child application. The CDA project included typical HVAC and lighting measures, e.g. building envelope, VRF systems, etc. A post-inspection and utility commissioning were performed for the measures included in the larger CDA project, but reviewing the washers and dryers was not included in the post-inspection, though they were marked as installed. The washer/dryer applications should have been post-inspected. The project resulted in 0% RR.

1.3.3 Considerations

Using the results of the study, the evaluation team generated a list of considerations, summarized below.

1.3.3.1 C1: Washer and Dryer Measures

Discrepancies from washer and dryer measures were common for the two sites evaluated in this study. The discrepancies varied from tracking savings discrepancies, administration errors, and post-commissioning errors. To avoid these issues, National Grid may consider using invoices for savings verification.

2018RIG78: The claimed savings appear to be based upon three washers and three dryers. The project documentation includes a revised memo where the applicant re-calculated savings for two washers and two dryers. It does not appear that the application was updated with these values. The customer installed two of each unit, not three of each unit. The application should have been updated to include the revised savings calculations, though this issue was not as important as the fact that the washers and dryers were never installed as discussed above. The evaluator discussed the project implementation process for this specific application with the PA which resulted in a 0% RR, as it was determined that the equipment was never installed.

2 INTRODUCTION

This section presents the objectives for the DNV GL's Impact Evaluation of the Program Year (PY) 2018 Custom Gas Installations for National Grid in Rhode Island (RI). DNV GL performed a site-based Measurement and Verification (M&V) impact evaluation to quantify the achieved natural gas energy savings for a sample of custom gas projects from the Program Year 2018 (PY2018) population.

2.1 Study Purpose, Objectives and Research Questions

This evaluation performed a site-based M&V impact evaluation to quantify the achieved natural gas energy savings for 8 RI custom gas projects for PY2018. The results of this study were combined with the results from the PY2016 and PY2017 studies to produce updated, statewide RRs.

2.2 Organization of Report

The remainder of this report is organized as follows:

- Section 3: Methodology and Approach. The methods associated with sampling and the M&V tasks will be described in this section.
- Section 4: Data Sources.
- Section 5: Analysis and Results. The rolling results and the results associated with the evaluation of PY2018 will be presented in this section.
- Section 6: Conclusions, Recommendations, and Considerations. Conclusions and recommendations from analyzing the M&V findings are presented in this section.

3 METHODOLOGY AND APPROACH

The evaluation team approach was consistent with the procedures and protocols developed during the previous round of custom gas impact evaluation conducted for PY2016 and PY2017[3]. As described in the next subsections, the impact evaluation consisted of on-site visits and metering of a randomly selected sample of projects at participating facilities.

3.1 Description of Sampling Strategy

As discussed earlier, DNV GL designed the sample for the PY2018 impact evaluation to pool the annual evaluation results with PY2016 and PY2017 results to produce a rolling updated result. This allowed the sampling precision to meet the targets laid out in Table 3-1.

PY2016, PY2017, and PY2018 results were pooled together to use in the PY2021 planning cycle. In subsequent years, the realization rate will reflect the pooling of the three most recent impact results.

Based on the results achieved in the previous studies, this sample design assumed the error ratios shown in Table 3-1 for the targets listed. The sample design for this round of study was developed assuming the results would be pooled with prior (and future) custom gas results. The general principle used in this design is that the results from each year would need to achieve ±35% precision at 80% confidence interval to maintain a three-year pooled result of ±20% precision at 80% confidence for gross therms savings RRs. DNV GL used Model-Based Statistical Sampling (MBSS) techniques to develop the sample design. The sampling unit is the sum of all projects installed in the evaluated program year at an account.

Table 3-1: Sampling Targets

Annual Sampling Target	Three-Year Pooled Sampling Target	Error Ratio
±35% expected relative precision - 80% CI	±20% expected relative precision - 80% CI	0.40 (non-steam trap)
		0.65 (steam trap)

CI = confidence interval

3.1.1 PY2018 Sample Frame

The initial population for this impact evaluation was the set of custom gas projects rebated in 2018. Table 3-2 shows the distribution of all tracking records and the associated savings by National Grid.

Table 3-2: PY2018 Population Distribution of Custom Gas Accounts

Distribution	Number of Accounts	Gas Savings (Therms)	% Savings
Population Frame	87	2,350,739	79.8%
CDA projects	5	112,258	3.8%
Small Sites (<1,000 therms savings)	12	5,289	0.2%
Custom-Prescriptive	21	147,112	5.0%
Not in the 2018 Pop (child application payment date in 2019)	6	328,764	11.2%
Grand Total	**131**	**2,944,161**	**100%**

As was done in previous evaluations, small sites were excluded from the sample frame. These small sites account for less than 1% of total tracking savings and do not warrant the expense of site M&V. There were

[3] PY2017 study report was not finalized during the planning of this study.

12 such gas accounts with annual savings less than 1,000 therms that were removed from the population frame, with a total savings of 5,289 therms as shown in Table 3-2. There were 5 sites that completed CDA projects but were also removed from the population frame as the CDA projects are typically evaluated in a different study. 21 sites were considered prescriptive and 6 sites that were not fully paid within the 2018 fiscal year. The sites were removed from the population. Therefore, the original population included 87 unique customer accounts or sites.

The final PY2018 population frame has a total of 87 accounts with savings of 2,350,739 therms. Table 3-3 shows the selected sample frame after dropping the small sites, dropping CDA projects, removing prescriptive measures, and removing sites not paid in 2018.

Table 3-3: PY2018 Adjusted (Final) Project Sample Frame

Accounts	Tracking Savings (Therms)
87	2,350,739

3.1.2 PY2018 Sample Design

Table 3-4 shows the selected sample for this project. DNV GL estimated that 8 sampled sites would give reliable precisions to achieve the required target per Table 3-1. Though the general principle is for an individual year to target ±35% precision at 80% confidence interval, a target of ±21.0% precision at 80% confidence was set to account for the fact that not all planned sites were completed in previous years of the rolling study. The table also shows that DNV GL completed 8 of the designed 8 sites regarding non-operational adjustment factors in the 2-sample approach for PY2018, and DNV GL completed 6 of the 8 operational adjustment factor evaluations. The study also achieved the reliable statistical precision targets (±22.6%) at an 80% confidence interval.

Table 3-4: PY2018 Project Sample

Accounts	Savings	Error Ratio	Sample (n)		Expected Relative Precision @ 80% CI	Achieved Relative Precision @ 80% CI
			Designed	Completed		
87	2,350,739	0.40 (non-ST) 0.65 (ST)	8	8 non-OP 6 OP	±21.0%	±22.6%

ST = Steam Trap; OP = Operational;

3.1.3 Rolling Sample Design

To calculate combined expected relative precision, the expected precision from the PY2018 sample design was combined with the PY2016 & PY2017[4] study results. Table 3-5 provides the combined expected precision at the statewide level, based on this sample design.

[4] Expected RP; this study was not finalized during the designing stage of this study.

Table 3-5: PY2016, PY2017, and PY2018 Combined Expected Precision at 80% Confidence Interval

Program Year	Accounts (N)	Therms Savings	Error Ratio	Sample (n)		RP @80% CI	
				Designed	Completed	Design	Achieved
PY2016	87	1,114,770	0.6	8	8	±26.8%	±10.6%
PY2017	98	1,948,383	0.6	7	6	±30.0%	±2.3%
PY2018	87	2,350,739	0.40 (non-ST) 0.65 (ST)	8	8 non-OP 6 OP	±21.0%	±22.6%
PYs (2016, 2017, & 2018)	**268**	**5,413,892**	**N/A**		**20**[5]	±16.0%	**±10.1%**

ST = Steam Trap; OP = Operational; DNC = Did not calculate;

3.1.4 PY2018 Final Sample Disposition

One primary site was dropped from the study and was replaced by a secondary site. The site was removed and replaced due to the risk involved with completing the site visit before the National Grid's planning deadline. The energy savings measure was piping insulation on a steam pipe at an asphalt plant. The pipe loop was de-energized due to construction of a heat exchanger replacement that feeds the loop. The site contact believed that construction would keep the loop de-energized through March 2020 should the project timeline not experience delays. In addition to the risk of missing the construction completion date, this section of the facility would have only come online due to production demand. Therefore, to reduce the risk of unrepresentative metered data or missing a data collection point for the study stratum, the team replaced the site with the subsequent backup.

The final (achieved) sample includes 8 sites as shown in Table 3-5. Appendix A summarizes the 8 sites for which M&V activities were completed and their respective post-stratified weights. The summary includes the site ID, the verified measure description, and the tracking savings and site RR.

3.2 Site M&V Planning

The site evaluation plan played an important role in establishing approved field methods and ensuring that the ultimate 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 GL submitted full individual M&V plans for each evaluated site. These plans were reviewed by National Grid. 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 used
  - Identification of the key baseline assumptions
  - Identification of the key proposed assumptions
  - Evaluator assessment of tracking savings methods or assumptions, including program-reported baseline

[5] Overall sample size is based on the minimum of the 2-sample approach for PY2018.

- **Project evaluation –** A short description of the methods 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 collected by DNV GL; where several similar items have been installed or are being controlled, the 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 by the site (e.g., EMS trends, production, pre-metering, etc.) and/or National Grid.
  - The expected 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 GL 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 were determined through the evaluation and compared to those used in the original savings estimate.

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

3.3 Data Collection

DNV GL scheduled a site visit to perform the tasks described in the site M&V plan.

3.3.1 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 evaluation, the scope of measures installed, availability of on-site trend/EMS/production data, any other applicable parameters relevant to the evaluation, and confirmed that the site will allow DNV GL to conduct the site visits. The site-specific M&V planning effort did not commence until the customer site contact indicated they were willing to accommodate the ex-post on-site evaluation process. After the customer outreach discussion, if the engineer determined significant barriers were preventing M&V of substantial parts of the completed project, the site was flagged for review, and, if warranted, replaced with a backup site. This study replaced one primary site due to risks involved with successfully collecting data with a backup site since the facility was under construction.

3.3.2 Site Visit

Each initial site visit consisted of the verification of installed equipment, a discussion with facility personnel regarding the baseline characteristics of the measure, the installation of measurement equipment, the collection of available trend data, and/or the creation of a plan to gather trend data coinciding with the measurement period. Trend data beyond the measurement period was also requested and used when it improved the accuracy of measure savings estimates.

A second site visit to retrieve meters was scheduled for sites where evaluators installed meters during the initial visit.

3.3.3 M&V Plan Update

DNV GL submitted an updated site M&V plan to National Grid after the completion of the initial site visit if there were significant deviations from the approved plan. This updated plan 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 included cases where a portion of the proposed M&V plan was not feasible for unforeseen reasons.
- Provides a summary of the collected information, information that will not be available for analysis purposes, and lists tasks to complete on the return for meter pickup.

The update intended to keep National Grid current on the status of the site evaluation and communicate any anticipated or resultant deviations from the plan.

3.3.4 Meter Pickup during COVID-19

Due to COVID-19, meter pickup was extended by a few additional months since engineers were prohibited from contacting and visiting sites where meters were installed. After field restrictions were lifted, site contacts retrieved loggers that were installed 5-6 months prior. The long period between installation and pickup along with the site contact retrieving meters themselves in many cases caused loss of meters (data) for some sites and incomplete follow-ups for others. For 2 sites where engineers were unable to collect trend data and answer technical questions from site contacts and only non-operational adjustment factors were used, data collection issues were likely caused by interruptions in business caused by COVID. However, most meters were retrieved, 6 of the 8 sites were fully evaluated, and overall study integrity and precision were maintained above targets.

3.4 Site Analysis

DNV GL reviewed all data collected and then utilized the data to complete an evaluation analysis for 6 of the 8 sampled projects. For 6 of 8 projects, the analysis generated evaluated savings estimates for all measures installed at each sampled site. Results were normalized to typical production or weather data. For the two weather-dependent measures (2 sites) that resulted in savings, the site analysis involved normalizing the models to weather data using Typical Meteorological Year 3 (TMY3) data from the closest representative weather station to each site.

For 2 sites, engineers did not complete an analysis due to a lack of participation from the site contacts. One site did not provide the trend data as promised during the site visit and the other did not respond to questions needed to finish the analysis from trend data received from vendors. Both sites that did not have an analysis competed were still included in the final project realization rate using the 2-Sample Ratio Estimation described in detail in Section 1.2.2 due to the considerable amount of information collected. These 2 sites have full desk reviews and some on-site and installation review, but no metered or trended data to calculate operational adjustments.

3.5 Site Reporting

DNV GL submitted draft site reports to National Grid, and they provided comments or questions to the engineer who led the site analysis. The engineer responded to comments and questions raised 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 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 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 GL, summarized in graphical or tabular form for each data point
  - The data provided by the site and/or National Grid, with key data summarized in graphical or tabular form
  - Evaluation baseline used
  - The evaluation analysis method used, identifying any deviations from the original savings estimation method
  - Key savings parameters determined through the 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 evaluation savings estimates
  - Lifetime savings

All site reports were reviewed by an internal quality assurance lead. This review determined if the reports complied with the requirements for this deliverable and if the document communicates information clearly and consistently.

3.5.1.1 Measure Event Type and Baseline Review

A review of event measure types and baselines for each measure installed at sites in the sample selected for the evaluation was completed for this study. DNV GL selected a measure baseline event type based on a preponderance of evidence presented in the project file, the data gathered during the site contact interview, and information gathered during the site visit. National Grid classified measures into two event types: 1) new construction measures which include both new buildings and replace on failure or planned new measure purchases and 2) retrofit measures. Evaluation observed the following measure event types: retrofit with a single baseline, add-on, early replacement, and lost opportunity.

Table 3-6 below shows the measure event types used in tracking and evaluation. Sites 2018RIG43, 2018RIG55, and 2018RIG078 have multiple application numbers for certain measures that were part of one project. They are considered Parent/Child[6] projects.

[6] For some large projects, National Grid typically doesn't pay out the total incentive upfront but splits the project into 2 applications as parent and child. The child payment is made after the project is fully commissioned and completed. Saving are split between parent and child applications.

Table 3-6: Measure event type in tracking and evaluation

Site Id	National Grid Application#	Tracking Event Type	Evaluation Event Type
2018RIG19	7919893	Retrofit	Retrofit with single baseline
2018RIG26	8575048, 7464523	Retrofit	Add-on
2018RIG27	8575046	Retrofit	Add-on
2018RIG43	6795554, 5771727	Retrofit	Early Replacement
2018RIG55	8898960, 8898962, 8124543, 8038935	Retrofit	Add-on
2018RIG58	7474075	Retrofit	Retrofit with single baseline
2018RIG64	7454434	New Construction	Lost Opportunity
2018RIG78	7031427, 8766309	New Construction	Lost Opportunity

After the measure event type was selected, the evaluator selected the evaluated baseline for the event type. Measures classified as retrofit or add-ons used pre-existing conditions as a 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 GL assessed the reasonableness of the baseline for each sampled project.

3.6 Desk Reviews Including 1st Site Visit Collected Data

When the COVID-19 emergency had stopped all fieldwork, the team could not estimate a possible date to enter facilities as circumstances surrounding the global crisis were unforeseeable. At this point complete desk reviews were added as a backup plan for calculating program savings for 2018 as the team was unsure if evaluators were going to have permission to access sites where meters were installed before the August reporting deadline.

Permission to contact recruited sites for this effort was eventually given and 6 sites participated in logger removal. The other two sites had promised trend data or provided some undocumented trend data prior to the pandemic. Results were tabulated using the desk reviews to provide realization rates for the 2 projects that did not participate or deliver key trend data during the second site visit. Therefore, operational and HVAC interactive adjustment factors were not included as they would be in a full evaluation. The remaining 6 desk reviews were appended with the operational and HVAC interactive adjustment factors for the 6 sites that permitted entry to remove loggers.

To complete the desk reviews for all 8 sampled sites, the team reviewed project files and information collected from the initial site visit before the engineer performed a site contact interview for the measures installed. The goal of the desk review was to complete the following:

- Conduct an in-depth review of the baseline, methodology, administrative tracking/documentation, quantity and technology for each evaluated measure to provide the stakeholders an early and accurate assessment of the impact of savings changes for evaluation planning purposes. The additional quantity and technology adjustments are not traditionally evaluated in a desk review; however, the inclusion of these measures is due to additional information acquired while performing initial site visits and some data collection.

- Serve as a backup option for annual planning purposes due to delays from COVID-19 and the risk that a preliminary realization rate from a sample of site reports may not be delivered before the August reporting deadline.

The desk review data collection instrument focused on measure-specific assessments towards the impact change in categories for each sampled site accounting for the following criterion:

- Measure event type classifications (retrofit, add-on, lost opportunity)
- Applicant baseline source
- Applicant and evaluator measure life
- Evaluator assessment of the baseline (preexisting single/dual, ISP, unique)
- Assessment of baseline change impact on the measure savings
- Savings calculation method used by the applicant
- Most applicable savings calculation method, per evaluator
- Applicant key assumptions quality
- Assessment of methodology change impact on the measure savings
- Availability of native tracking savings calculations in electronic form
- Tracking savings source (applicant, equipment vendor/contractor, National Grid implementer, independent TA consultant)
- Assessment of quantity of items installed
- Verify the unit(s) is/are installed and if there are any discrepancies for installed quantities
- Does the installed technology match the applicant claimed technology or serve the same function?
- Does the applicant analysis consider interactivity with other end-uses, equipment, or fuel types?
- Were the applicant results normalized?
- Evaluator assessment of the quality of the applicant's savings estimations
- Calculation of the measure savings fraction completed by dividing the tracking savings from the pre-installation annual gas consumption (only for the sites for which billing data is available at the time of desk review)

The desk review collection instrument presented the evaluator assessment of the applicant savings calculation methods and presented a savings fraction for each evaluated measure for the baseline, admin/tracking, methodology, quantity and technology factors in sequential order. The team compiled the desk review findings into a spreadsheet template for uniform capture.

The results of the desk reviews and the 6 completed site reports were summarized in a separate memo submitted to National Grid for annual planning purposes.

3.7 Sample Expansion with 2-Sample Ratio Estimation

The ratio estimation accounts for the difference within the program year of 2018 from two separate samples due to non-response for two sites during the second site visit. Table 3-7 shows the adjustment factors used by evaluators to categorize discrepancies from tracking data and how those factors are categorized within the 2018 program year.

Table 3-7. Adjustment Factors for Evaluation

	Adjustment Factors						
Ratio Name:	**Non-Operational Adjustments**					**Operational Adjustments**	
Obtained:	**In-depth desk review**			**1st site-visit**		**logger pickup**	
Factor:	Baseline	Methodology	Tracking & Admin	Technology	Quantity	Operational	HVAC Interactive

The formulas below are used to calculate the realization rates for both sample components of the 2018 program year. The realization rates/adjustment factors are calculated as a ratio estimator over the sample of interest (Cochran[7], 1977, p.165).

Therefore, the overall 2018 program year realization rate is calculated as such:

$$RR_{2018} = AR_{Non-Operational\,(n=8)} * AR_{Operational\,(n=6)}$$

$$AR_{Non-Operational\,(n=8)} = \frac{\sum Quantity\ Adjusted\ Savings * Site\ Weight}{\sum Tracking\ Savings * Site\ Weight}_{Completed\ Sites\ for\ Non-Operational\ Adjustments\,(n=8)}$$

$$AR_{Operation\,(n=6)} = \left(\frac{\sum HVAC\ Interactive\ Adjusted\ Savings * Site\ Weight}{\sum Tracking\ Savings * Site\ Weight}\right)_{Completed\ Sites\ for\ Operation\ Adjustments\,(n=6)}$$

where,

AR	= Adjustment Ratio (-)
$Quantity$	= Therms savings including Admin/Tracking, Baseline, Technology, and Quantity adjustments
$HVAC\ Interactive$	= Therms savings including Admin/Tracking, Baseline, Technology, Quantity, Operational, and HVAC Interactive Savings adjustments
n	= sample size

[7] Sampling Techniques, 3rd Edition, William G Cochran.

4 DATA SOURCES

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

- PY2018 tracking data provided by National Grid
- PY2016 and PY2017 tracking data
- PY2016 and PY2017 impact evaluation results
- Project files, which typically include one or more of the following: original applications, BCR screenings, invoices, technical assistance studies, applicant savings calculations, and post-installation reports
- On-site observations and data collection including inspection and verifications of equipment, nameplate data, staff interviews, vendor interviews, spot measurements of various parameters including kW, longer-term measurements and combustion efficiency
- Metered and/or EMS trend data from each of the 7 sites that participated in the study, not including 2018RIG55 that did not provide trending data

5 ANALYSIS AND RESULTS

The RI PY2018 study achieved the target precisions while combining the latest 3 years (PY2016, PY2017, & PY2018). PY2016 impact evaluation results were finalized[8] in March 2019, and the PY2017 impact evaluation results were finalized[9] in May 2020. The following subsections provide more details on the PY2018 results.

5.1 PY2018 Results

This section provides an overview of the results from comparing PY2018 tracking and evaluated results.

5.1.1 Site-Level Results

Figure 5-1 and Figure 5-2 illustrate the comparison of reported (x-axis) and evaluated (y-axis) annual natural gas savings for each of the 8 sites included in the evaluation sample for PY2018. Figure 5-1 shows all sites and Figure 5-2 shows a magnified version for the smaller savings sites.

Ideally, the evaluated savings would always match the reported savings; this ideal is shown as a solid green line in each chart. Figure 5-1 shows the largest evaluated site which has tracking savings of about 700,000 therms per year. The evaluated site almost lies directly on the 100% RR line at 100.4% RR. Any evaluated sites above the 100% RR line indicates a RR greater than 100%, and any evaluated site below the 100% RR line indicates a RR less than 100%. Similarly, the same exists for the 83.3% evaluated gross savings RR line.

Three evaluated sites have a 0% RR rate and are shown along the bottom of both graphs with 0 evaluated therms savings. Appendix A summarizes the 8 sites for which M&V activities were completed, with vital statistics such as the site ID, the verified measure description, tracking savings, and RR.

8 Impact Evaluation of PY2016 Custom Gas Installations in Rhode Island

9 Impact Evaluation of PY2017 Custom Gas Installations in Rhode Island

Figure 5-1: PY2018 Reported and Evaluated Annual Natural Gas Savings (all savings sites)

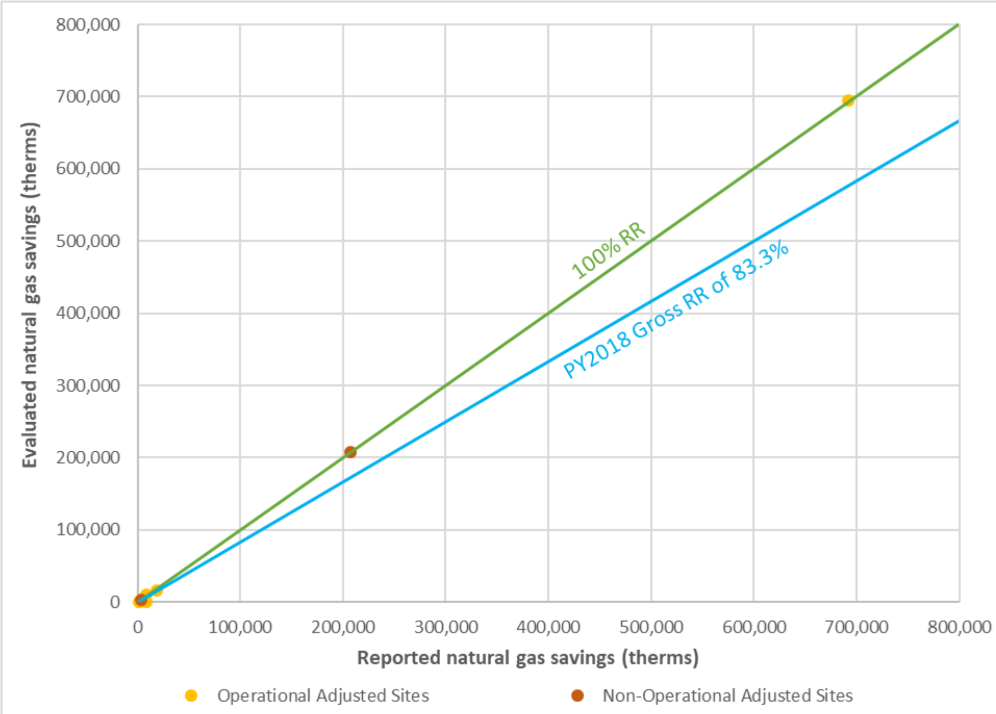
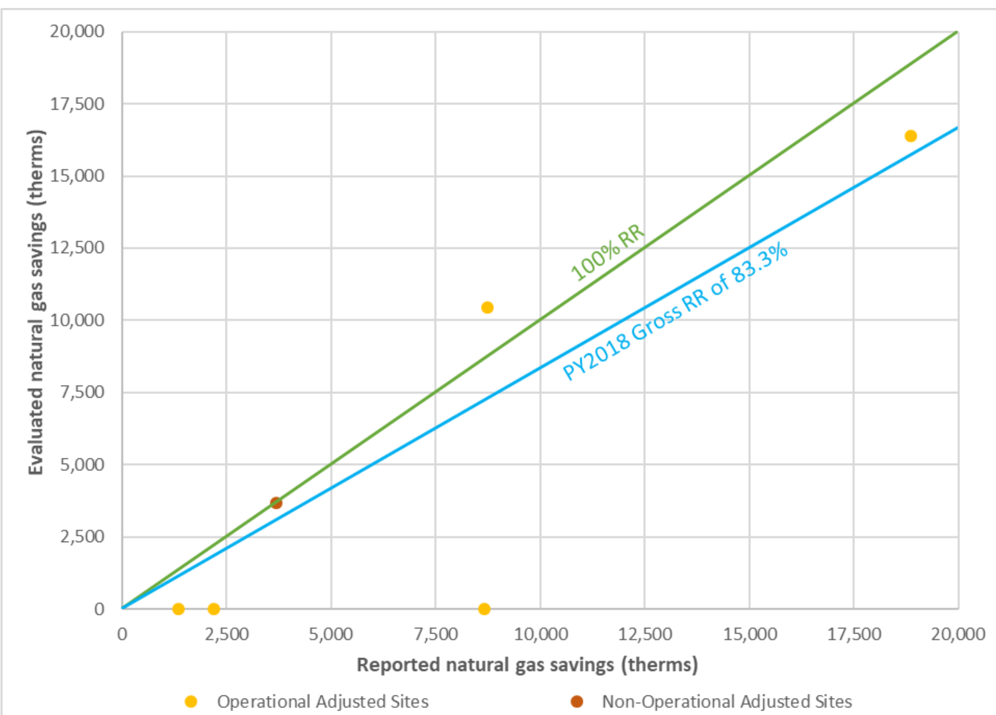


Figure 5-2: PY2018 Reported and Evaluated Annual Natural Gas Savings (small savings sites only)



5.1.1.1 Non-Operational Adjustment Results

Traditional desk reviews contain baseline, methodology, and tracking/admin adjustment factors. These factors are completed with project files, tracking data, and preferably a site contact interview. Technology and quantity adjustments are verified and obtained during the 1st site-visit or through a virtual visit. The team was able to perform the desk review and 1st site visits on all 8 of the sampled sites.

Table 5-1. PY2018 site-level unweighted non-operational adjustments

Site	Measure Type	Tracking Savings (therms)	Non-Operational Adjustments				
			Baseline	Methodology	Tracking /Admin	Technology	Quantity
2018RIG78	Process - Laundry	17,625	0	0	-8,961	-8,664	0
2018RIG26	Controls and EMS	1,349	0	0	0	0	0
2018RIG27	Controls and EMS	8,011	0	-5,808	0	-1,362	0
2018RIG64	Process - Laundry	3,687	0	0	0	0	0
2018RIG43	Process – Equipment/Controls	691,953	0	0	0	0	0
2018RIG55	Process – Equipment/Controls	207,347	0	0	0	0	0
2018RIG19	Steam Traps	8,730	0	0	0	0	0
2018RIG58	Steam Traps	18,863	0	0	0	0	0

The site 2018RIG78 had 51% of savings removed in tracking and admin adjustment factors since tracking savings appear to be based upon three washers and three dryers. The project documentation includes a revised memo where the applicant re-calculated savings for two washers and two dryers, and it does not appear that the tracking savings were updated with these values. The customer installed two of each unit, not three of each unit. The remaining 49% of savings were removed since the proposed washer was not installed. The team chose technology over quantity since there was an operating washer in place, but the replacement technology was never installed to improve efficiency.

For 2018RIG27, evaluators found the installed technology was not capable of maintaining a hot water setpoint to properly implement the DDC controls and hot water reset controls. Additionally, the original analysis algorithm from which savings were based was based on consumption data that was not verified in the billing data. Therefore, the savings from methodology were reduced after consumption data was calculated from billing data collected for this site.

All other sites did not contain non-operational adjustment factor discrepancies, but rather all discrepancies are operational adjustments.

Forthcoming sections presents the descriptions of the general discrepancies for all sampled sites in non-operational and operational adjustment factors. Table 5-6 contains the weighted adjustment factors for all 8 sampled sites.

5.1.1.2 Operational Adjustment Results

The results from a full evaluation include all adjustment factors found in the desk review and 1st site visit while also including the additional operational adjustments (operational and HVAC-interactive adjustments). These factors are obtained after logger pickup and analyzing long-term data (trending data is categorized in these adjustments). Table 5-2 shows the operational adjustments after the non-operational adjustment factors are summed from Table 5-1. As mentioned, operational adjustments for sites 2018RIG64 and 2018RIG55 were not calculated as the 2nd site visit has not been completed due to the non-responsiveness of the customer.

Table 5-2. PY2018 site-level unweighted operational adjustments.

Site	Measure Type	Non-Operational Adjustments	Operational Adjustments	
			Operation	Interactive
2018RIG78	Process - Laundry	0	0	0
2018RIG26	Controls and EMS	1,349	-1,349	0
2018RIG27	Controls and EMS	841	-841	0
2018RIG64	Process - Laundry	3,687	Not calculated*	Not calculated*
2018RIG43	Process – Equipment/Controls	691,953	+2,989	0
2018RIG55	Process – Equipment/Controls	207,347	Not calculated*	Not calculated*
2018RIG19	Steam Traps	8,730	+1,725	0
2018RIG58	Steam Traps	18,863	-2,476	0

*Future attempts will be made to evaluate the sites where operational adjustments were not obtainable.

Both steam trap sites were adjusted based on metering data that captured operating hours for the facility. Savings were also adjusted based on steam pipe pressure or temperature and boiler efficiency. All adjustments are operational which require metered data or multiple observations.

2018RIG43 contained operational differences include RTO effectiveness, airflow, baseline combustion temperature, pollutant burn-off heat, and system efficiency. The overall adjustment is small (0.4%) when compared to the overall savings at the site level.

The controls and EMS project savings were reduced to 0 savings after the evaluation team determined the operating behavior of the system did not perform as documented. The sites either did not have proper programming of the governing controls to achieve savings or the system itself was incapable of achieving savings from technological constraints that were observed from trend data.

5.1.1.3 PY2018 Combined Operational and Non-Operational Results

As previously discussed, a 2-sample approach was implemented since two sites did not provide enough information to calculate operational adjustment factors. Therefore, two sets of weights are applied in aggregating study results, one set based on the eight sites receiving non-operational adjustments, and the second set based on the six sites analyzed for operational adjustments. Results are tabulated using the methodology described in Section 3.7. Table 5-3 below presents the case weights, realization rates for non-operational and operational inner-year samples, and the overall realization rate for PY2018.

Table 5-3. Realization Rate Calculation

Site ID	Unweighted Tracking Savings (therms)	Non-Operational			Operational		
		Weight (-)	Weighted Tracking Savings (therms)	Weighted Evaluated Savings (therms)	Weight (-)	Weighted Tracking Savings (therms)	Weighted Evaluated Savings (therms)
2018RIG78	17,625	4.50	79,313	0	9.00	0	0
2018RIG26	1,349	20.33	27,430	27,430	30.50	41,145	0
2018RIG27	8,011	20.33	162,890	17,103	30.50	25,655	0
2018RIG64	3,687	20.33	74,969	74,969	N/A*	N/A*	N/A*
2018RIG43	691,953	1.00	691,953	691,953	1.00	691,953	694,942
2018RIG55	207,347	4.50	933,062	933,062	N/A*	N/A*	N/A*
2018RIG19	8,730	8.00	69,840	69,840	8.00	69,840	83,640
2018RIG58	18,863	8.00	150,904	150,904	8.00	150,904	131,096
		Total	**2,190,360**	**1,965,261**		**979,497**	**909,678**
		Non-Operational RR		**89.7%**	**Operational RR**		**92.9%**
					PY2018 Overall RR		**83.3%**

*Future attempts will be made to evaluate the sites where operational adjustments were not obtainable.

The realization rate for PY2018 RI Custom Gas installations is 83.3%. The overall RR is calculated using the 2 inner-year samples from non-operational (89.7%) and operational (92.9%) realization rates.

The realization rate is higher than expected when considering there were 3 sites that contained 0 therm savings after all adjustments. The overall realization rate is largely impacted by 2018RIG43 which can be seen in Table 5-3 by comparing the weighted savings. 2018RIG43 accounts for 70.6% of the operational, weighted tracking savings totals. After tracking savings are weighted for operational adjustments, the 694,942 weighted therms saving site is larger than all other sites combined. Therefore, 100% RR of this large site is compensating for the zero or low RR sites.

5.1.2 Discrepancy Results

For each of the 8 sites included in the PY2018 study, the site engineers identified factors that led to differences between the program-reported (tracking) savings and the evaluated savings. The factors are classified into seven categories: baseline, methodology, tracking/administrative, technology, quantity, HVAC interaction, and operational. A more discrete breakdown of differences is presented below in Table 5-4.

Table 5-4: PY2018 Discrepancy Factors and their Mapping to Major Categories

Major Discrepancy	Basic Discrepancy
Baseline	Baseline
Methodology	Analysis Methodology
Tracking/Admin	Tracking Savings
Technology	Differences in proposed vs. installed technology
Quantity	Quantity of installed equipment
	Boiler combustion efficiency
	Difference in equipment hours of operation
	Equipment load profile
Operational	Inaccurate pre-project characterization
	Steam operating pressure
	System optimization or programming not implemented
	Faulty or improperly installed equipment
HVAC Interaction	Interactive effects

The evaluation team used the site-specific sampling weights and the site-specific impacts of discrepancy to calculate the impact of adjustment factors for differences between the program and evaluated results at the population level. Table 5-2 below presents the discrepancy factors and their impacts. There were no baseline or quantity adjustments discrepancies found in the sample. Most discrepancies are operational with site-specific comparisons found in Table 5-6.

Table 5-5: PY2018 Weighted Discrepancy Factors Between Tracking and Evaluated Results

Adjustment Factor	Site Counts	Impact on RR	Impact (%)
Baseline	0		0.00%
Methodology	2		-0.41%
Tracking/Admin	1		-0.63%
Technology	2		-0.71%
Quantity	0		0.00%
Operational*	4		-14.94%
Interactive*	0		0.00%
Total			-16.70%

*Only for the 6 sites with full evaluation completed

Adjustment percentages found in Table 5-6 are the magnitude of changes for each site and are reported at the site level. The percentages are the total adjustments for operational and non-operational adjustments when compared to site-level savings.

The largest tracking savings sites' discrepancies factors are discussed below:

2018RIG27 had the largest discrepancy at the site level due to a non-operational difference of -65% for the total site-level savings. 2018RIG27 did not install DCV measures per the proposed case and the original methodology estimated a much higher gas consumption than billing data history shows.

2018RIG26 had the second largest site-level discrepancy as an operational adjustment of -59%. The EMS system was not programmed and did not operate at the specific levels necessary to achieve savings. The operational conditions resulted in 0 therms savings for the site.

Table 5-6: Non-Operational and Operational Weighted Discrepancies

Site ID	Tracking Savings	Evaluated Savings	Non-Operational Weighted Discrepancy (%)	Operational Weighted Discrepancy (%)	RR
2018RIG78	17,625	0	-35%	0%	0.0%
2018RIG26	1,349	0	0%	-59%	0.0%
2018RIG27	8,011	0	-65%	-37%	0.0%
2018RIG64	3,687	3,687	0%	0%	100.0%
2018RIG43	691,953	694,942	0%	4%	100.4%
2018RIG55	207,347	207,347	0%	0%	100.0%
2018RIG19	8,730	10,455	0%	20%	119.8%
2018RIG58	18,863	16,387	0%	-28%	86.9%

Detailed information on site-specific differences is presented in Section 3 of each site report, which is included in Appendix B.

5.2 Combined Results

The evaluators calculated the gross RR using the results from PY2016, PY2017, and PY2018. The results are summarized in Table 5-7. PY2016 and PY2017 achieved much better precisions than estimated in the design (Table 3-5) primarily due to the low variance in large stratum site results. Sites 2018RIG43 and 2018RIG55 tracking savings cover nearly 39% of the entire program savings and sampling both the large sites have reduced the error in the overall expanded results. The PY2018 relative precision is higher than the two prior evaluation years due to the 2-sample approach introduced from non-participation of two sites during logger retrieval and trend data delivery (2018RIG55 and 2018RIG64). The decision to use the 2-sample approach for PY2018 was made to avoid having to drop these two sites. It allowed incorporation of information found from the initial site visits of the 2 non-participating sites, and 2018RIG55 was a large site that the team deemed important for the evaluation. Efforts will continue to acquire the trending data from this site to provide a full evaluation in the future, however, the combined results summarized below are valid for application until the next year of the rolling evaluation is completed.

Table 5-7. 3-Year Rolling Plan Results and Statistics

Parameter	PY2016	PY2017	PY2018	PYs 2016+2017 +2018
Tracking Savings	1,114,770	1,948,383	2,350,739	5,413,892
Sample Size	8	6	6[10]	20
Realization Rate (RR)	71%	92%	83.3%	84.2%
Relative Precision @ 80% CI (%)	±10.6%	±2.3%	±22.6%	±10.1%
Error Ratio (ER)	0.27	0.30	0.27	0.55

The relative precision of the RR (±10.1%) meets the design precision targets proposed and presented above, in Section 3.1.3, after combining the current evaluation year (2018) and the prior 2 years of results (2016 & 2017).

The original sample was designed to estimate the overall realization rate of the program by combining results from three program year evaluation studies (PYs 2016, 2017, and 2018) to achieve the agreed-upon precision targets of ±20% relative precision at 80% confidence for a Custom gas study. In this case, the precision target was achieved by combining results from PY2016, PY2017, and modified PY2018 (based on the methodology discussed in Section 5.1). Table 5-7 shows the individual PY2016, PY2017, and PY2018 results along with the combined 3-year rolling evaluation for PY2016, PY2017, & PY2018.

5.3 Conclusions, Recommendations and Considerations

This section presents the conclusions, recommendations, and of the impact evaluation study.

5.3.1 Conclusions

PY2018 Performance. The program continues to generate significant natural gas savings. In RI, the PY2018 custom gas projects saved an estimated 2.35 million therms (adjusted gross savings) annually with 83.3% of the savings realized based on the evaluation sample for RI PY2018 sites. Combined over the 3-year rolling sampling period, the program realized 5.4 million therms with 84.2% of savings realized.

DNV GL will continue to work with National Grid to finalize the remaining two full site reports should the sites continue with the evaluation. However, the current results are accurate within state and regulatory standards and provide adequate planning and program reporting savings estimations. Should the sites finish the evaluations, DNV GL does not expect a large deviation from current results.

Site-specific sample weights are shown in APPENDIX A. More details on the PY2018 results are presented in section below, and in each site-report included in APPENDIX B.

5.3.2 Recommendations

DNV GL reviewed project files, conducted detailed analyses of the information provided in the files, and quantified discrepancies to make the recommendations presented below.

[10] The minimum sample size of each of the inner samples for the PY2018 evaluation (non-operational adjustments sample size is 8 and operational adjustments sample size is 6) dictates the overall sample size of the year.

5.3.2.1 R1: Realization Rate

DNV GL recommends National Grid to use the PY2016, PY2017, & PY2018 combined RR of 84.2% for planning and program reporting, starting with PY2021 and continuing to subsequent years until new impact evaluation study results are available. The applicable RRs are noted in Table 5-7. This recommendation was based on the following factors:

- When PY2016 (71%), PY2017 (92%), & PY2018 (83.3%) results are pooled, the study produced state-wide results that met precision targets of ±20% relative precision at 80% confidence (actual: ±10.1% at 80% confidence level).

Based on the results listed for PY2018, an Error Ratio Target of 0.55 has been recommended for 2019 RI Custom Gas Impact Evaluation to achieve the next 3-year rolling savings evaluation precision targets.

5.3.2.2 R2: EMS/Control Calculation Method and Commissioning

EMS and Control measure projects (2) evaluated in the PY2018 sample resulted in 0 savings. EMS systems are difficult at best to achieve an accurate savings estimate without prior system behavior monitoring, and the deemed savings calculator is inadequate for these types of projects. Additionally, several checks were not performed at the sites to ensure proper EMS programming was completed or if the system could perform at the levels necessary to ensure savings were achieved. DNV GL recommends the following items to improve EMS and Control based measures to improve the current process:

d) For all EMS/Control based projects, including smaller projects, consider adding certain levels of verification such as: 1) verify trend data demonstrates controls are operating as designed, 2) capture screenshots of the new interface that contains setpoints, or 3) some other meaningful form of documentation to ensure control based claimed savings are operational and achieving savings
e) Update the energy management system (EMS) savings calculator or require custom savings calculators from vendors with better post-installation verification to better document energy savings
f) Document pre-installation site conditions, pre-installation trend data, pre-installation operating protocols, and pertinent information for evaluators to compare baseline conditions to new operation with the overall intent of verifying system changes and evaluating savings

2018RIG26 and 2018RIG27: Pre-existing control sequences determine the energy savings associated with implementing simple control sequences, such as the ones considered for this project, but there is solely anecdotal information available about the pre-existing system operation. The custom express EMS program does not require documentation to inform baseline system assumptions for the energy savings calculations, so a comparative pre-condition is missing for energy savings calculations. The evaluation finding indicates the EMS custom express tool does not adequately consider pre-existing system control sequences to allow for accurate energy saving calculations. In addition, the evaluator found that the sequences claimed for savings are not implemented as expected. Optimal start/stop is not implemented, HW reset is not working properly, and there is very little difference between occupied and unoccupied operation although there is an occupancy schedule. Both sites resulted in 0% RRs.

5.3.2.3 R3: Post Inspection Verification for Large Projects

A smaller project, discussed below, had its commissioning combined with a larger, CDA project at the same site which resulted in not observing a measure that was not installed. DNV GL recommends that National Grid examines the system in place for post-commissioning and post-inspecting to determine how the error was caused and to place mitigation efforts to improve future practices. For example, invoice quantities can verify amounts purchased for the measures especially when there are multiple applications for a specific location.

2018RIG78: The project, installation of high efficiency washing machines, was completed at the same time as a larger CDA project for the hotel that was included in a separate Parent/Child application. The CDA project included typical HVAC and lighting measures, e.g. building envelope, VRF systems, etc. because the washing machines were not installed, and it was determined they were never post inspected. A post-inspection and utility commissioning were performed for the measures included in the larger CDA project, but reviewing the washers and dryers was not included in the post-inspection, though they were marked as installed. The washer/dryer applications should have been post-inspected. The project resulted in a 0% RR.

5.3.3 Considerations

Using the results of the study, the evaluation team generated a list of considerations, summarized below.

5.3.3.1 C1: Washer and Dryer Measures

Discrepancies from washer and dryer measures were common for the two sites evaluated in this study. The discrepancies varied from tracking savings discrepancies, administration errors, and post-commissioning errors. To avoid these issues, National Grid may consider using invoices for savings verification.

2018RIG78: The claimed savings appear to be based upon three washers and three dryers. The project documentation includes a revised memo where the applicant re-calculated savings for two washers and two dryers. It does not appear that the application was updated with these values. The customer installed two of each unit, not three of each unit. The application should have been updated to include the revised savings calculations, though this issue was not as important as the fact that the washers and dryers were never installed as discussed above. The evaluator discussed the project implementation process for this specific application with the PA which resulted in a 0% RR, as it was determined that the equipment was never installed.

APPENDIX A. POST STRATIFIED SAMPLE WEIGHTS

This Appendix lists the weights that were used to calculate over realization rates for the program.

Table 5-8: Post-Stratified Sample Weights.

Sample ID	Applications	Non-Operational Weights	Operational Weights	Tracking Savings	Evaluated Savings	Realization Rate
2018RIG19	7919893	8.00	8.00	8,730	10,455	119.8%
2018RIG26	8575048, 7464523	20.33	30.50	1,349	0	0.0%
2018RIG27	8575046	20.33	30.50	8,011	0	0.0%
2018RIG43	6795554, 5771727	1.00	1.00	691,953	694,942	100.4%
2018RIG55	8898960, 8898962, 8124543, 8038935	4.50	N/A	207,347	207,347	100.0%
2018RIG58	7474075	8.00	8.00	18,863	16,387	86.9%
2018RIG64	7454434	20.33	N/A	3,687	3,687	100.0%
2018RIG78	8766309, 7031427	4.50	9.00	17,625	0	0.0%

APPENDIX B. SITE REPORTS

2018RIG19

Report Date: 7/21/20

Program Administrator	National Grid	
Application ID(s)	7919893	
Project Type	Retrofit	
Program Year	2018	
Evaluation Firm	DNV GL	DNV·GL
Evaluation Engineer	Harsh Engineer; Laeng Khoun; Glenn Gavi	
Senior Engineer	Chad Telarico	

Evaluated Site Summary and Results

The project was implemented at a high school and consisted of replacing or repairing 50 pre-existing steam traps that had failed. Failed traps were classified as leaking. The total project savings for this measure is 8,730 therms. The measure was classified as a retrofit measure. The pre-existing condition was based on a steam trap survey conducted by a third-party steam specialist. In the survey, each trap was classified as fully operational, leaking, or not in service. 170 traps were inspected as part of the survey.

The evaluation results are presented in Table 5-9. The project is classified as a retrofit with a single baseline. Evaluators were permitted to access 13 of the 50 replaced steam traps. The evaluators conducted ultrasonic leak checks, took infrared pictures with temperature readings, and installed thermocouple loggers where feasible. It was also found that the facility's heating season typically lasts from mid-October to mid-May.

Table 5-9. Evaluation Results Summary

PA Application ID	Measure Name	Annual Savings (therms)	
7919893	Steam Traps	Tracked	8,730
		Evaluated	10,455
		Realization Rate	119.9%

Explanation of Deviations from Tracking

The evaluated savings resulted in an increase of 19.9% as compared to the tracked savings. The key reason is an increase in usage hours of steam traps which increased savings. Other discrepancies are: an increase in operating pressure that increases savings; some steam traps were found leaking during the site visit which decreased savings; and boiler combustion efficiency tests were completed which decreased savings.

Recommendations for Program Designers & Implementers

Overall, the tracking savings estimation and inputs to the steam trap calculator were well documented. The main discrepancy is the applicant assumed, annual operating hours of 1,700 hours for steam traps used for space heating in Rhode Island. This assumption is under the average hours metered and weather normalized by evaluators (2,125 annual hours).

Customer Alert

The customer was happy with the relatively minor upgrade project and is happy to continue to work with National Grid in the future.

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 with the information available.

The measure evaluated was implemented by the site to fix steam leaks in the facility's steam distribution system by replacing or repairing failed steam traps. The measure involves replacing (50) steam traps that were found to be leaking. This was a result of a facility-wide steam trap survey that was conducted. A total of (170) steam traps were inspected as part of the survey. The main function of steam traps is to remove condensate from the steam lines while reducing steam loss. A failed steam trap would result in leaking of pressurized steam from the steam lines either to the outside air or into the condensate lines. This could result in multiple problems such as water hammer, increased boiler load, reduced system efficiency, steam line rupture etc. Maintenance of steam traps is essential for proper functioning of equipment in the steam distribution system.

The tracking documentation lists the steam traps that were inspected as part of the survey and classifies them as fully operational, leaking, or not in service. The following sections present the applicant and evaluator approaches for determining the gas savings resulting from fixing the steam leaks.

Application Information and Applicant Savings Methodology

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

Applicant Description of Baseline

The measure was classified as a retrofit measure. The pre-existing condition was described based on a steam trap survey conducted by a third-party steam specialist. In the survey, each trap was classified as fully operational, plugged, leaking, blowing by or not in service. A total of (170) traps were inspected as part of the survey. The steam distribution system consists of multiple boilers serving multiple heating systems (such as unit heaters, heat exchangers etc.) in one main building at the facility. The pre-existing steam traps were of the following types:

- Float and Thermostatic
- Thermostatic Angle or Straight
- Inverted Bucket

The traps were located between 3 and 10-feet above the ground. The steam pressure in the lines is documented as 4 psi_g. Based on an interview with the site contact, the facility's heating season typically lasts from mid-October to mid-May. The 50 steam traps which were replaced are found in Table 5-10.

Table 5-10 shows the list of traps that were proposed to be fixed during the steam leak survey and the steam trap characteristics.

Table 5-10. Summary of Baseline Equipment

Sl.No	Trap Tag	Trap Application	Pipe Dia (in)	Orifice Dia (in)	Steam Pressure (psig)
1	215515	Radiator Trap	1/2"	0.25	4
2	215404	Radiator Trap	1/2"	0.25	4
3	215516	Radiator Trap	1/2"	0.25	4
4	215508	Radiator Trap	1/2"	0.25	4
5	181856	Univent	3/4"	0.21875	4
6	181840	Radiator Trap	1/2"	0.25	4
7	181842	Radiator Trap	1/2"	0.25	4
8	181843	Radiator Trap	1/2"	0.25	4
9	181847	Radiator Trap	1/2"	0.25	4
10	181893	Radiator Trap	1/2"	0.25	4
11	181897	Radiator Trap	1/2"	0.25	4
12	181898	Radiator Trap	1/2"	0.25	4
13	181900	Radiator Trap	1/2"	0.25	4
14	181904	Radiator Trap	1/2"	0.25	4
15	181838	Radiator Trap	1/2"	0.25	4
16	215401	Radiator Trap	1/2"	0.25	4
17	203543	Radiator Trap	1/2"	0.25	4
18	203460	Radiator Trap	1/2"	0.25	4
19	215509	Radiator Trap	1/2"	0.25	4
20	200100	Radiator Trap	1/2"	0.25	4
21	203542	Radiator Trap	1/2"	0.25	4
22	215513	Radiator Trap	1/2"	0.25	4
23	215505	Radiator Trap	1/2"	0.25	4

Sl.No	Trap Tag	Trap Application	Pipe Dia (in)	Orifice Dia (in)	Steam Pressure (psig)
24	181868	Univent	3/4"	0.21875	4
25	181861	Radiator Trap	1/2"	0.25	4
26	181869	Radiator Trap	1/2"	0.25	4
27	184780	Radiator Trap	1/2"	0.25	4
28	184800	Radiator Trap	1/2"	0.25	4
29	184604	Radiator Trap	1/2"	0.25	4
30	203541	Radiator Trap	1/2"	0.25	4
31	184799	Unit Heater	1/2"	0.25	4
32	176421	Radiator Trap	1/2"	0.25	4
33	184790	Drip Leg	3/4"	0.25	4
34	184791	Drip Leg	3/4"	0.25	4
35	184794	Unit Heater	1/2"	0.25	4
36	184795	Drip Leg	3/4"	0.188	4
37	200098	Unit Heater	1/2"	0.25	4
38	184796	Drip Leg	3/4"	0.188	4
39	184797	Drip Leg	3/4"	0.188	4
40	184798	Drip Leg	3/4"	0.188	4
41	203540	Radiator Trap	1/2"	0.25	4
42	184785	Drip Leg	3/4"	0.188	4
43	184786	Drip Leg	3/4"	0.188	4
44	184787	Drip Leg	3/4"	0.188	4
45	184788	Radiator Trap	1/2"	0.25	4
46	184789	Radiator Trap	1/2"	0.25	4
47	184610	Drip Leg	3/4"	0.188	4
48	184601	Drip Leg	3/4"	0.188	4
49	184607	Radiator Trap	1/2"	0.25	4
50	184777	Unit Heater	1/2"	0.25	4

Applicant Description of Installed Equipment and Operation

The site conducted a facility-wide steam trap survey to detect faulty steam traps. The site fixed the leaks by replacing (50) failed steam traps out of the (170) traps that were inspected as part of the survey. The steam traps that were fixed are shown in Table 5-10 above.

Applicant Energy Savings Algorithm

The applicant used the new state-wide 2017 Steam Traps calculator to calculate the savings for repaired or replaced failed traps. The custom savings equation developed through the referenced study has been adopted by the evaluators and is described below.

$$Svgs = \left(60 \times \frac{\pi}{4} D^2 \times (P + 14.7)^{0.97}\right) \times \frac{LF \times C_D \times (h_g - h_f) \times CR \times Hours}{100{,}000 \times \eta}$$

where,

$Svgs$	= Annual energy savings per year (therms)
60	= Empirically derived factor in Grashof equation ($lb_m/(in^{0.06}\text{-}lb^{0.97}\text{-}hr)$)
D	= Diameter of steam trap orifice (inches)
P	= Pressure of steam in line at trap (psig); add 14.7 to get psia
0.97	= Empirically derived factor in Grashof equation
LF	= Leak factor is determined through field testing and accounts for partially obstructed orifices or non-ideal steam flow. Plugged traps use a value of 0% (i.e. no savings result from fixing a plugged trap), leaking traps use a value of 26% and blowing by traps use a value of 55%
C_D	= Discharge coefficient (70%) due to trap hole not being a perfect orifice
h_g, h_f	= Enthalpy of saturated steam and liquid, respectively; associated with specified trap operating pressure (Btu/lb)
CR	= Condensate return factor accounting for energy returned from leaking/blowing by traps via a condensate return line. (36.3%)
$Hours$	= Hours per year that a trap is pressurized and operating
100,000	= Therms per Btu conversion
η	= Boiler plant efficiency

Evaluation Assessment of Applicant Methodology

The applicant used the state-wide 2017 Stream Traps calculator which is the standard template used by the Program Administrator to calculate the savings for repaired or replaced traps. The evaluator agrees with the savings approach used by the applicant.

On-Site Inspection and Metering

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

Summary of On-site Findings

A site visit was conducted in February 2020 to verify the steam traps were replaced. Spot measurements were conducted (temperature checks and ultrasonic readings) and HOBO thermocouple loggers were installed to confirm the operation of the steam traps that were claimed to be replaced as part of the project. The site visit involved a combination of visual inspection, measuring temperature, using an ultrasonic leak detector, and boiler combustion tests to determine if the traps operate as intended along with steam distribution system efficiency.

The site is a public high school that consists of a single building. The facility's steam distribution system has three boilers that serves all the facility's steam requirements. The boilers are built in a lead lag system with a backup for high load periods. The steam is used for space heating purposes and the different steam lines serve multiple end-use applications such as unit heaters, heat exchangers, and other heating systems. The operating pressure of the steam is documented at 4 psi_g, but onsite engineers found the operating pressure of all steam lines at 5 psi_g. Onsite evaluators pressure determination is further verified by a commissioning report performed by Rise Engineering with the same determination of 5 psi for the steam pressure. The evaluators evaluated (13) steam traps that were claimed as part of the project in the applicant documentation. Evaluators monitored (11) of the steam traps either with a single channel HOBO thermocouple logger or through a multichannel logger.

During the site visit, the evaluators visually inspected 13 steam traps. The evaluators conducted ultrasonic leak checks, took infrared pictures, took spot temperature readings, and installed thermocouple loggers to measure long term temperature where feasible. The evaluators found that 2 of the 13 inspected steam traps were not energized during the time of the initial visit, i.e. there was no steam passing through the lines on which the two traps were located. The steam traps were not operating since the school was on a break and construction was underway in specific areas of the school during the week evaluators visited. Two other steam traps were faulty as one was found leaking water and another failed the ultrasonic test. Site contact confirmed the traps were normally operating and would energize once construction ended within a day or two. The site contact confirmed that the heating season is typically from October to May.

Table 5-11 summarizes the measures verified after project installation and the changes found during verification.

Table 5-11. Measure Verification

Measure Name	Verification Method	Verification Result
Steam Traps	Conduct ultrasonic leak checks, take infrared pictures, document temperature readings, and install thermocouple loggers	Most steam traps are operating as expected. 2 of 13 inspected steam traps were found to be leaking (one visibly leaking water and the other through ultrasonic inspection). Operation hours vary compared to applicant estimations.

Measured and Logged Data

The tasks completed by the evaluators during the site visit is summarized below:

- Visually inspected (sampled) new/repaired steam traps (13 inspected)
- Take infrared pictures with temperature readings of new/repaired steam traps
- Performed ultrasonic leak checks using an ultrasonic leak detector of new/repaired steam traps (inspected 13)
- Install thermocouple loggers to meter temperature data on sampled steam traps where feasible (installed on 11 unique steam traps)

Steam traps were binned based on the steam trap type and pipe diameter as found in Table 5-12. Annual hours and pressure are constant throughout the steam trap population, so they were not used in the sampling method. Most steam traps are grouped in sample group numbers 2 & 3. They account for 45 of the 50 steam traps repaired or replaced at the facility. These sample groups were spot checked more than others and had meters placed to capture enough operating hour schedules.

Table 5-12. Steam Trap Sample Bins Based on Steam Trap Type and Pipe Diameter

Bin	Annual Hours	Steam Trap Type	Pressure (psig)	Pipe Diameter (in)	Count of Repair/ Replace
1	1,700	Float & Thermostatic	5	3/4"	2
2	1,700	Inverted Bucket	5	3/4"	11
3	1,700	Thermostatic Angle	5	1/2"	34
4	1,700	Thermostatic Straight	5	1/2"	3

The steam trap grouping numbers are found in Table 5-13 for the population of replaced/repaired steam traps. A summary of the sample groups and the amount of steam traps spot measured or metered are found in Table 5-14.

Table 5-13. Steam Trap Groups

Sl.No	Trap Tag	Group #	Trap Application	Trap Type	Pipe Dia (in)	Orifice Dia (in)	Steam Pressure (psig)
1	215515	3	Radiator Trap	Thermostatic Angle	1/2"	0.25	5
2	215404	3	Radiator Trap	Thermostatic Angle	1/2"	0.25	5
3	215516	1	Radiator Trap	Float & Thermostatic	1/2"	0.25	5
4	215508	3	Radiator Trap	Thermostatic Angle	1/2"	0.25	5
5	181856	3	Univent	Thermostatic Angle	3/4"	0.21875	5
6	181840	3	Radiator Trap	Thermostatic Angle	1/2"	0.25	5
7	181842	3	Radiator Trap	Thermostatic Angle	1/2"	0.25	5
8	181843	3	Radiator Trap	Thermostatic Angle	1/2"	0.25	5
9	181847	3	Radiator Trap	Thermostatic Angle	1/2"	0.25	5
10	181893	3	Radiator Trap	Thermostatic Angle	1/2"	0.25	5
11	181897	3	Radiator Trap	Thermostatic Angle	1/2"	0.25	5
12	181898	4	Radiator Trap	Thermostatic Straight	1/2"	0.25	5
13	181900	3	Radiator Trap	Thermostatic Angle	1/2"	0.25	5
14	181904	3	Radiator Trap	Thermostatic Angle	1/2"	0.25	5
15	181838	3	Radiator Trap	Thermostatic Angle	1/2"	0.25	5
16	215401	1	Radiator Trap	Float & Thermostatic	1/2"	0.25	5
17	203543	3	Radiator Trap	Thermostatic Angle	1/2"	0.25	5
18	203460	3	Radiator Trap	Thermostatic Angle	1/2"	0.25	5
19	215509	3	Radiator Trap	Thermostatic Angle	1/2"	0.25	5
20	200100	3	Radiator Trap	Thermostatic Angle	1/2"	0.25	5
21	203542	3	Radiator Trap	Thermostatic Angle	1/2"	0.25	5
22	215513	3	Radiator Trap	Thermostatic Angle	1/2"	0.25	5
23	215505	3	Radiator Trap	Thermostatic Angle	1/2"	0.25	5
24	181868	3	Univent	Thermostatic Angle	3/4"	0.21875	5

Sl.No	Trap Tag	Group #	Trap Application	Trap Type	Pipe Dia (in)	Orifice Dia (in)	Steam Pressure (psig)
25	181861	3	Radiator Trap	Thermostatic Angle	1/2"	0.25	5
26	181869	3	Radiator Trap	Thermostatic Angle	1/2"	0.25	5
27	184780	3	Radiator Trap	Thermostatic Angle	1/2"	0.25	5
28	184800	3	Radiator Trap	Thermostatic Angle	1/2"	0.25	5
29	184604	3	Radiator Trap	Thermostatic Angle	1/2"	0.25	5
30	203541	3	Radiator Trap	Thermostatic Angle	1/2"	0.25	5
31	184799	3	Unit Heater	Thermostatic Angle	1/2"	0.25	5
32	176421	2	Radiator Trap	Inverted Bucket	1/2"	0.25	5
33	184790	2	Drip Leg	Inverted Bucket	3/4"	0.25	5
34	184791	2	Drip Leg	Inverted Bucket	3/4"	0.25	5
35	184794	3	Unit Heater	Thermostatic Angle	1/2"	0.25	5
36	184795	3	Drip Leg	Thermostatic Angle	3/4"	0.188	5
37	200098	3	Unit Heater	Thermostatic Angle	1/2"	0.25	5
38	184796	3	Drip Leg	Thermostatic Angle	3/4"	0.188	5
39	184797	3	Drip Leg	Thermostatic Angle	3/4"	0.188	5
40	184798	3	Drip Leg	Thermostatic Angle	3/4"	0.188	5
41	203540	3	Radiator Trap	Thermostatic Angle	1/2"	0.25	5
42	184785	3	Drip Leg	Thermostatic Angle	3/4"	0.188	5
43	184786	2	Drip Leg	Inverted Bucket	3/4"	0.188	5
44	184787	2	Drip Leg	Inverted Bucket	3/4"	0.188	5
45	184788	2	Radiator Trap	Inverted Bucket	1/2"	0.25	5
46	184789	3	Radiator Trap	Thermostatic Angle	1/2"	0.25	5
47	184610	2	Drip Leg	Inverted Bucket	3/4"	0.188	5
48	184601	2	Drip Leg	Inverted Bucket	3/4"	0.188	5
49	184607	2	Radiator Trap	Inverted Bucket	1/2"	0.25	5
50	184777	4	Unit Heater	Thermostatic Straight	1/2"	0.25	5

Table 5-14. List of Steam Traps with Ultrasonic Readings or Metered with Loggers

Group	Properties			Steam Trap Count	Ultrasonic Inspected Steam Trap Count	Metered Steam Trap Count
	Type	Pipe Size (in)	Pressure (psig)			
1	Float & Thermostatic	3/4"	5	2	1	1
2	Inverted Bucket	3/4"	5	11	2	4
3	Thermostatic Angle	1/2"	5	34	9	5
4	Thermostatic Straight	1/2"	5	3	1	1

The thermocouple loggers were installed to estimate the operating hours of the steam traps, i.e. the total hours the steam lines were energized during the metering period. Table 5-15 below shows the list of HOBO thermocouple temperature loggers that were installed during the site visit:

Table 5-15. List of Thermocouple temperature loggers installed

Sl.No	Logger Type	Metering Period	Logger ID	Metering Interval	Steam Trap Tag #	Group #
1	HOBO Thermocouple	02/20/20 – 07/17/20	20556573	5-Minutes	181856	1
2	HOBO Thermocouple	02/20/20 – 07/17/20	20531927	5-Minutes	181847	3
3	HOBO Thermocouple	02/20/20 – 07/17/20	20790564	5-Minutes	215508	3
4	HOBO Thermocouple	02/20/20 – 07/17/20	20556570	5-Minutes	215401	3
5	HOBO Thermocouple	02/20/20 – 07/17/20	20790561	5-Minutes	203543	3
6	HOBO Thermocouple	02/20/20 – 07/17/20	20580014	5-Minutes	200098	3
7	HOBO Thermocouple	02/20/20 – 07/17/20	20557177	5-Minutes	184796	2
8	HOBO Thermocouple	02/20/20 – 07/17/20	20557177	5-Minutes	184797	2
9	HOBO Thermocouple	02/20/20 – 07/17/20	20557177	5-Minutes	184798	2
10	HOBO Thermocouple	02/20/20 – 07/17/20	20790563	5-Minutes	184789	4
11	HOBO Thermocouple	02/20/20 – 07/17/20	20790562	5-Minutes	184601	2

The loggers captured surface temperature of the steam line and ambient air temperature in 5-minute intervals. One logger (installed on Trap# 215401 in sample group 3) was not returned by the site contact.

Evaluation Methods and Findings

This section describes the evaluator methods and findings.

Evaluation Description of Baseline

The evaluation baseline is a retrofit with a single baseline. The evaluator agrees with the applicant baseline based on data collected during the site visit and the results of the steam trap survey conducted. Discussion with the site contact confirmed that the pre-existing traps were leaking and that a total of (50) traps were fixed, which agrees with the number claimed in the applicant documentation.

Evaluation Calculation Method

The evaluated savings for this site were calculated using the state-wide 2017 Steam Trap calculator.

Spot temperature measurements were taken, and loggers monitored surface temperature data to confirm the inlet steam pressure using the saturated steam properties which proved the system operates at 5psi. Ultrasonic decibel readings were taken before and after each trap, as well as in proximity to each trap’s orifice, to determine whether the trap appears to function. Traps that are failed open typically have a decibel reading at the orifice that is higher than the decibel reading before or after the trap. One of the traps tested exhibited that characteristic, so this trap is considered to have failed at some point before the evaluator inspected the trap. Another trap was clearly leaking water and not functioning properly during operation. All other traps were found to be functioning properly. The following table shows the Ultrasonic readings taken at the following steam traps:

Table 5-16. List of Steam Traps with Temperature and Ultrasonic Readings with Metered Hours

Sl. No	Trap Tag #	Evaluator Inlet Pressure (psi_g)	Logged TMY3 Normalized Evaluated Hours (hr)	Temperature (°F)			Ultrasonic (dB)			[Max(In,Out) - Orifice]	Trap Functional from Ultrasonic
				Inlet temp (°F)	Outlet Temp (°F)	Orifice Temp (°F)	Inlet (dB)	Outlet (dB)	Orifice (dB)		
1	181856	5	2,542	187	183	213	23	20	15	8	YES
2	181847	5	2,220	221	140	170	10	8	5	5	YES
3	215508	5	3,116	211	128	192	10	15	16	-1	YES
4	215401	5	0[11]	213	152	210	41	38	33	8	YES
5	203543	5	798	218	146	174	12	16	10	6	YES
6	203460	5	N/A	Water Leak						N/A	N/V
7	200098	5	2,536	192	205	213	15	16	15	1	YES
8	184604	5	N/A[12]	111	131	153	11	7	7	4	YES
9	184799	5	5,184	Not in Operation[13]						N/A	N/V
10	184797	5	0[14]	223	210	220	13	13	9	4	YES
11	184789	5	1,404	175	110	168	18	7	4	14	YES
12	184601	5	3,273	216	210	220	36	34	26	10	YES
13	184607	5	2,542	Not in Operation[3]						N/A	N/V

The evaluators logged a sample (11) of the total number of traps (50) and classified the traps into subgroups based on pipe size and steam trap type. The loggers were installed to capture the maximum number of steam traps that were classified based on the sample groups. The thermocouple loggers were not able to confirm if traps are energized until May since the school was affected by the current health emergency as stated by the site contact. The school setback the heating system on March 31st, 2020, a week after students left school due to the current health emergency. Annual hours are therefore calculated from the number of hours during the normal operating period with students occupying the school (Feb 20th – March 31st) and normalizing metered data to TMY3 weather data per outside air temperature of the energized period from NOAA hourly weather data.

Operation hour results from logger data are extrapolated to the groups based on the sample group the logger represents. Metered and normalized annual hours from loggers are averaged together to have an average annual operating schedule for the sample group. Each group is then assigned the specific sample group annual operating hour schedule. All sample subgroups were metered so each sample subgroup has a metered average from within the sampled subgroup. The tracking savings assumed 1,700 annual hours of operation, and the evaluation found the average of all metered steam traps to be 2,125 annual hours of operation.

The evaluation team found two dysfunctional steam traps. One was leaking water and the other failed the ultrasonic test. Both traps were within the sample subgroup #3. These represent 4% (2 of 50) repaired steam traps within the sample evaluated by the site engineer. The failed steam traps do not meet the criteria to modify savings based on guidelines for short measure life technologies.[15] Table

11 Logger data shows variable operation with reduction to 0 with TMY3 weather normalized annual hours.
12 Logger was not found upon meter retrieval.
13 These traps were found to not be energized during the site visit but logger data showed they did operate over the longer term
14 Logger data shows that the steam trap did not operate during logged period.
15 Factoring in Rates of Failure for Measures with A Short Life. May 18, 2018. ERS.

5-17 contains the reasoning for not including a failed steam trap discrepancy adjustment in the evaluated savings calculations.

Table 5-17. Steam Trap Failure Extrapolation Guidelines

Criterion	Pass/Fail	Reason	Notes
The measure being reviewed is at least 1 year and 15% into its EUL at the time of evaluation.	Pass	The measure was evaluated 1 year and 2 months after installation which equates to 19% of EUL.	15% of EUL is 10 months.
The measure includes at least a dozen discrete elements at the site in question that can be evaluated (e.g. steam traps),	Pass	There are 50 discrete steam traps in the facility that were repaired.	
The observed failure rate is at least 15% worse than would be expected based on a simple linear survival rate curve	Fail	The failure rate is estimated at 15% (2 of 13 sampled) which is not 15% worse than expected (25% = 10% Expected Failure Rate+15%)	Expected Failure Rate = 10% = $\frac{50\%\ expected\ failed}{6\ years\ EUL} * \left(1+\frac{2}{12}\right) years$

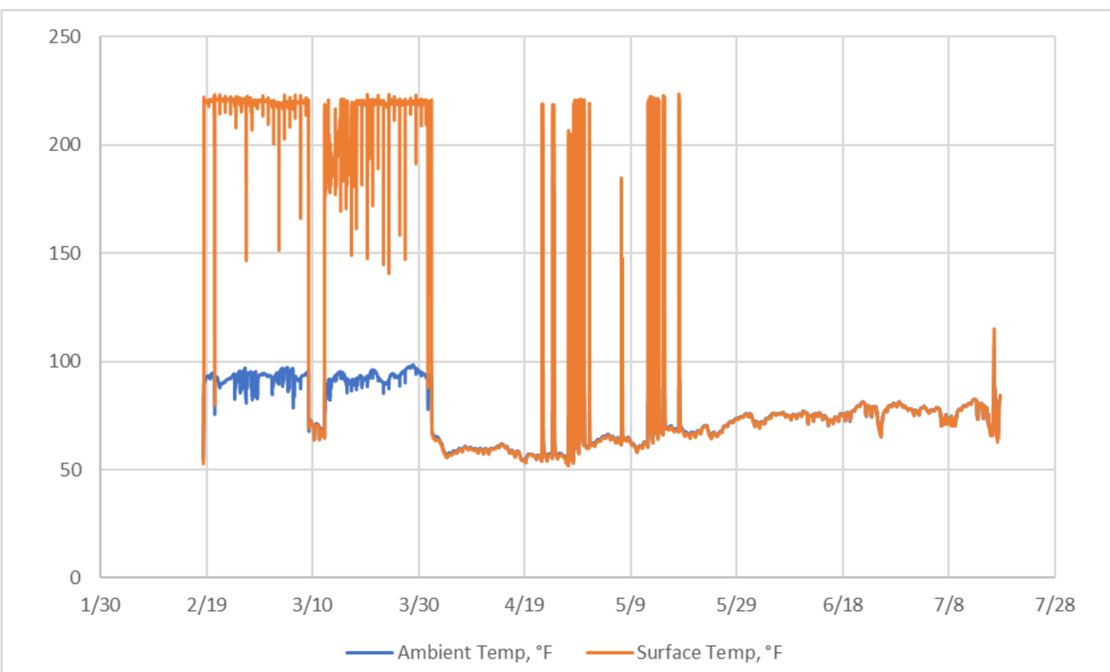


Figure 5-3. Steam trap operation for tag # 181847 in group 3

Figure 5-3 and Figure 5-4 shows the constant energized period during normal operation until the end of March when schools were shutdown. On/off behaviour for calls for heat during the shoulder months of April and May were for operation of the school without students. The operation of the school after March is not typical and the site contact did not provide much explanation for the reasoning of variability and usage from end of April through May. Data after March is therefore omitted since students are not in school and usage is abnormal.

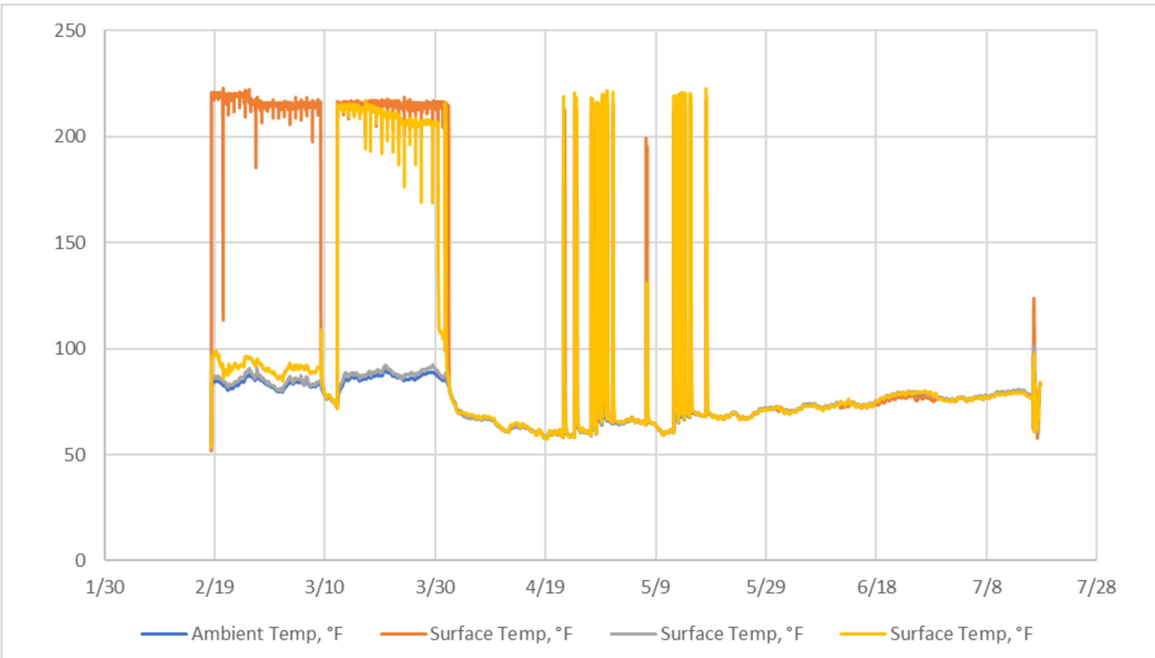


Figure 5-4. Steam trap operation for tag #184796, 184797, & 184798 in group 2

The site engineer also tested all 3 operating boilers. An estimation of boiler efficiency that is used in the steam trap calculator is an average of all 3 tests as shown in Table 5-18. Boiler test #3 represents the main boiler and boiler test #2 is the lag of the system. Boiler test #1 represents the backup system. The average of the 3 provides an accurate assessment for the heating season.

Table 5-18. Boiler Combustion Efficiency Tests

Test #	Efficiency
1	86.8%
2	86.7%
3	88.3%
Avg	**87.3%**

2.3.3 Gas Billing Analysis

The evaluators analysed the site's billing data for a period of 22 months prior to the installation and 10 months post installation of the project. The natural gas consumption (in therms) obtained for this site from the utility billing data was plotted against the heating degree days (HDD) as shown in Figure 5-5.

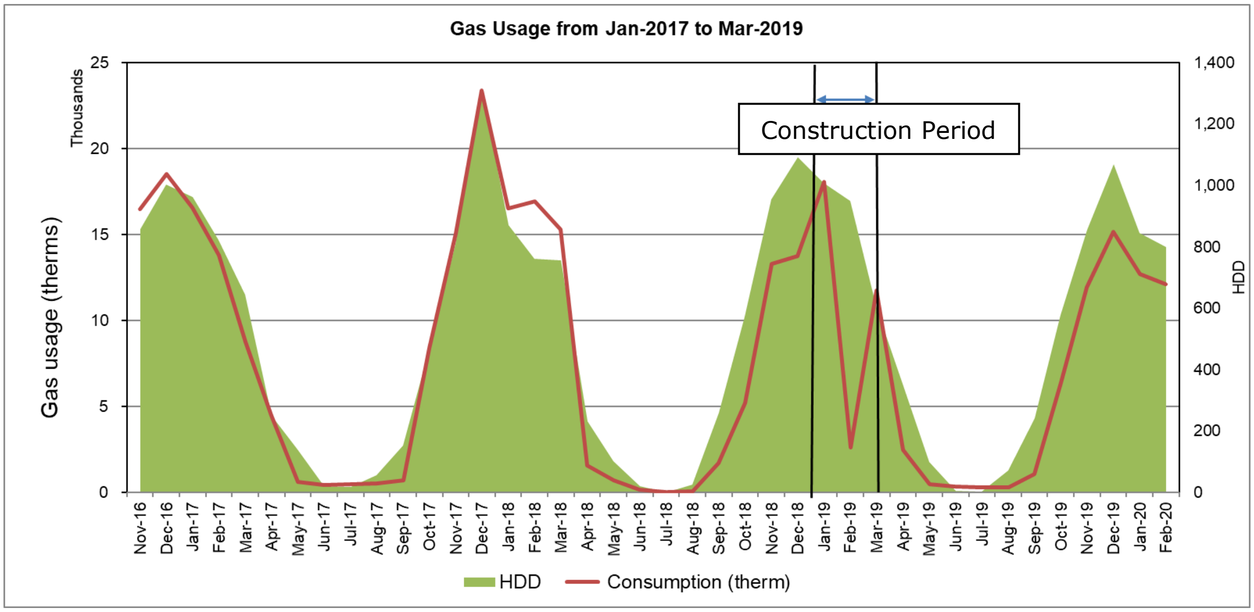


Figure 5-5. Therms consumption vs. HDD from utility billing data

The therms obtained from the billing data was normalized using actual and TMY3 weather data for both the pre and post case therms consumption data to ascertain if the billing data reflected the changes in the site's gas consumption profile resulting from the implementation of the project. As shown in Figure 5-6, the billing data shows a significant reduction in gas consumption in the post case following the implementation of the project. The billing analysis indicates a reduced gas usage of 26,436 therms after normalizing the billing data to local weather with annual consumption for the last 12 months of billing data totalling 74,930 therms. The billing analysis savings value is 35% of consumption. Though this level of savings is higher than the final results of the metering/engineering analysis of 10,455 therms described above and listed below, it is thought that for steam traps the engineering analysis is more reliable as long as the savings are a reasonable percentage of total consumption, which it is. The evaluated savings percentage of total consumption is 14%.

Normally, it is unlikely that 50 steam traps would show a considerable change in gas consumption in a large school, however, tracking savings were estimated savings at 14.0% of gas consumption. Given that space heating is major end-use and 50 of the 170 (29%) steam traps were repaired, this high percentage of savings is reasonable and is in the same order of magnitude as the billing analysis.

Below in Figure 5-6, regression equations are shown for pre- and post-installation gas consumption when compared to HDD.

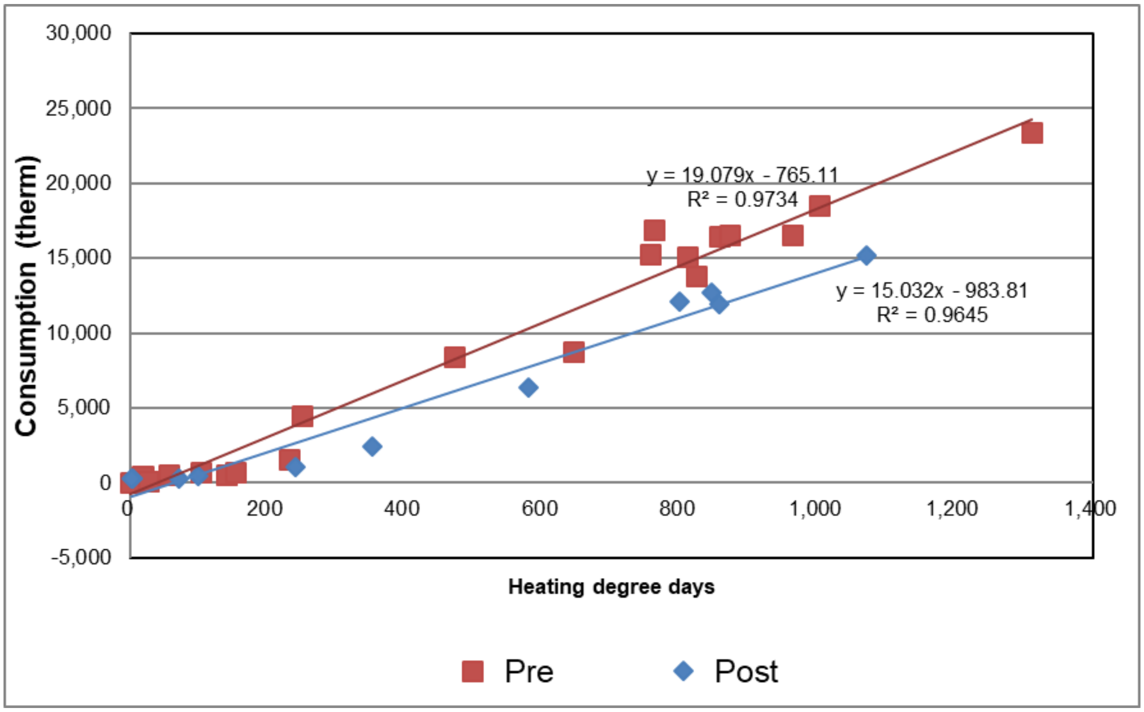


Figure 5-6. Pre- and post-installation correlation with degree days

Final Results

This section summarizes the evaluation results determined in the analysis above. Both the applicant and evaluation savings are based on the new state-wide 2017 Steam Traps calculator. The total evaluation results and realization rate are found below in Table 5-19.

Table 5-19. Evaluation Results Summary

PA Application ID	Measure Name	Annual Savings (therms)	
7919893	Steam Traps	Tracked	8,730
		Evaluated	10,455
		Realization Rate	119.9%

The evaluation observed 19.9% more savings than the tracking analysis predicted. Operating hours were higher for a significant amount of steam traps resulted in the largest discrepancy with boiler efficiency savings reduction the second largest discrepancy.

Table 3-1 below is a summary of key tracking and evaluated parameters.

Table 5-20. Summary of Key Parameters

	BASELINE	PROPOSED / INSTALLED

Parameter	Tracking Value(s)	Evaluation Value(s)	Tracking Value(s)	Evaluation Value(s)
Steam Pipe Pressure	4 psi	5 psi	4 psi	5 psi
Average Operating Hours	1,700	2,125	1,700	2,125
Boiler Combustion Efficiency	80%	87.3%	80%	87.3%

Explanation of Differences

This section describes the key drivers behind any difference in the application and evaluation estimates of therm savings. Table 5-21 provides a summary of the differences between tracking and evaluated values.

Table 5-21. Summary of Deviations

End-use	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
Steam Pipe Pressure	Operational	The operating pressure of all steam traps were increased from 4psi to 5psi	5.5%	Increase in savings due to higher operating pressure
Average Operating Hours	Operational	The average hours of operation for the repaired steam traps is different than the applicant estimation. The average hours increased by 1,697 hours.	24.3%	Increase in savings due to higher number of hours of operation
Boiler Combustion Efficiency	Operational	Boiler tests found the combustion efficiency is higher than the standard 80% default in the 2017 state-wide steam trap calculator	-10.0%	Decrease in savings due to higher combustion efficiency

Lifetime Savings

The replaced equipment is classified as a single baseline retrofit replacement. The evaluators 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 smaller than the tracking lifetime savings because the evaluated first year savings are smaller than the tracking first year savings. Table 5-22 provides a summary of key factors that influence the lifetime savings.

Table 5-22. Lifetime Savings Summary

Factor	Tracking	Application	Evaluator
Lifetime savings	52,381 therms	52,381 therms	62,730 therms
First year savings	8,730 therms	8,730 therms	10,455 therms
Measure lifetime	6 years	6 years	6 years
Baseline classification	Retrofit	Retrofit	Retrofit Single

The evaluation uses the same 6-year measure life as the applicant.

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

Ancillary impacts

There are no ancillary impacts from this retrofit measure.

2018RIG26

Report Date: 20 October 2020

Program Administrator	National Grid
Application ID(s)	8575048
Project Type	Add-on Retrofit
Program Year	2018
Evaluation Firm	DMI
Evaluation Engineer	Bennett Rose, DMI
Senior Engineer	Mickey Bush, DMI

Evaluated Site Summary and Results

This retrofit project consisted of a new energy management system (EMS) at a ~30,000 sq. ft. elementary school. The new EMS controls the space heating hot water boiler and three hot water circulating pumps. The EMS controls the hot water system by enabling the firing of the boilers and controlling a mixing valve to maintain the hot water setpoint which is commanded by the EMS. The boiler has its own controller which is not controlled by the EMS which cycles the boiler as required to maintain 180°F primary hot water. The hot water system serves baseboards and unit ventilators throughout the building. The new EMS does not control space thermostats, baseboards, or unit ventilator operation. The project was submitted using the Prescriptive EMS application and the incentive was paid based on the prescriptive dollar per control point value, but savings were claimed as a custom measure using the custom express savings tool. The gas savings associated with this project is 1,349 therms. The gas incentive was $1,800 based on $300/point and 6 control points. The electric incentive was $2,100 based on $300/point and 7 control points. The total incentive of $3,900 was ~23% of the total project cost shown in the invoice ($17,000).

Gas savings associated with the new EMS were claimed based on the following boiler control strategies:

- 7-day schedule
  - Applicant: The applicant documentation indicates that in the proposed case the hot water system is enabled from 7am to 6pm on weekdays from October through May implying that the hot water system is enabled continuously during the heating season in the baseline.
  - Evaluation Finding: The hot water system is in occupied mode from 6am to 6pm on weekdays. The system is unoccupied mode on weekday nights, all day on weekends and during school breaks and holidays. The hot water system will be enabled in both occupied and unoccupied mode based on the outside air temperature. In occupied model the system is enabled when the outside air temperature is below 61°F and in unoccupied mode the system is enabled when the outside air temperature is below 60°F. Therefore, although the system is setup for occupied/unoccupied operation there is very little actual difference between the two operating modes.
- Optimal Start/Stop
  - Applicant: The custom express tool indicates that optimal start/stop is included in the EMS control sequences.
  - Evaluation Finding: The hot water system does not include an optimal start/stop sequence.
- DDC Temp Control
  - Applicant: The custom EMS tool indicates that the hot water system will have DDC temperature control
  - Evaluation Finding: The new EMS determines the hot water supply setpoint and controls the mixing valve to maintain the hot water setpoint. DDC temperature

control has been implemented, however it is unclear how DDC temperature control of the hot water system will provide energy savings.

- OA HW Reset
  - Applicant: The applicant documentation indicates that the hot water temperature setpoint will reset based on outside air temperature in the proposed case implying that the hot water temperature setpoint is fixed in the baseline.
  - Evaluation Finding: There is an issue with the control of the mixing valve used to control HW supply temperature and hot water temperature reset is not being implemented as intended.

The evaluation results are presented in Table 5-9.

Table 5-23. Evaluation Results Summary

PA Application ID	Measure Name		Annual Savings (therms)
8575048	New EMS	Tracked	1,349
		Evaluated	0
		Realization Rate	-0%

Explanation of Deviations from Tracking

The evaluated savings are 100% less than the applicant-reported savings. There is a gas penalty associated with the project based on the bill data analysis for the site. However, due to lack of pre-existing system information, it cannot be confirmed definitively that the penalty is a result of implementing the proposed case control sequences as opposed to other factors so the evaluated savings are 0 for the project.

Pre-existing control sequences will determine the energy savings associated with implementing simple control sequences such as the ones considered for this project and there is only anecdotal information available about the pre-existing system operation. The prescriptive EMS program does not require documentation to inform baseline system assumptions for the energy savings calculations. This evaluation finding indicates that the EMS custom express tool does not adequately consider pre-existing system control sequences to allow for accurate energy saving calculations.

The evaluator found that the sequences claimed for savings are not being implemented as expected. Optimal start/stop is not being implemented, HW reset is not working properly, and there is very little difference between occupied and unoccupied operation although there is an occupancy schedule.

Recommendations for Program Designers & Implementers

The evaluator recommends documenting pre-retrofit conditions for any controls upgrades projects.

It is not possible to definitively confirm why the project does not result in energy savings due to lack of information about pre-existing system operation. Quantifying energy savings for controls measures requires a more detailed understanding of baseline system operation than the EMS custom express tool allows for.

When considering the implementation of basic control sequences such as scheduling and basic temperature control, the opportunity for energy savings relies heavily on pre-existing system operation. The pre-existing case for this project was a combination of automatic pneumatic controls and manual controls. It is not uncommon for controls projects to implement best practices that may actually result in increased energy use. For example, implementing a scheduled occupancy control sequence would not save energy if the boiler was manually shut down during unoccupied hours in the baseline and cycle on a call for heating during unoccupied hours in the proposed case.

Customer Alert

The evaluator found that there is an issue with the mixing valve leaking by. The impact of this issue is that the EMS is unable to effectively control the hot water supply temperature.

The evaluator also found that the occupied and unoccupied outside air enable temperatures are nearly the same which means that the anticipated savings associated with reducing unoccupied operating hours are not being realized. This is an adjustable parameter in the EMS.

Evaluated Measures

The project consists of the installation of a new EMS system to replace pneumatic control of the heating hot water system at an elementary school. The applicant savings claim that the new EMS includes a 7-day schedule, optimal start, hot water reset, and DDC temperature control of the hot water system.

Application Information and Applicant Savings Methodology

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

Applicant Description of Baseline

The pre-installation site inspection form states that the baseline system is an outdated pneumatic control system but provides no specific details on how equipment was controlled.

The applicant documentation describes the pre-retrofit sequence of operation for the 7-day schedule measure. In the pre-retrofit case the boiler was enabled continuously from September through June and off from July through August. The pre-inspection form for this project simply states that the existing HVAC equipment is controlled by a pneumatic control system.

Table 2-24. Applicant baseline key parameters

		BASELINE		
Measure	**Parameter**	**Value(s)**	**Source of Parameter Value**	**Note**
New EMS	Boiler Plant Capacity	2,700 MBH	Custom Express Tool	
	Boiler Plant EFLH	555 Hours	Custom Express Tool	
	Control system	Pneumatic	Pre-Inspection Form	

Applicant Description of Installed Equipment and Operation

This section describes the proposed condition assumed in the application analysis. It only discusses the assumptions made in the original analysis, not any information gained through this evaluation.

Table 2-25: Application proposed key parameters

		PROPOSED		
Measure	**Parameter**	**Value(s)**	**Source of Parameter Value**	**Note**
New EMS	7-Day Schedule	Yes	Custom Express Tool	
	Optimal Stop/Start	Yes	Custom Express Tool	
	DDC Temperature Control	Yes	Custom Express Tool	
	OA HW Reset	Yes	Custom Express Tool	
	Control system	DDC	Minimum Requirement Document	

Applicant Energy Savings Algorithm

Applicant savings are calculated using a custom express savings tool for EMS installations. The custom express tool calculates savings for each of the new control sequences based on an estimated percent reduction in boiler gas use.

The calculation of annual baseline boiler gas use is shown below.

Boiler Annual Gas Input: 2,700 MBH full load input x 555 equivalent full load hours = 1,498,500 MBTU (14,985 therms).

Where 555 EFLH is a direct input in the applicant's spreadsheet.

The savings for each control sequence are calculated based on a percent reduction in baseline boiler gas use. The savings factors are hard coded values in the custom express tool.

Savings = Boiler Baseline Annual Input (MBtu) x Savings factor / (100 MBH / Therm)

The savings factors used for this formula are presented in the table below. The basis for these values is not explained in the tool itself.

Table 2-26. Summary of Savings Factors

Measure	Savings Factor	Applicant Therms Saved
Equipment Run Time (7 day schedule & Optimal Stop/Start)	1.5%	225
DDC Temp	2.5%	375
OA HW Temp Reset	5%	749
Total	9%	1,349

Note that equipment run time is a binary function in the custom express tool. Equipment runtime is a savings factor because the inputs for 7-day schedule and optimal start are selected and both inputs are associated with equipment runtime savings in the custom express tool. If only one or the other (7-day schedule or optimal start) was selected as opposed to both being selected the savings impact would be unchanged.

Evaluation Assessment of Applicant Methodology

The annual gas usage for 2016 and 2017, which was the pre-retrofit period, was 16,550 therms and 15,692 therms respectively. The applicant's estimated boiler full usage is 7% less than actual annual pre-existing case gas usage based on bill data. This is reasonable because the hot water system is the primary gas user at the site however it is unclear if the actual site gas usage was considered by the applicant when calculating the equivalent full load hours.

With the exception of optimal start which was not included in the scope of work for the project, the applicant entered inputs to the custom express tool that reflected the proposed control sequences. The custom express tool generally is a one-size-fits-all tool used for quantifying the savings associated with implementing basic control sequences with a new EMS. The custom express tool does not require the applicant to document existing system control sequences beyond estimating the equivalent full load hours. The energy savings for retrofit control measures rely entirely on existing system operation. The lack of documentation and calculation inputs for the existing system operation in the custom express tool results in unreliable savings estimates.

On-Site Inspection and Metering

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

Summary of On-site Findings

On February 19, 2020 the evaluator met with the controls contractor that installed the new EMS at the site. The evaluator reviewed the project scope and the EMS interface with the controls contractor and conducted a walkthrough of the site. The onsite findings are as follows:

- The EMS includes an occupancy schedule. The EMS will lockout the boiler based on outside air temperature and the enable temperature is 61°F during occupied hours, and 60°F during unoccupied hours.
- New BacNet controllers were installed. The EMS commands the hot water supply temperature setpoint and controls the water temperature by modulating the mixing valve. The boiler has

its own pre-existing controller that commands the boiler to cycle based on its internal primary hot water setpoint of 180°F. The EMS sends the enable command to the boiler's controller.

- The evaluator found that the system does not have optimal start. Optimal start was not part of the controls contractor's scope of work for the project.
- There is an issue with the control of the mixing valve that prevents the hot water temperature reset sequence from working as intended. This was brought to the evaluator's attention by the controls contractor during the site visit and trends confirm that the hot water setpoint is not being maintained.

Table 2-27. Measure Verification

Measure Name	Verification Method	Verification Result
New EMS	Review trends to confirm measure implementation. Review bill data to determine measure savings.	The trend data shows that a 7-day schedule is included with the new EMS, optimal start was not implemented, the EMS commands the hot water supply temperature setpoint, but a faulty mixing valve results in the setpoint not being maintained which prevents the hot water reset sequence from being implemented effectively.

Measured and Logged Data

These tables below summarize the data used to evaluate the savings for site 2018RIG26.

Table 2-28. Evaluation data collection – installed equipment

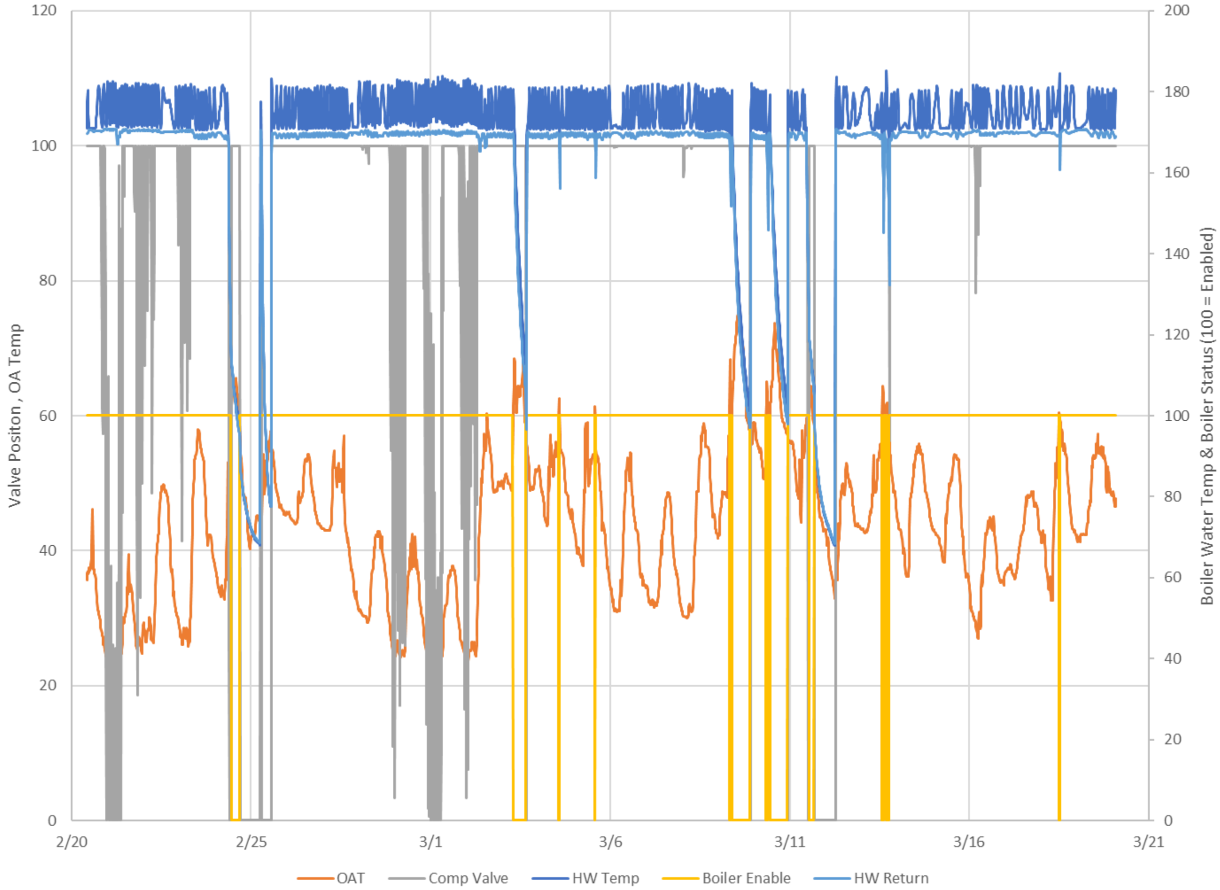
Parameter	M&V Equipment Brand and Model	Metering Start/Stop Dates	Metering Interval
None			

Table 2-29 Evaluation data collection – data received

Source	Parameter	Interval	Duration
Facility EMS	Hot water supply and return temperature Outside air temperature Boiler enable status Pump statuses Pump speeds Mixing valve position	15 Minute	One month (February 20,2020 – March 20, 2020)
Utility Meter Reads	Gas Bill Data	1 month	4 years (January 2016 – December 2019)

The figure below presents the raw trend data provided for the hot water system by the controls contractor that installed the new EMS.

Figure 2-1. Raw Trend Data



A summary of the trend data is below.

The OAT, hot water supply temperature and boiler status enable trends show that the system is enabled when the OAT is less than 60°F and disabled when OAT is greater than 60°F.

The data also shows that the hot water temperature is not modulating with OAT which indicates that hot water reset is not being implemented effectively, which confirms the information relayed by the controls contractor that the mixing valve is not functioning properly. The mixing valve command is 100% during a majority of the trend periods; where 100% is intended to bypass the boiler and only use return water. The valve is being commanded to bypass the boilers because the ~180°F hot water temperature is higher than the setpoint. When the outside air temperature gets cold enough the hot water temperature setpoint approaches the actual hot water temperature and the valve command drops below 100% return water only. The fact that the valve position command does not impact actual hot water supply (combined supply and return) temperature indicates that the command does not match the actual valve position and there is an issue with the mixing valve.

The hot water supply temperature is indicative of a cycling on/off boiler with no capacity modulation. The boiler cycle on as required to maintain the primary hot water temperature within the deadband defined by its local controller. It also shows that the operation of the mixing valve does not impact the hot water supply temperature as intended.

Evaluation Methods and Findings

This section describes the evaluator methods and findings.

Evaluation Description of Baseline

The baseline system for this project is pre-existing pneumatic controls. The evaluator was able to confirm that the pre-existing control system was pneumatic controls during the site visit because the pre-existing controls were partially abandoned in place. The measure is classified as an add-on retrofit project and the evaluator agrees with this classification.

During the site visit that was conducted with the controls contractor for the project, the evaluator was informed that prior to the installation of the EMS the boiler plant was enabled continuously from September through June. The boiler has its own controller that commands the boiler to cycle on as required to make 180°F primary hot water. It is assumed that the hot water supply temperature was always 180°F in the baseline. Based on discussions with the controls contractor, there were a variety of manual overrides and work arounds implemented by the school district’s boiler technicians to circumvent the pneumatic control system and minimize comfort complaints.

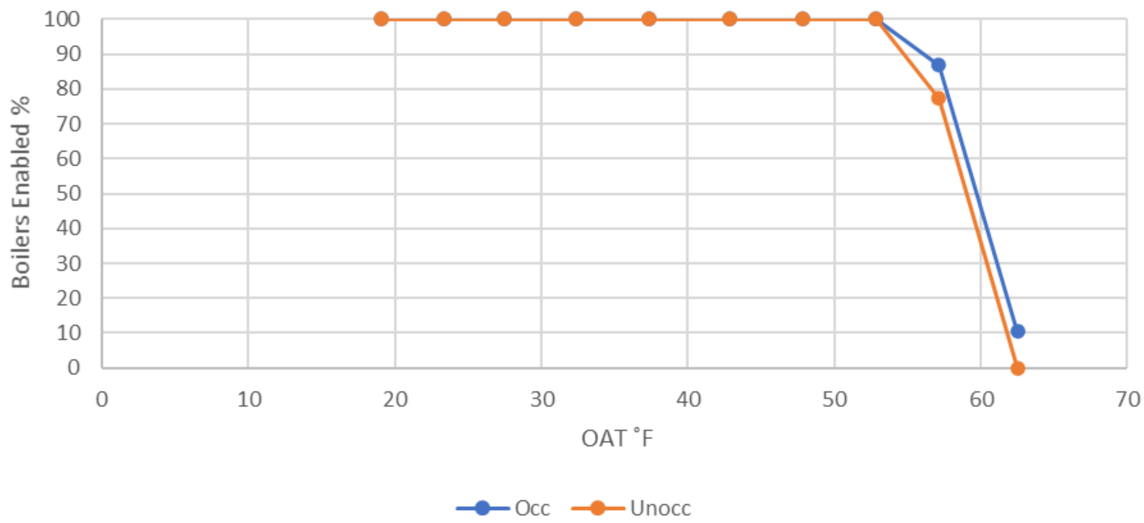
Evaluation Calculation Method

7-Day Schedule

The evaluator was able to confirm the installed EMS occupancy schedule during the site visit. The hot water system is in occupied mode from 6am to 6pm on weekdays. The system is unoccupied mode on weekday nights, all day on weekends and during school breaks and holidays. The hot water system will be enabled in both occupied and unoccupied mode based on the outside air temperature. In occupied model the system is enabled when the outside air temperature is below 61°F and in unoccupied mode the system is enabled when the outside air temperature is below 60°F. Because the hot water system is enabled at nearly the same outside air temperature during occupied and unoccupied hours, the 7-day schedule does not have any significant impact on hot water system operation.

To demonstrate the impact of the 7-day schedule control sequence on boiler plant operation, the figure below shows the trended percentage of time that the boiler is enabled when the outside air temperature is less than 61°F as a function of time of day for each day of the week over the course of the trend period. Note that trends were not provided for actual boiler status.

Figure 2-2. Boiler Plant Enabled vs OAT (Occupied/Unoccupied Comparison)



The lack of correlation between boiler runtime and time of day/day of week shows that as implemented the 7-day schedule has little to no effect on the operation of the boiler plant. The only impact compared to the pre-existing case is that the system is automatically enabled at 60°F OAT rather than manually enabled/disabled.

Optimal Start

It was confirmed during the site visit that optimal start is not part of the installed control sequence.

DDC Temperature control

It is unclear what is meant by DDC temperature controls as a measure. The evaluator confirmed on the site visit that the new EMS controls the hot water supply temperature setpoint by modulating the mixing valve position and cycling the boiler.

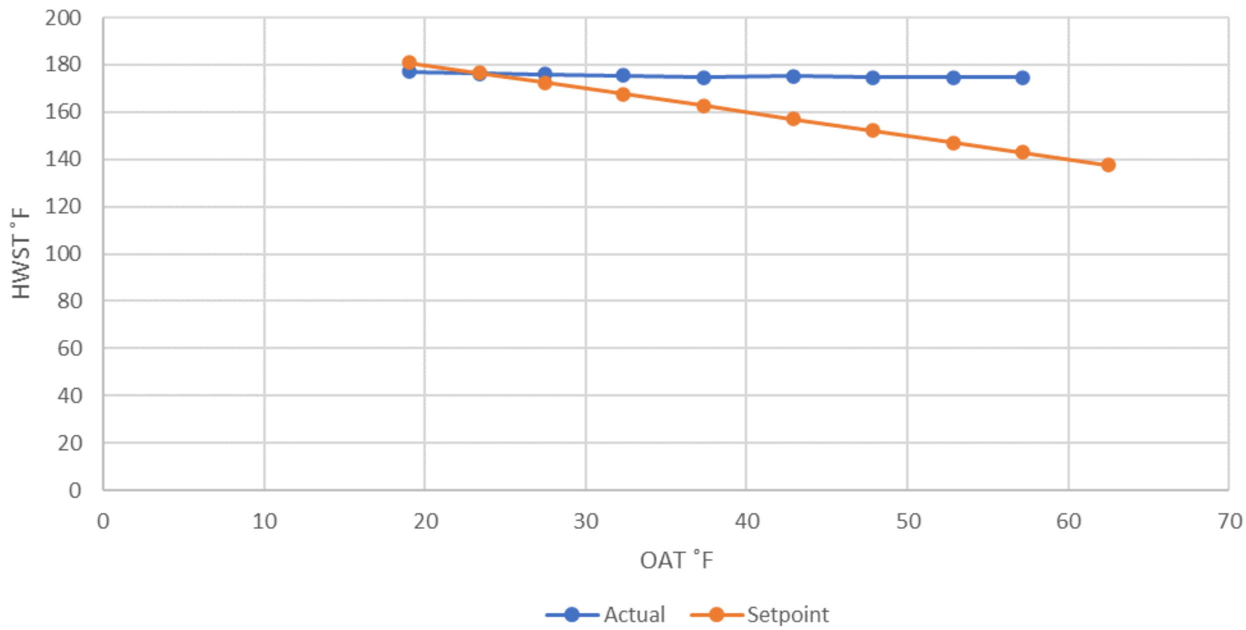
The boiler is controlled with its own controllers from the pre-existing case and cycle on and off as required to make 180°F primary water when the hot water system is enabled. There is a three-way valve that mixes hot water leaving the boiler with return water to achieve the desired supply temperature setpoint. The valve was pneumatically controlled and this project added a controller so that the EMS could send a signal to the valve pneumatic control. According to the controls contractor the valve needs to be repaired. Based on a spot observation of the EMS the valve was reported to be closed (full recirculation mode), but the actual supply temperature was 171˚F and the setpoint was 145°F, which indicates that the valve was leaking by.

It is not clear that this measure would provide any savings even with a properly operating mixing valve because the pre-existing setpoints are not known.

OA HW Reset

Trends confirm that hot water supply temperature does vary slightly with outside air temperature; the average hot water supply temperature only varies by about 4°F over a 50°F range of outside air temperatures indicating that the reset sequence is not being implemented as expected. The figure below shows the average hot water supply temperature and hot water supply setpoint as a function of outside air temperature.

Figure 2-3. Average HWST˚F vs OAT˚F



A screenshot of the EMS provided by the controls contractor demonstrated that the HWST setpoint is being reset based on outside air temperature. However, the faulty mixing valve described above is preventing the hot water reset schedule from being implemented as intended. The boiler provides ~180°F primary water which shows the faulty mixing valve is always leaking by into the circulation loop.

Note that the boiler at the site is not a condensing boiler so the source of savings associated with lowering the hot water supply temperature would be related to system heat losses, not boiler efficiency. It is not clear based on the custom express EMS tool if the hot water reset savings calculation assumes that the site has condensing boilers or not.

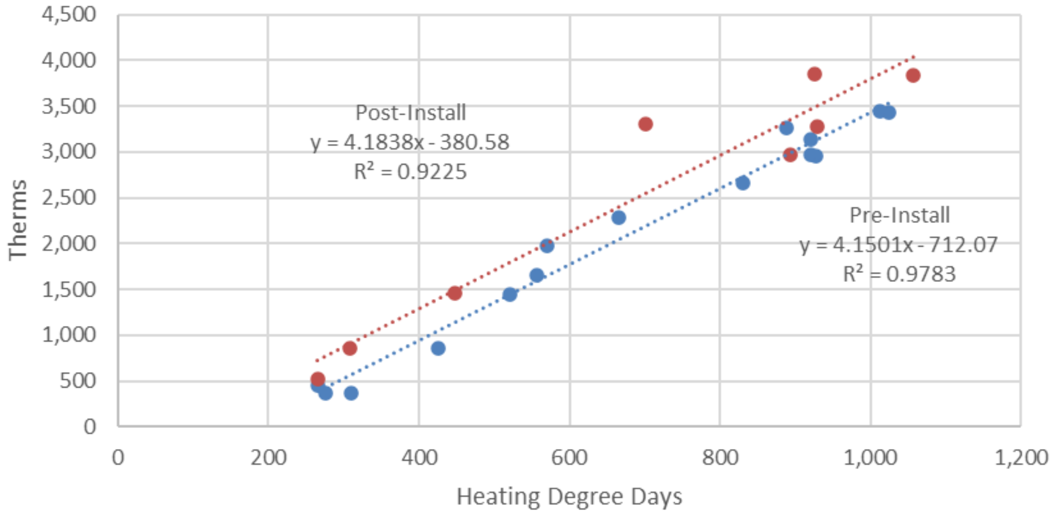
When reviewing the EMS with the controls contractor it appeared that the outside air temperature sensor reading was not accurate and may be impacted by sunlight. The sensor was reading 60°F, but the actual outside air temperature was ~40°F. The boiler is enabled based on the outside air temperature and the hot water supply temperature is reset based on the outside air temperature, so boiler operation is impacted by the sensor issue.

2.3.3 Gas Billing Analysis

Monthly gas bill data was provided for this site. Data was provided from January 2016 through December 2019. The measure was installed in 2018. For the bill data analysis, the years 2016 and 2017 are used to document pre-installation gas usage, and 2019 gas data is used to document post-installation gas usage. It is assumed that the EMS was installed in 2018 based on the December 2018 date on the controls contractor invoice included in the tracking documents.

Hourly weather station data from TF Green Airport in Providence was used to calculate the actual heating degree days (HDD) associated with each gas bill. Figure 2-4 below shows the pre-installation and post-installation relationship between monthly gas usage and heating degree days excluding months with less than 200 HDD.

Figure 2-4. Actual Pre-Install vs Post-Install Gas Usage



The bill data shows that the boiler plant uses more gas per heating degree day with the new EMS.

The evaluated savings for this project are calculated using TMY3 weather data from TF Green Airport to calculate weather normalized gas savings. Months with less than 200 HDD are not considered in the evaluated savings. Note that the annual heating degree days calculated using TMY3 weather data (5,976 HDD) are greater than the heating degree days in the years of gas bill data used to calculate the relationship between heating degree days and gas usage (2016: 5,304 HDD, 2017: 5,296 HDD, 2018: 5,560 HDD, 2019: 5,678). Table 2-6 summarizes the weather normalized gas savings calculated for the project based on pre- and post-installation gas bill data.

Table 2-30. Evaluation Monthly Gas Savings Analysis Using TMY Data

Month	HDD	Pre-Install Gas Use Therms	Post-Install Gas Use Therms	Gas Savings Therms
1	1,112	3,902	4,271	-369
2	917	3,093	3,455	-362
3	811	2,652	3,011	-359
4	535	1,506	1,856	-350
5	260	367	707	-340
6	85			0
7	18			0
8	27			0
9	107			0
10	379	862	1,206	-344
11	675	2,087	2,442	-354
12	1,051	3,649	4,016	-367
Total	**5,976**	**18,120**	**20,965**	**-2,845**

Final Results

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

Given the fact that trend data shows that for the most part the EMS strategies were not working as installed and the bills showed an increase in savings, it was concluded that the project did not save natural gas.

Table 3-31. Evaluation Results Summary

PA Application ID	Measure Name		Annual Savings (therms)
8575048	New EMS	Tracked	1,349
		Evaluated	0
		Realization Rate	-0%

Table 3-2 is a summary to the key saving parameters.

Table 3-32. Summary of Key Parameters

Parameter	BASELINE Tracking Value(s)	BASELINE Evaluation Value(s)	PROPOSED / INSTALLED Tracking Value(s)	PROPOSED / INSTALLED Evaluation Value(s)
7-Day Schedule	Not implemented	unclear	Implemented	Implemented but has minimal impact on HW system operation
Optimal Start	Not Implemented	Unclear	Implemented	Not Implemented

Temperature Control	Pneumatic	Pneumatic	DDC	DDC, but not clear how savings result
HWST Control	Constant	Unclear	OA Reset	OA Reset not operating as intended

Explanation of Differences

This section describes the key drivers behind the differences between the tracking and evaluated gas savings. The purpose of this table is to describe how changes to the key parameters influenced the final project savings. Table 5-21 provides a summary of the differences between tracking and evaluated values.

Table 3-33. Summary of Deviations

End-use	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
HVAC	Operational	Equipment Run Time	-16.7%	Decreased Savings – Optimal start not implemented. 7-day schedule was implemented, but occupied and unoccupied OAT enable temps are almost the same so there is no runtime reduction.
HVAC	Operational	DDC Temperature control	-27.8%	Decreased Savings – Faulty mixing valve is resulting in hot water supply temperature greater than setpoint. Unclear what the source of savings would be for DDC temperature control anyways.
HVAC	Operational	OA HW Temp Reset	-55.5%	Decreased Savings - HW reset is not being implemented as expected

The evaluation found that the control sequence inputs that were used to calculate savings for this project were either not implemented or implemented in a way that is not expected to result in energy savings.

The EMS does have a 7-day schedule with occupied and unoccupied OAT enable temperatures for the hot water system, however the occupied and unoccupied enable temperatures are nearly identical. Optimal start was not implemented or included in the controls contractors' scope of work.

The billing analysis corroborated the finding of no savings.

Lifetime Savings

The evaluated lifetime savings are smaller than the tracking lifetime savings because the evaluated first year savings are smaller than the tracking first year savings. Table 5-22 provides a summary of key factors that influence the lifetime savings.

Table 3-34. Measure 5891377 - Lifetime Savings Summary

Factor	Tracking	Application	Evaluator
Lifetime savings	13,490 therms	13,490 therms	0 therms
First year savings	1,349 therms	1,349 therms	0 therms

Factor	Tracking	Application	Evaluator
Measure lifetime	10 years	10 years (project BCR)	10 years (MA TRM)
Baseline classification	N/A	N/A	Add-on single

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

Ancillary impacts

Electric savings were calculated under a different application.

2018RIG27

Report Date: 20 October 2020

Program Administrator	National Grid	
Application ID(s)	8575046	
Project Type	Add-on Retrofit	
Program Year	2018	
Evaluation Firm	DMI	
Evaluation Engineer	Bennett Rose, DMI	
Senior Engineer	Mickey Bush, DMI	

Evaluated Site Summary and Results

This retrofit project consisted of a new energy management system (EMS) at a ~52,000 sq. ft. elementary school. The new EMS controls seven space heating hot water boilers, four hot water circulating pumps, and a rooftop unit with a gas-fired heating section, which serves a multi-purpose or gymnasium type room. The hot water system primarily serves unit ventilators in the classrooms along with some fan coil units and baseboard heaters. The project was submitted as a custom express EMS application and savings were claimed using the custom express savings tool. The gas savings associated with this project is 1,349 therms. The gas incentive, using the values from the prescriptive offering for EMS was $3,600 based on $300/point and 12 control points. The electric incentive was $7,500 based on $300/point and 25 control points. The total incentive of $11,500 was ~63% of the total project cost shown in the invoice ($18,250).

Gas savings associated with the new EMS were claimed based on the following boiler control strategies:

- 7-day schedule
  - Applicant: The applicant documentation indicates that in the proposed case the hot water system is enabled from 7am to 6pm on weekdays from October through May implying that the hot water system is enabled continuously during the heating season in the baseline.
  - Evaluation Finding: The hot water system is in occupied mode from 6am to 6pm on weekdays. The system is unoccupied mode on weekday nights, all day on weekends and during school breaks and holidays. The hot water system will be enabled in both occupied and unoccupied mode based on the outside air temperature. In occupied model the system is enabled when the outside air temperature is below 60°F and in unoccupied mode the system is enabled when the outside air temperature is below 40°F.
- Optimal Start/Stop
  - Applicant: The custom express tool indicates that optimal start/stop is included in the EMS control sequences.
  - Evaluation Finding: The hot water system does not include an optimal start/stop sequence.
- DDC Temp Control
  - Applicant: The custom EMS tool indicates that the hot water system will have DDC temperature control
  - Evaluation Finding: The new EMS determines the hot water supply setpoint however the boilers are unable to maintain the hot water setpoint.
- OA HW Reset
  - Applicant: The applicant documentation indicates that the hot water temperature setpoint will reset based on outside air temperature in the proposed case implying that the hot water temperature setpoint is fixed in the baseline.

  - Evaluation Finding: The EMS does control the hot water setpoint which is reset based on outside air temperature, however the boilers are unable to maintain the hot water temperature setpoint.

- Demand Control Ventilation
  - Applicant: Install a space CO2 sensor and control the RTU OA damper to maintain space CO2 concentration setpoint.
  - Evaluation Finding: After the site visit the contractor shared the proposed scope of work for the project with the evaluator and the scope did not include demand control ventilation. The site observations of the EMS confirmed that the new controls system integrates with the existing RTU control panel, but primarily provides read only observation of RTU operation. The only control provided by the new EMS is an enable command to the RTU controller based on time of day. The control of the outside air damper was not modified, a CO2 sensor is not installed and the pre-existing thermostat remains in use.

The evaluation results are presented in Table 5-9.

Table 5-35. Evaluation Results Summary

PA Application ID	Measure Name		Annual Savings (therms)
8575048	New EMS	Tracked	8,011
		Evaluated	0
		Realization Rate	-0%

Explanation of Deviations from Tracking

The evaluated savings are 100% less than the applicant-reported savings. There is a gas penalty associated with the project based on the bill data analysis for the site. However, due to lack of pre-existing system information, it cannot be confirmed definitively that the penalty is a result of implementing the proposed case control sequences as opposed to other factors so the evaluated savings are 0 for the project.

Pre-existing control sequences will determine the energy savings associated with implementing simple control sequences such as the ones considered for this project and there is only anecdotal information available about the pre-existing system operation. The prescriptive EMS program does not require documentation to inform baseline system assumptions for the energy savings calculations. This evaluation finding indicates that the EMS custom express tool does not adequately consider pre-existing system control sequences to allow for accurate energy saving calculations.

The evaluator found that the sequences claimed for savings are not being implemented as expected. Optimal start/stop and demand control ventilation are not being implemented. DDC control of the hot water setpoint and hot water reset are being implemented, however the boilers are unable to maintain the hot water setpoint so these control sequences are not effective. The system has an occupancy schedule however it is unclear if this control sequence results in a reduction in run hours compared to pre-existing system operation.

Recommendations for Program Designers & Implementers

The evaluator recommends documenting pre-retrofit conditions for any controls upgrades projects.

It is not possible to definitively confirm why the project does not result in energy savings due to lack of information about pre-existing system operation. Quantifying energy savings for controls measures requires a more detailed understanding of baseline system operation than the EMS custom express tool allows for.

When considering the implementation of basic control sequences such as scheduling and basic temperature control, the opportunity for energy savings relies heavily on pre-existing system operation. The pre-existing case for this project was a combination of automatic pneumatic controls and manual controls. It is not uncommon for controls projects to implement best practices that may actually result in increased energy use. For example, implementing a scheduled occupancy control sequence would not save energy if the boiler was manually shut down during unoccupied hours in the baseline and cycle on a call for heating during unoccupied hours in the proposed case.

Customer Alert

The boilers are not maintaining the hot water setpoint. It is suspected that the issue is related to the underlying equipment and not the new EMS. It is expected that to resolve the issue the supply and return boiler headers need to be modified with control valves to prevent hot water flow through inactive boilers.

Evaluated Measures

The project consists of the installation of a new EMS system to replace pneumatic control of the heating hot water system and rooftop unit at an elementary school. The applicant savings claim that the new EMS includes a 7-day schedule, optimal start, hot water reset, and DDC temperature control of the hot water system and that demand control ventilation will be implemented for the RTU.

Application Information and Applicant Savings Methodology

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

Applicant Description of Baseline

The pre-installation site inspection form states that the baseline system is an outdated pneumatic control system.

The applicant documentation describes the pre-retrofit sequence of operation for the 7-day schedule measure. In the pre-retrofit case the boilers were enabled continuously from September through June and off from July through August. Table 2-1 summarizes the applicant's baseline assumptions.

Table 2-36. Applicant baseline key parameters

		BASELINE		
Measure	**Parameter**	**Value(s)**	**Source of Parameter Value**	**Note**
New EMS	Boiler Plant Capacity	2,895 MBH	Custom Express Tool	
	Boiler Plant EFLH	1,153 Hours	Custom Express Tool	
	Control system	Pneumatic	Pre-Inspection Form	
	Minimum Outside Air Control Method	Constant	Custom Express Tool	

Applicant Description of Installed Equipment and Operation

This section describes the proposed condition assumed in the application analysis. It only discusses the assumptions made in the original analysis, not any information gained through this evaluation. Table 2-2 summarizes the applicant's proposed case system assumptions.

Table 2-37: Application proposed key parameters

		PROPOSED		
Measure	**Parameter**	**Value(s)**	**Source of Parameter Value**	**Note**
New EMS	7-Day Schedule	Yes	Custom Express Tool	
	Optimal Stop/Start	Yes	Custom Express Tool	
	DDC Temperature Control	Yes	Custom Express Tool	
	OA HW Reset	Yes	Custom Express Tool	
	Control system	DDC	Minimum Requirement Document	
	Minimum Outside Air Control Method	CO2 based demand control	Custom Express Tool	

Applicant Energy Savings Algorithm

Applicant savings are calculated using a custom express savings tool for EMS installations. The custom express tool calculates savings for each of the new control sequences based on an estimated percent reduction in boiler gas use.

The calculation of annual baseline boiler gas use is shown below.

Boiler Annual Gas Input: 2,895 MBH full load input (for all 7 boilers) x 1,153 equivalent full load hours = 3,337,935 MBTU (33,379 therms).

Where 1,153 EFLH is a direct input in the applicant's spreadsheet.

The savings for each control sequence are calculated based on a percent reduction in baseline boiler gas use. The savings factors are hard coded values in the custom express tool.

Savings = Boiler Baseline Annual Input (MBtu) x Savings factor / (100 MBH / Therm)

The savings factors used for this formula are presented in the table below

Table 2-38. Summary of Savings Factors

Measure	Savings Factor	Applicant Therms Saved
Equipment Run Time	1.5%	501
DDC Temp	2.5%	834
OA HW Temp Reset	5%	1,669
DCV	15%	5,007
Total	24%	8,011

Note that equipment run time is a binary function in the custom express tool. Equipment runtime is a savings factor because the inputs for 7-day schedule and optimal start are selected and both inputs are associated with equipment runtime savings in the custom express tool. If only one or the other (7-

day schedule or optimal start) was selected as opposed to both being selected the savings impact would be unchanged.

Evaluation Assessment of Applicant Methodology

The annual gas usage for 2016 and 2017, which was the pre-retrofit period, was 9,451 therms and 8,875 therms respectively. The applicant's estimated boiler full usage is 264% more than actual annual pre-existing case gas usage based on bill data. The applicant did not use actual gas bill data to inform the equivalent full load hours assumptions.

With the exception of optimal start and demand control ventilation which were not included in the scope of work for the project, the applicant entered inputs to the custom express tool that reflected the proposed control sequences. The custom express tool generally is a one-size-fits-all tool used for quantifying the savings associated with implementing basic control sequences with a new EMS. The custom express tool does not require the applicant to document existing system control sequences beyond estimating the equivalent full load hours. The energy savings for retrofit control measures rely entirely on existing system operation. The lack of documentation and calculation inputs for the existing system operation in the custom express tool results in unreliable savings estimates.

On-Site Inspection and Metering

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

Summary of On-site Findings

On February 19, 2020 the evaluator met with the controls contractor that installed the new EMS at the site. The evaluator reviewed the project scope and the EMS interface with the controls contractor and conducted a walkthrough of the site. The onsite findings are as follows:

- The EMS includes an occupancy schedule. The EMS will lockout the boilers based on outside air temperature and the enable temperature below 60°F during occupied hours, and below 40°F during unoccupied hours.
- New BacNet controllers were installed. The EMS commands the hot water supply temperature setpoint and enables the boilers. The boilers cycle to maintain the setpoint however it was found that the boilers often fail to fire and are unable to maintain the hot water setpoint. Based on feedback from the controls contractor there are no comfort complaints related to the hot water system, the system maintains a hot water temperature that is lower than the setpoint but is still warm enough to serve space heating loads. It is expected that the boiler configuration in which hot water flows through all inactive boilers is a contributing factor to the inability of the system to maintain the hot water setpoint.
- The system does not have optimal start as verified by a review of control sequences.
- Demand control ventilation was not implemented as part of this project and was not included in the scope of work although savings were claimed by the applicant for implementing this feature.

Table 2-4 summarizes the evaluators approach to verifying the savings for this project.

Table 2-39. Measure Verification

Measure Name	Verification Method	Verification Result

New EMS	Review trends to confirm measure implementation. Review bill data to determine measure savings.	The trend data shows that the boilers are unable to maintain the hot water setpoint. The hot water system is enabled based on outside air temperature and the enable temperature is 60°F during occupied hours, and 40°F during unoccupied hours.

Measured and Logged Data

Table 2-5 below summarize the data used to evaluate the savings for site 2018RIG26. Note that since trending was available no additional metering equipment was installed.

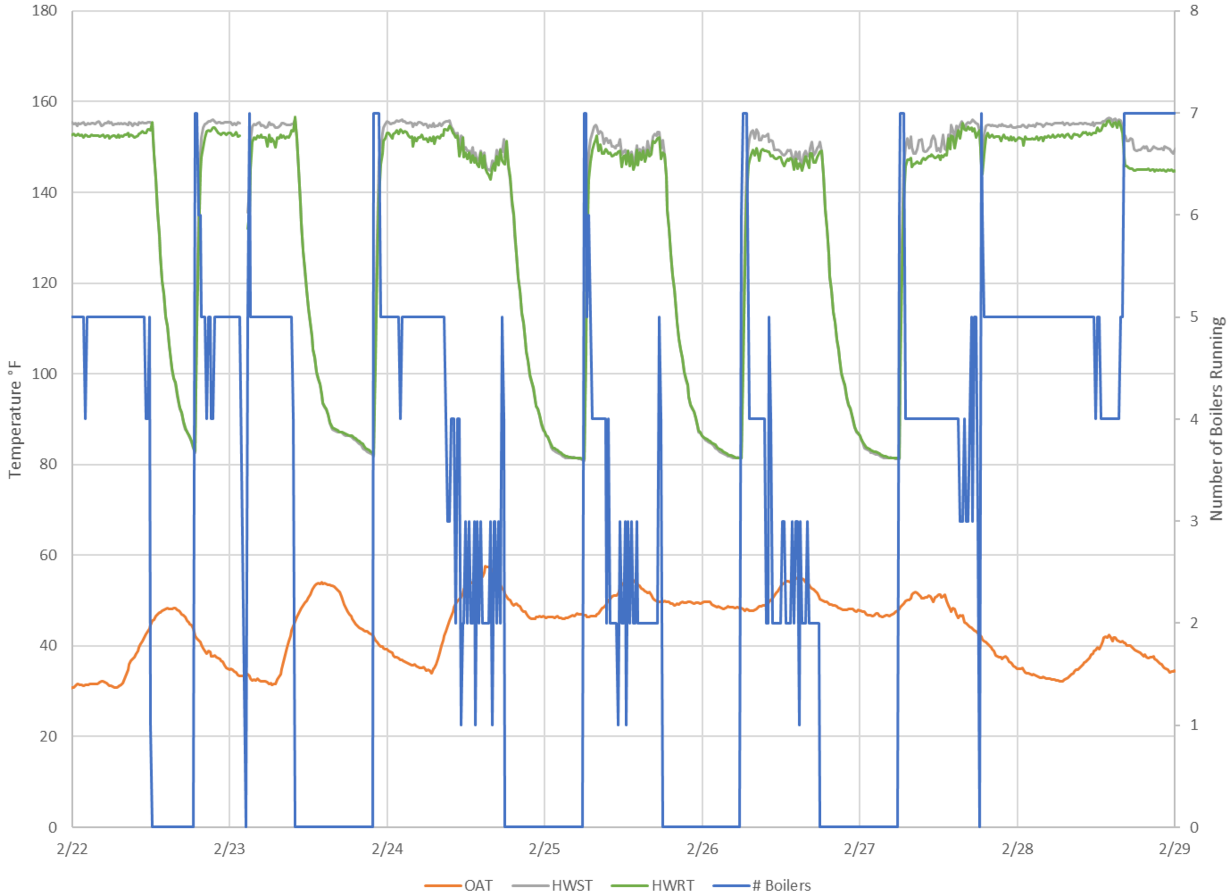
Table 2-5. Evaluation data collection – data received

Source	Parameter	Interval	Duration
Facility EMS	Hot water supply and return temperature Outside air temperature Boiler status (for all 7 boilers) Pump statuses Pump speeds	15 Minute	One month (February 20,2020 – March 20, 2020)*
Facility EMS	Occupancy status Furnace status DX status Fan status Fan speed Mixed air damper position Mixed air temperature Return air temperature Supply air temperature setpoint	15 Minute	One month (with one four day data gap and one 14 day data gap) (February 10,2020 – March 12, 2020)*
Utility Meter Reads	Gas Bill Data	1 month	4 years (January 2016-December 2019)

**Trend Data Analysis is based on trend data from February 20, 2020 through March 5, 2020. Additional data was provided by the controls contractor after analysis was in progress.*

The figure below presents a representative portion of the raw trend data provided for the hot water system by the controls contractor that installed the new EMS.

Figure 2-1. Raw Trend Data (HW System)

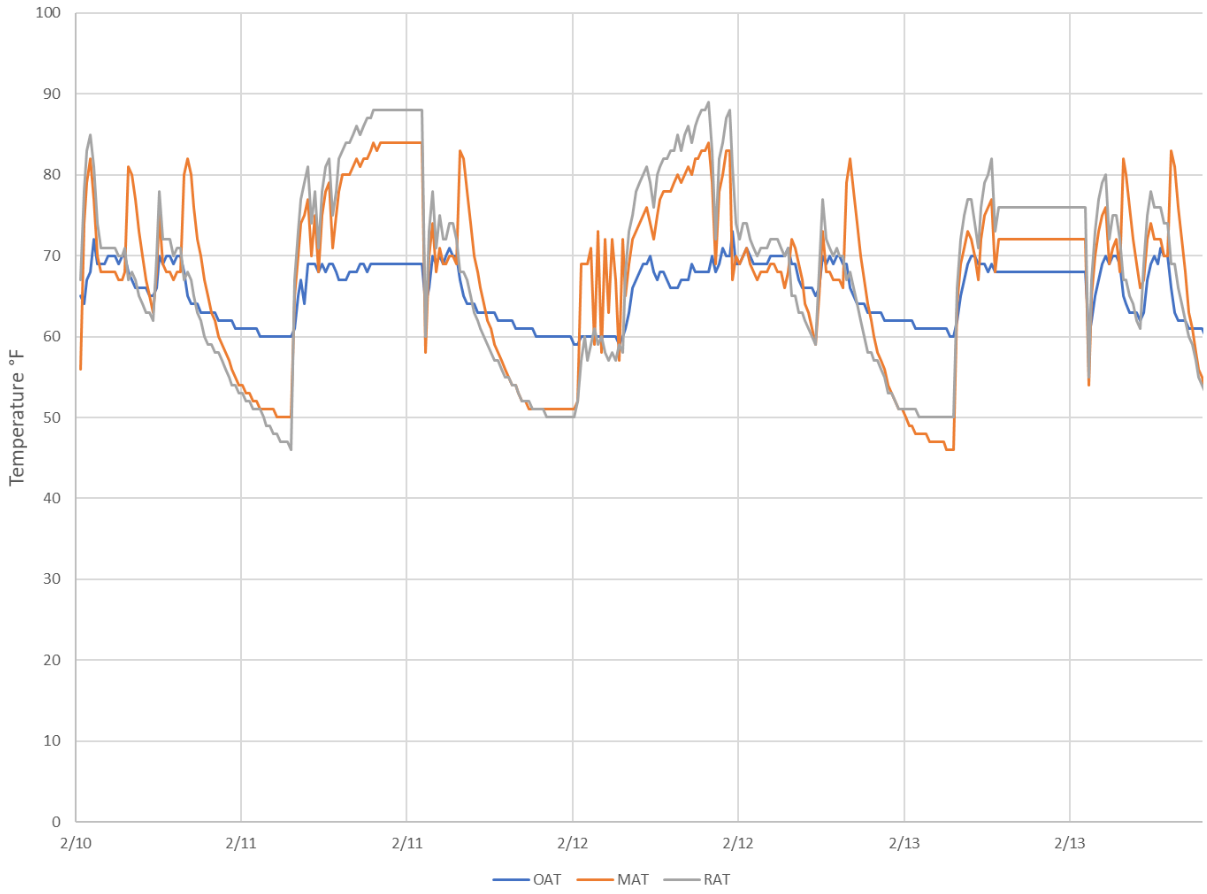


The trend data shows that the boilers cycle on and off however the hot water supply temperature does not exceed ~155°F for the duration of the trend period. The hot water supply temperature setpoint is not trended, but the observed temperature does not match the setpoint reset schedule. The supply temperature setpoint was observed during the site visit. On the site visit the outside air temperature reported by the EMS was 27.7°F and the hot water supply setpoint was 173.3°F, which matches the design linear reset of 180°F at 0°F to 145°F at 60°F. The actual supply temperature was 155.6°F, which is in line with the trends.

The boilers all shutoff when outside air temperature exceeds the outside air enable temperature determined by the EMS demonstrating that the occupancy schedule is operating as expected (see section 2.4.2 for more details). Note the time period between 2/25 and 2/28; the OAT during this entire time period is between 40°F (the unoccupied enable temperature) and 60°F (the occupied enable temperature). As the system goes from occupied to unoccupied mode during this time period the boilers all shutoff. Preceding this time period on 2/24, the OAT is less than 40°F in the morning prior to occupied hours and the boilers do not shutoff.

The figure below presents a representative portion of the raw trend data provided for the rooftop unit by the controls contractor that installed the new EMS. Note that there is a

Figure 2-2. Raw Trend Data (RTU)



significant gap in the RTU trend data provided. The data shows that the mixed air temperature roughly follows the return air temperature suggesting that the RTU operates at a fixed outside air percentage another indication besides no CO2 sensor, that the demand control ventilation strategy is not working.

Evaluation Methods and Findings

This section describes the evaluator methods and findings.

Evaluation Description of Baseline

The baseline system for this project is pre-existing pneumatic controls. The evaluator was able to confirm that the pre-existing control system was pneumatic controls during the site visit because the pre-existing controls were partially abandoned in place. The measure is classified as an add-on retrofit project and the evaluator agrees with this classification.

During the site visit that was conducted with the controls contractor for the project, the evaluator was informed that prior to the installation of the EMS the boiler plant was enabled manually by the head custodian via the emergency shutdown button. Other than that, the evaluators were not able to collect details about specific baseline control sequences. Based on discussions with the controls contractor, there were a variety of manual overrides and work arounds implemented by the school district's boiler technicians to circumvent the pneumatic control system and minimize comfort complaints.

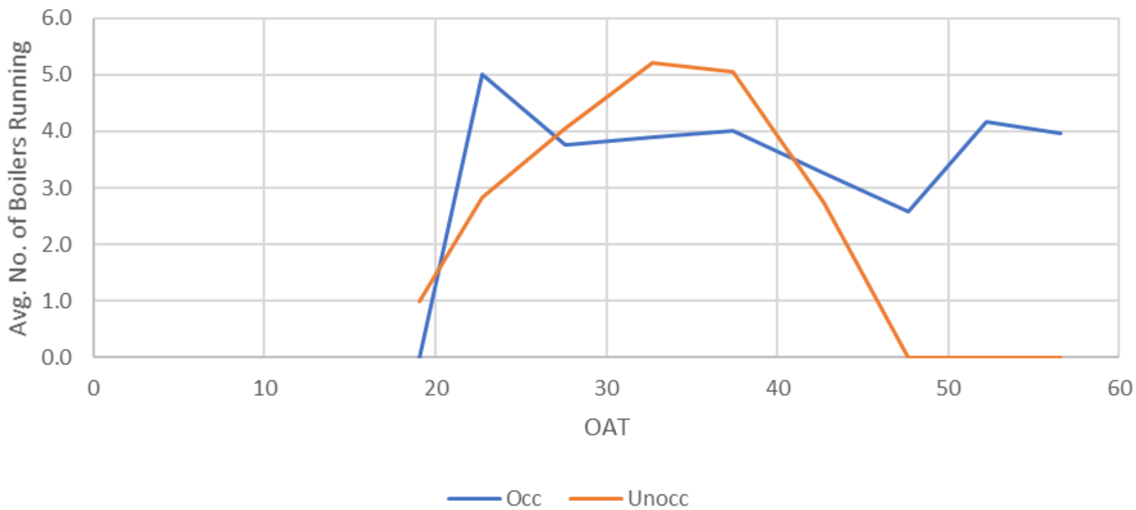
Evaluation Calculation Method

7-Day Schedule

The evaluator was able to confirm the installed EMS occupancy schedule during the site visit. The hot water system is in occupied mode from 6am to 6pm on weekdays. The system is in unoccupied mode on weekday nights, all day on weekends and during school breaks and holidays. The hot water system will stage on in both occupied and unoccupied mode based on the outside air temperature. In occupied model the system is enabled when the outside air temperature is below 60°F and in unoccupied mode the system is enabled when the outside air temperature is below 40°F. A more detailed explanation of the hot water temperature control sequences is explained in the DDC Temperature Control section below.

To demonstrate the impact of the 7-day schedule control sequence on boiler plant operation, the figure below shows the average number of boilers running as a function of outside air temperature during occupied and unoccupied hours.

Figure 2-3. Number of Boilers Running vs OAT (Occupied/Unoccupied Comparison)



The trends show that there is a different outside air enable temperature during occupied and unoccupied hours. It is unclear if the implementation of the 7-day schedule results in a reduction in hot water system run hours compared to the pre-existing control strategy of manually shutting down the hot water system with the emergency shutoff.

Figure 2-3 shows that more boilers run during unoccupied hours than occupied hours when OAT is between 30°F and 40°F. It is suspected that this is because there is less internal heat gain (occupant body heat, lighting heat, plug loads) during unoccupied hours than occupied hours.

Optimal Start

It was confirmed during the site visit that optimal start is not part of the installed control sequence.

DDC Temperature Control

It is unclear what is meant by DDC temperature controls as a measure. The evaluator confirmed on the site visit that the new EMS controls the hot water supply temperature setpoint by cycling the boilers with a lead lag sequence. It is unclear how DDC control of the hot water system is expected to result in energy savings and it does not appear that the DDC temperature control is impacting the actual hot water temperature due to issues with the underlying equipment (boilers).

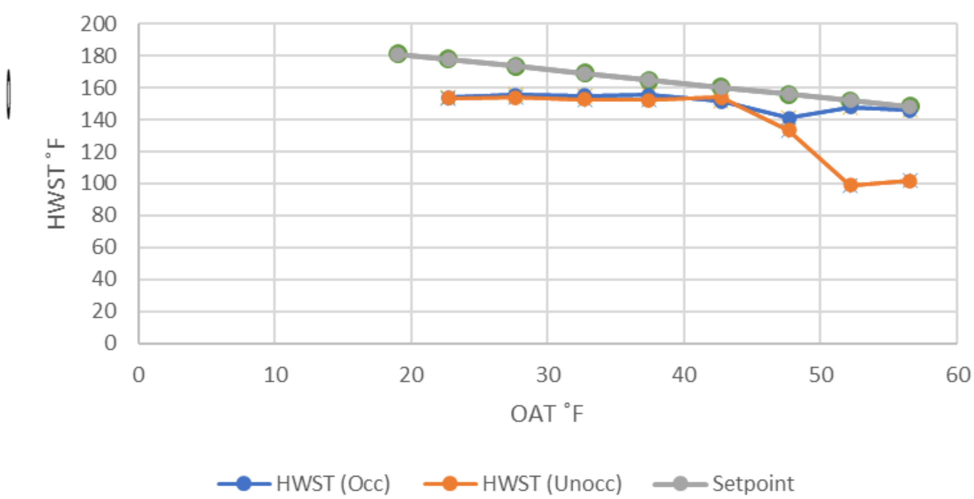
The evaluator found that the hot water system is unable to maintain a hot water supply temperature above ~155°F. It is suspected based on the site visit observations and conversations with the controls contractor that the system cannot maintain the hot water setpoint because each of the 7 boilers do not have flow control valves and hot water flows through each boiler including offline boilers whenever the hot water loop is circulating. The operating boiler(s) may be providing 180°F hot water, but this water mixes with return water flowing through the idle boilers which lowers the temperature in the supply header. In addition, the controls contractor has found that the boilers regularly are in alarm because they fail to fire however the lead/lag staging sequence stages on the first "lag" boiler when the lead boiler fails to fire which prevents the hot water system from failing completely. These are two known issues that are contributing factors to the finding that the underlying equipment is unable to meet the hot water supply setpoint.

It is not clear why savings were expected from the DDC control of the hot water system compared to pre-existing system operation; particularly when coupled with the fact that the installed system is unable to maintain the setpoint commanded by the EMS.

OA HW Reset

Trends confirm that hot water supply temperature does vary slightly with outside air temperature. The figure below shows the average hot water supply temperature and hot water supply setpoint as a function of outside air temperature. The water temperature declines as outdoor air temperature increases during unoccupied hours because the hot water system is not enabled.

Figure 2-4. Average HWST˚F vs OAT˚F



A screenshot of the EMS provided by the controls contractor demonstrated that the HWST setpoint is being reset based on outside air temperature. However, the boilers are unable to maintain the hot water setpoint.

The basis of energy savings associated with hot water reset is that the baseline average hot water temperature is greater than the average hot water temperature in the proposed case based on the resetting of the setpoint in the proposed case. The evaluator observed that the boilers are unable to meet the hot water temperature setpoint in the proposed case because of issues with the underlying equipment and not with issues from the new controls. Because of this having a lower hot water setpoint in the proposed case does not change actual system operation and no savings result from implementing this control sequence.

Note that the boilers at the site are not condensing boilers so the source of savings associated with lowering the hot water supply temperature would be related to system heat losses, not boiler efficiency. It is not clear based on the custom express EMS tool if the hot water reset savings calculation assumes that the site has condensing boilers or not.

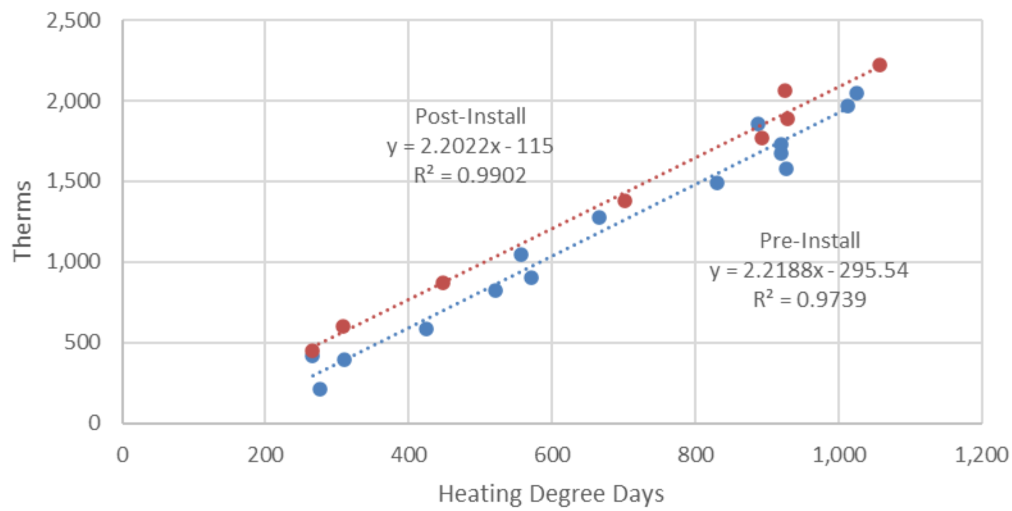
When reviewing the EMS with the controls contractor it appeared that the outside air temperature sensor reading was not accurate and may be impacted by sunlight. The sensor was reading 60°F, but the actual outside air temperature was ~40°F. The boiler is enabled based on the outside air temperature and the hot water supply temperature is reset based on the outside air temperature, so boiler operation is impacted by the sensor issue. The outside air temperature trends from the site are used for the creation of Figure 2-4.

2.3.3 Gas Billing Analysis

Monthly gas bill data was provided for this site. Data was provided from January 2016 through December 2019. The measure was installed in 2018. For the bill data analysis, the years 2016 and 2017 are used to document pre-installation gas usage, and 2019 gas data is used to document post-installation gas usage. It is assumed that the EMS was installed in 2018 based on the December 2018 date on the controls contractor invoice included in the tracking documents.

Hourly weather station data from TF Green Airport in Providence was used to calculate the heating degree days (HDD) associated with each gas bill. The figure below shows the pre-installation and post-installation relationship between monthly gas usage and heating degree days excluding months with less than 200 HDD.

Figure 2-5. Pre-Install vs Post-Install Gas Usage



The bill data shows that the boiler plant uses more gas per heating degree day with the new EMS.

Billing analysis savings for this project are calculated using TMY3 weather data from TF Green Airport to calculate weather normalized gas savings. Months with less than 200 HDD are not considered in the evaluated savings. Note that the annual heating degree days calculated using TMY3 weather data (5,976 HDD) are greater than the heating degree days in the years of gas bill data used to calculate the relationship between heating degree days and gas usage (2016: 5,304 HDD, 2017: 5,296 HDD, 2018: 5,560 HDD, 2019: 5,678). Table 2-6 summarizes the weather normalized gas savings calculated for the project based on pre- and post-installation gas bill data.

Table 2-6. Evaluation Monthly Gas Savings Analysis Using TMY HDD

Month	HDD	Pre-Install Gas Use Therms	Post-Install Gas Use Therms	Gas Savings Therms
1	1,112	2,171	2,333	-162
2	917	1,739	1,904	-165
3	811	1,503	1,670	-167
4	535	891	1,062	-172
5	260	282	458	-176
6	85			0
7	18			0
8	27			0
9	107			0
10	379	546	720	-174
11	675	1,201	1,370	-169
12	1,051	2,036	2,199	-163
Total	**5,976**	**10,369**	**11,718**	**-1,349**

Final Results

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

The controls sequences are not implemented in a way that is expected to result in energy savings and the billing analysis results in a gas penalty associated with the installation of the new EMS. However, due to lack of pre-existing system information, it cannot be confirmed definitively that the penalty is a result of implementing the proposed case control sequences as opposed to other factors so the evaluated savings are 0 for the project.

Table 3-40. Evaluation Results Summary

PA Application ID	Measure Name		Annual Savings (therms)
8575048	New EMS	Tracked	8,011
		Evaluated	0
		Realization Rate	-0%

Table 3-2 is a summary to the key saving parameters.

Table 3-41. Summary of Key Parameters

Parameter	BASELINE		PROPOSED / INSTALLED	
	Tracking Value(s)	Evaluation Value(s)	Tracking Value(s)	Evaluation Value(s)
7-Day Schedule	Not implemented	Unclear	Implemented	Implemented but has minimal impact on HW system operation
Optimal Start	Not implemented	Unclear	Implemented	Not Implemented
Temperature Control	Pneumatic	Pneumatic	DDC	DDC
HWST Control	Constant	Unclear	OA Reset	OA Reset not operating as intended
Minimum Ventilation Control	Constant	Constant	DCV	Constant

Explanation of Differences

This section describes the key drivers behind the differences between the tracking and evaluated gas savings. The following table summarizes these differences. The purpose of this table is to describe how changes to the key parameters influenced the final project savings through the end use summary analysis. Table 5-21 provides a summary of the differences between tracking and evaluated values.

Table 3-42. Summary of Deviations

End-use	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
HVAC	Operational	Equivalent full load hours	72.5%	Decreased Savings – Adjusting the EFLH assumption based on existing case bill data decreases baseline energy use.
HVAC	Operational	Demand Control Ventilation	17.2%	Decreased Savings – DCV was not implemented and was not part of the controls contractor's scope of work.
HVAC	Operational	OA HW Temp Reset	5.7%	Decreased Savings - HW reset is being implemented but the system is unable to maintain the hot water setpoint.
HVAC	Operational	DDC Temperature control	2.9%	Decreased Savings – EMS commands hot water setpoint but boilers are unable to maintain setpoint.
HVAC	Operational	Equipment Run Time	1.7%	Decreased Savings – Optimal start not implemented. 7-day schedule was implemented but it is not clear that run hours are less than pre-existing system operation.

The applicant inputs assume that the baseline annual gas usage is 33,379 therms and the average pre-existing annual usage was actually 9,163 therms. Adjusting the savings calculations to reflect actual baseline usage decreases the calculated savings significantly as shown above.

The evaluation found that the control sequence inputs that were used to calculate savings for this project were either not implemented or implemented in a way that is not expected to result in energy savings.

The EMS does have a 7-day schedule with occupied and unoccupied OAT enable temperatures for the hot water system, however it is not clear that system run hours are less than in the pre-existing case. Optimal start was not implemented or included in the controls contractors' scope of work.

The EMS is commanding the hot water setpoint and the hot water setpoint is being reset based on outside air temperature, however the boilers are unable to maintain the setpoint. The actual hot water supply temperature is always ~150°F.

Demand control ventilation was not part of the controls contractor's scope of work for this project and was not implemented, however the applicant claimed savings for implementing demand control ventilation.

The billing analysis corroborated the finding of no savings.

Lifetime Savings

The evaluated lifetime savings are smaller than the tracking lifetime savings because the evaluated first year savings are smaller than the tracking first year savings. Table 5-22 provides a summary of key factors that influence the lifetime savings.

Table 3-43. Measure 5891377 - Lifetime Savings Summary

Factor	Tracking	Application	Evaluator
Lifetime savings	80,110 therms	80,110 therms	0 therms
First year savings	8,011 therms	8,011 therms	0 therms
Measure lifetime	10 years	10 years (project BCR)	10 years (MA TRM)
Baseline classification	N/A	N/A	Add-on single

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

Ancillary impacts

Electric savings were calculated under a different application.

2018RIG43

Report Date: 6/29/20

Program Administrator	National Grid
Application ID(s)	6795554
Project Type	Early Replacement Retrofit
Program Year	2017
Evaluation Firm	DMI
Evaluation Engineer	Shannon Taylor
Senior Engineer	Jay Robbins

1.1 Evaluated Site Summary and Results

This project includes installation of a new recuperative thermal oxidizer (RTO) to serve existing biological vent gas oxidizer and siloxane regeneration flare system. The pre-existing oxidizer removes pollutants without heat recovery. The new oxidizer is rated at 6,050 cfm. The new oxidizer includes a second heat exchanger in addition to the RTO heat exchanger that is used to preheat purge air for the siloxane system.

Gas savings result from the 70% heat recovery effectiveness of the oxidizer compared to the pre-existing oxidizer and siloxane regeneration flare systems without heat recovery. Electric savings also result from a second heat exchanger that recovers heat from the oxidizer discharge to pre-heat siloxane bed purge air.

The evaluation results are presented in Table 5-9. Analysis of utility billing pre and post gas consumption data indicate that the gas savings are very similar to the applicant saving. The tracking analysis included a commissioning effort after the project was installed. Commissioning updated the project savings based on a pre/post utility data review and the original calculations do not impact the final post-commissioning revised savings. Evaluation reviewed trend data and observed that although the overall savings are similar to the applicant, there are variations in the operating conditions from the applicant's original energy model.

In addition to the gas savings, there were 199,156 kWh claimed as part of this project. The evaluation observed considerably more electric savings, at 624,801 kWh.

Table 5-44. Evaluation Results Summary

PA Application ID	Measure Name		Annual Savings (therms)
6795554	Recuperative Thermal Oxidizer and Secondary Heat Exchanger	Tracked	691,953
		Evaluated	694,942
		Realization Rate	100.4%

1.1.1 Explanation of Deviations from Tracking

The evaluated savings are 0.4% more than the applicant-reported savings. The applicant effort consisted of a tracking analysis study and commissioning effort after the project was installed. The original applicant savings of 432,478 therms were updated based on a pre/post utility data review during commissioning. The commissioning effort resulted in a significant increase in savings to 691,953 therms. Evaluation savings are also based on utility data and are similar to the applicant commissioning result.

Evaluation reviewed trend data from the facility's SCADA system in addition to the utility data review. Deviations in operating parameters were observed from the original tracking analysis calculations, which is not relevant to the final savings calculation which was based only on utility data. Major deviations from the original tracking analysis calculations included lower RTO effectiveness than expected (53% vs 70%) and 10% less airflow than expected. There appear to be additional deviations that are difficult to measure with the available data, including heat contribution of pollutant burn-off and the system efficiencies of the baseline and installed pollutant removal systems. Savings are unaffected by these changes because the applicant did not use the original heat flow analysis calculations, deferring to the pre/post consumption data once it became available.

1.1.2 Recommendations for Program Designers & Implementers

The applicant approach of performing a commissioning effort after the installation was effective in both improving the original estimate based on actual data and claiming additional project savings. Commissioning increased the applicant savings by 70% and avoided major savings discrepancies including a calculation error and multiple variations in operating conditions.

Thermal oxidizer models can include assumptions that are difficult to measure and verify. In this case, the thermal flow calculations were performed in detail, but underestimated the gas consumption and energy savings. Specifically, the uncertainty is related to the heat contribution of pollutant burn-off and system efficiencies. For thermal oxidizer models based on heat flow calculations and not burner input, commissioning involving pre/post consumption data is recommended to improve both calculation accuracy and operation. While significant savings were achieved in this application, the finding that the RTO effectiveness is 53% instead of 70% suggests potential for additional savings.

1.1.3 Customer Alert

While the customer expressed that they were happy that National Grid identified this energy efficiency opportunity, the customer also expressed frustration with installing an adequate recuperative thermal oxidizer. The RTO installation in 2017 failed shortly after going online (within 2 months), requiring a significant increase in project cost to resolve issues. Specifically, the thermal oxidizer was designed with heat exchanger wall thicknesses that were too thin for the application. The site now performs a one-day shutdown quarterly instead of bi-annually for maintenance.

1.2 Evaluated Measures

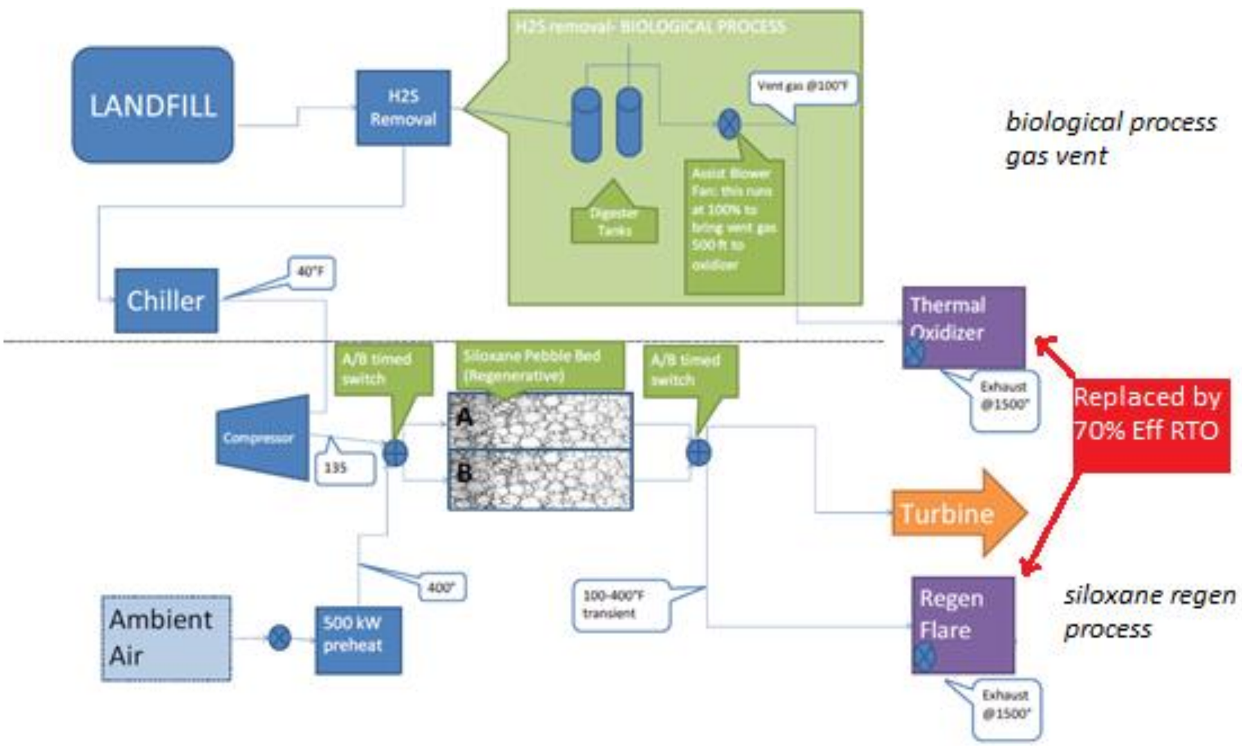
The following sections present the evaluation procedure, including the findings from an in-depth review of the supplied applicant calculations and the evaluation methodology determined to be the best fit for the site and information available.

This retrofit project involves the process of using landfill gas as a fuel for electrical power generation. During the treatment process for the landfill gas, two stages result in by-product gases that need to be treated. The first treatment stage removes hydrogen sulfide, H_2S. Biological vent gas from this stage goes through an oxidizer for odor control. Pre-existing equipment included a 3,000 cfm natural gas direct fired catalytic oxidizer with no heat recovery.

Additionally, a second treatment stage processes gas including siloxanes. The pre-existing equipment included a siloxane pebble bed that is periodically regenerated. The siloxane bed regeneration process involves heating purge air to 400°F with a 500 kW electric resistance array. After passing through the bed, the purge air is released via a flare at 1550°F at the end of the process. The siloxane regeneration flare includes a gas burner, 9,000 MBH capacity and 3,000 cfm rated flow.

Figure 2-1 is a schematic of the pre-retrofit system. There are two major processes: a biological process for H_2S is shown in the top half and the siloxane regeneration in the bottom half. Natural gas is consumed at the biological process catalytic thermal oxidizer (purple) and regen flare (purple). These gas users were replaced by the 70% recuperative thermal oxidizer.

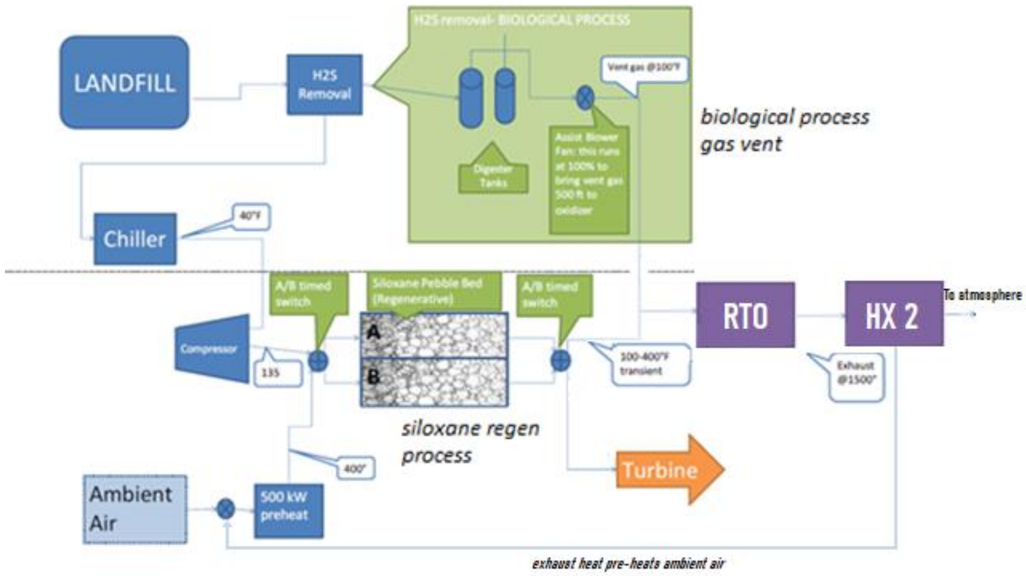
Figure 2-1: Pre-Retrofit System Diagram



Note: Natural gas consumed at thermal oxidizer and regen flare

This project involved installation of a 70% efficient recuperative thermal oxidizer. The recuperative thermal oxidizer serves the purpose of both the pre-existing catalytic oxidizer (upper purple box) and the siloxane regen flare (lower purple box). Energy savings result from the 70% recuperative heat recovery compared to no heat recovery in the existing case. There is an additional second heat exchanger in the new thermal oxidizer that is used to heat the siloxane bed purge air. The second heat exchanger offsets electric resistance heat resulting in electrical savings. Figure 2-2 shoes the post-retrofit configuration.

Figure 2-2: Post-Retrofit System Diagram



1.2.1 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.

1.2.1.1 Applicant Description of Baseline

This retrofit measure involves the replacement of existing equipment. The baseline is the pre-existing equipment, including a catalytic thermal oxidizer for biological vent gas and a thermal flare for siloxane bed purge air. The catalytic thermal oxidizer (upper purple box) was two years old when this project was considered. An 18-year measure list was selected.

Table 2-1 summarizes the critical baseline parameters. This table shows the two individual measures that were claimed under the project.

Table 2-45. Applicant Baseline Key Parameters

		BASELINE		
Measure	Parameter	Value(s)	Source of Parameter Value	Note
Recuperative Thermal Oxidizer	Biological Vent Gas -Heat Recovery Effectiveness	0%	TA study	-
Recuperative Thermal Oxidizer	Siloxane Flare - Heat Recovery Effectiveness	0%	TA study	-
Siloxane Pre-Heat Energy	Siloxane Pre-Heat - Electric kWh	716,722	TA study	-

1.2.1.2 Applicant Description of Installed Equipment and Operation

The proposed condition adds heat recovery to 3 parts of the process. A 70% efficient recuperative thermal oxidizer is used for the biological vent gas and siloxane purge air. A second heat exchanger prior to the recuperative thermal oxidizer stack is used to provide heat to the siloxane beds, when needed.

Table 5-46: Application Proposed Key Parameters

		Proposed		
Measure	Parameter	Value(s)	Source of Parameter Value	Note
Recuperative Thermal Oxidizer	Biological Vent Gas -Heat Recovery Effectiveness	70%	TA study	-
Recuperative Thermal Oxidizer	Siloxane Flare - Heat Recovery Effectiveness	70%	TA study	-
Siloxane Pre-Heat Energy	Siloxane Pre-Heat - Electric kWh	517,566	Cx	-

1.2.1.3 Applicant Energy Savings Algorithm

The 2015 tracking analysis energy model is an Excel analysis in which the baseline equipment and proposed measures are modelled in individual spreadsheets. Each analysis is based on a single operating condition, as ambient conditions and time of day have minor impacts on energy consumption and the process is relatively constant. Energy use is calculated based on process airflow, temperatures, and air properties. The energy model is a reasonable method of calculating energy savings and the evaluation uses the same model with the inputs updated based on post-retrofit operating data.

Commissioning was completed in 2018 and savings were updated based on a pre/post billing data analysis with 2015 and 2016 pre-retrofit data. Commissioning was delayed by a failure of the new thermal oxidizer in 2017. The failure was reportedly due to insufficient heat exchanger wall thickness. The RTO was repaired and improved to withstand the operating conditions, requiring an additional cost of approximately $500,000. The customer did not request an additional incentive for the repair. To prevent future failures, the site is performing more frequent shutdowns for cleaning, on a quarterly basis instead of bi-annually.

Figure 2-4 shows an example screenshot from the original applicant savings calculations file. This is the original TA study model. It was replaced with the commissioning effort which used a billing data analysis shown in Figure 2-3. The gas savings is the difference between the pre and post-retrofit periods.

Figure 5-3. Commissioning Savings Calculations

	CCF/day	therms/year
post	714.1735	267,903
pre	2558.778	959,856
annual therms saved		691,953

Pre-period: 5/31/15 through 11/30/16; Post-period: 7/6/18 through 10/11/18

Figure 5-4. Tracking Analysis Savings Calculations

	Not used	constants
STREAM TEMPERATURES		
Air inlet Temperature	132	F
RO normal operating temp	1550	F
RO skin losses (assumed)	3%	
Exhaust temperature to RO HX	1504	F
RO discharge temp to atmosphere	543	F
RO max operating temp	1800	F
Adjustment F to R	457.87	F
Average annual OAT	50.9	F
FUEL SOURCES		
Natural gas burner capacity	13,800,000	Btu/hr
Expected NG injection input	3,932,137	Btu/hr
Heating value, pollutant 1	*23811*	*Btu/lb*
Heating value, pollutant 2	12.8	Btu/cu ft
% pollutant 1	0.4	
Burnoff rate for pollutants	95.6	lb/hr
Pollutant burnoff heat flow	1,225,920	Btu/hr
NG Conv Factor	100000	BTU/Therm
NG heating value	23797	Btu/lb
Auto-ignition temperature, NG	1100	F (approximate)

OTHER STREAM PROPERTIES				
RO inlet air mass flow rate	19,512	lb/hr	264,000	cu ft/hr
RO inlet air Cp	0.250	Btu/lbF		
RO air Cp after combustion	0.275	Btu/lbF		
Average Cp during combustion	0.263	Btu/lbF		
RO inlet heat required for delta T	5,158,057	Btu/hr		
RO heat from pollutant burnoff	1,225,920	Btu/hr		
Required NG input	3,932,137	Btu/hr		
Required NG mass flow rate	165	lb/hr		
Operating hours	8,520	hr/yr		
Gas usage (Therms/yr)	335,018			
Equipment Cost				
Fan Penalty due to additional pressure dr	31%	Assumed		
Fan energy, annual	356,114			
Inflation adjustment multiplier	*1.4219*	*1999 to 2014 dollars*		
Technology advancement multiplier	*0.810374257*	*to account for improved manufacturing*		
Equipment Cost	*0*	*in 2014 dollars*		
Check fuel air ratio	TRUE			
Check RTO cfm	TRUE			
Check NG flow rate	TRUE			

A similar spreadsheet was used to calculate gas consumption for the two pieces of baseline equipment (biogas oxidizer and siloxane regeneration flare) and the installed RTO. Savings were calculated on a separate spreadsheet using the following expression:

> Gas savings, therms = [Biogas thermal oxidizer, therms + Siloxane regen, therms] – Installed RTO, therms

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

1.2.1.4 Evaluation Assessment of Applicant Methodology

The applicant performed a detailed spreadsheet analysis of baseline and installed systems based on a single, constant operating condition. The baseline analysis consists of two spreadsheets, one for each the biological vent gas and the siloxane purge air systems. In the installed case the recuperative thermal oxidizer serves both of those systems, and a single spreadsheet is used to model the proposed gas consumption. These analyses utilize heat flow data and fluid properties to estimate gas usage, including the heat content of the pollutants being oxidized.

The installed system also includes a secondary heat exchanger at the thermal oxidizer discharge. This heat exchanger captures heat which is then used to offset electric heat for the siloxane purge air. The applicant uses a separate spreadsheet analysis to model these electric savings.

While the heat flow calculations are a detailed energy modelling approach based on actual operating conditions, they do not account for additional system losses. Each model includes a system efficiency input that has a significant impact on the analysis. The baseline energy model consumption was calibrated to SCADA gas consumption data by adjusting the system efficiency inputs. This was performed for both the baseline siloxane flare and bio gas vent models.

The system efficiency calibration resulted in values of 55% for the two baseline systems. Since all heat goes to the combustion chamber and the combustion efficiency would be near 100%, the primary source of heat loss contributing towards the lower system efficiency is likely losses through the oxidizer jacket. 55% implies a surprising amount of loss and may be correcting for other model inaccuracies.

The installed case system efficiency could not be determined using the same methodology as the baseline when the original applicant study was performed since the system was not installed yet. The applicant calculation did not include a system efficiency value like the baseline systems, implicitly assuming 100% system efficiency. Since the system efficiency is likely to be less than 100%, this assumption underestimates installed case energy use and overestimates savings.

To summarize, there are several different efficiencies that apply to this analysis

1. RTO Effectiveness – 70%. This is the recuperative thermal oxidizer heat exchanger efficiency
2. Secondary heat exchanger – 70%. This is the amount of heat recovered from the RTO discharge and used to pre-heat the siloxane purge air, offsetting electric resistance heat.
3. Baseline heat recovery – 0%. There is no heat recovery in the two baseline systems, including the biogas vent and the siloxane regeneration flare.
4. Baseline Oxidizer System Efficiency – 57%. This TA value is intended to include losses through the jacket of the baseline biogas vent oxidizer.
5. Baseline Siloxane Flare System Efficiency – 53%. This TA value is intended to include losses through the jacket of the baseline siloxane flare.

Additionally, the installed case includes a calculation error related to the recuperative oxidizer heat exchange effectiveness. The model uses a calculation for determining the inlet heat required to bring the biogas vent and siloxane regen temperatures up to the combustion temperature. This calculation is based on the oxidizer discharge temperature (500°F) instead of the combustion inlet temperature (1,000°F). So, the heat flow calculation is based on going from 500°F to 1,550° instead of starting at 1,000°F. As a result, the oxidizer heat exchange effectiveness is modelled as 30% instead of 70%. This error would overstate the installed energy use and underestimate savings.

When commissioning was performed in 2018 the savings were updated based on a pre/post billing data analysis. As a result, the methodology issues described above do not affect the final tracking savings estimates. The commissioning savings adjustment considerably increased the project savings from 432,478 therms to 691,953 therms. While the original study had errors resulting in savings moving both directions, the error of modelling the heat recovery effectiveness as 30% instead of 70% is quite significant and accounts for most of the difference between the TA and Cx savings.

The evaluation agrees with the commissioning agent’s approach. The applicant’s detailed energy model is an appropriate approach to assist in decision making of purchasing the new RTO. The heat flow calculations serve a useful purpose in understanding the factors impacting gas consumption. Commissioning was an appropriate follow-up task for a project of this size and the billing data method is accurate since the oxidizers and flare are the only active gas equipment on the utility gas meter.

Gas consumption does vary slightly from month to month and the selected period for the baseline does have a small impact on the results. The applicant considered periods in 2015 to 2018, and ultimately applied a method to include only operation in 2015 and 2016. The new RTO initially went online around January 1, 2017, but failed within a month of start-up, resulting in more baseline operation in late 2017 and early 2018. This later operation could be considered atypical due to changes in the pre-retrofit system made to accommodate the new RTO. For example, setpoints may have been revised and ductwork modifications may have introduced new sources of heat loss. The

2015 and 2016 operation seems more representative of typical baseline operation; the evaluation and commissioning efforts agree on this approach.

The applicant assumed that the pollutant loads were the same in the pre and post periods. Electrical generation was similar during these periods (<5% difference) and is discussed in detail below.

1.2.2 On-Site Inspection and Metering

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

1.2.2.1 Summary of On-site Findings

The evaluators performed a site visit to observe the recuperative thermal oxidizer in operation and meet with facility operators including a plant engineer and finance staff. The M&V plan questions were reviewed and the available trend data was identified. Due to the significant amount of trending that was available, the evaluator did not install temporary metering equipment. Table 2-3 summarizes the data collected by the evaluation.

Table 5-47. Measure Verification

Measure Name	Verification Method	Verification Result
Recuperative Thermal Oxidizer	Collect SCADA trend data for a one-year period	The thermal oxidizer is operating as intended.
Siloxane Heat Exchanger	Collect SCADA trend data for a one-year period	The siloxane heat exchanger is operating as intended.

1.2.2.2 Measured and Logged Data

These tables summarize the data collected by the evaluation for the savings analysis. The evaluator did not install metering equipment at this site due to the amount of data that was available from the facility’s SCADA system. This trend data includes the heat flow monitoring points. The trend data also includes five years of total power plant production. Billing data was collected to perform a pre/post analysis of the facility’s natural gas consumption. This is summarized in Table 2-4.

Table 5-4 Evaluation Data Collection – Data Received

Source	Parameter	Interval	Duration
Facility SCADA	RTO Process Air Fan Speed Reference	1 hour	1 year
	RTO Process Fan Discharge Temperature	"	"
	RTO Combustion Chamber Inlet Temperature	"	"
	RTO Combustion Chamber Temperature	"	"
	RTO Heat Exchanger #1 Outlet Temperature	"	"
	RTO Stack Exhaust Temperature	"	"
	RTO Heat Exchanger #2 Air Inlet Temperature	"	"
	RTO Heat Exchanger #2 Air Outlet Temperature	"	"
	GCC Siloxane Regeneration Heater Output	"	"
	Siloxane Regen Heater Discharge Temperature	"	"
	Siloxane Train A Regen Out Temperature	"	"
	Siloxane Train B Regen Out Temperature	"	"
	RTO Process Air Fan Speed Reference	"	"
	Power Plant Electric Export	1 hour	5 years
	Power Plant Gross Generation	"	"
Billing Data	Natural Gas Consumption	Monthly	6/30/15 to 5/31/2020

1.2.3 Evaluation Methods and Findings

This section describes the evaluator methods and findings.

1.2.3.1 Evaluation Description of Baseline

The evaluator reviewed the project files and interviewed the site contact to gather information on the baseline. The baseline is the pre-existing conditions, which is the use of a biological vent gas oxidizer and siloxane flare with no heat recovery. The evaluation did not change the baseline equipment classification. This is an early replacement retrofit measure since the pre-existing equipment was operating before the retrofit and not at the end of its useful life. The biological vent gas oxidizer was two-years old and a single baseline is used in the evaluation.

The site reported that they had installed the original biological vent gas oxidizer as an urgent response to resolve neighbourhood odor complaints when a biological process went online in approximately 2013. The significant gas consumption of this oxidizer was unexpected and was the motivation to install the recuperative thermal oxidizer, but the baseline system was still operating.

1.2.3.2 Evaluation Calculation Method

Evaluation savings are based on a pre/post analysis of the facility's billing data, similar to the applicant's commissioning approach. The RTO is reportedly the only active equipment on the gas meter making the analysis feasible. The baseline siloxane flare and bio gas oxidizer were still in place prior to the retrofit and were the only active gas consumers on the utility meter prior to this retrofit project. The customer has not installed other gas efficiency projects over the past five years, although there are conflicting reports as to what the pre-retrofit combustion temperature was. Power plant production data was collected to verify that the generation has not changed significantly during the selected pre and post periods.

The evaluation analysis also includes heat flow calculations using the same energy model as the tracking analysis. These calculations are not used for the overall gas savings but only to provide insight as to discrepancies with the tracking analysis. The heat flow inputs are calibrated based on trend data collected from the facility's SCADA system. The evaluation calibrated the installed case gas consumption by adjusting the thermal oxidizer system efficiency.

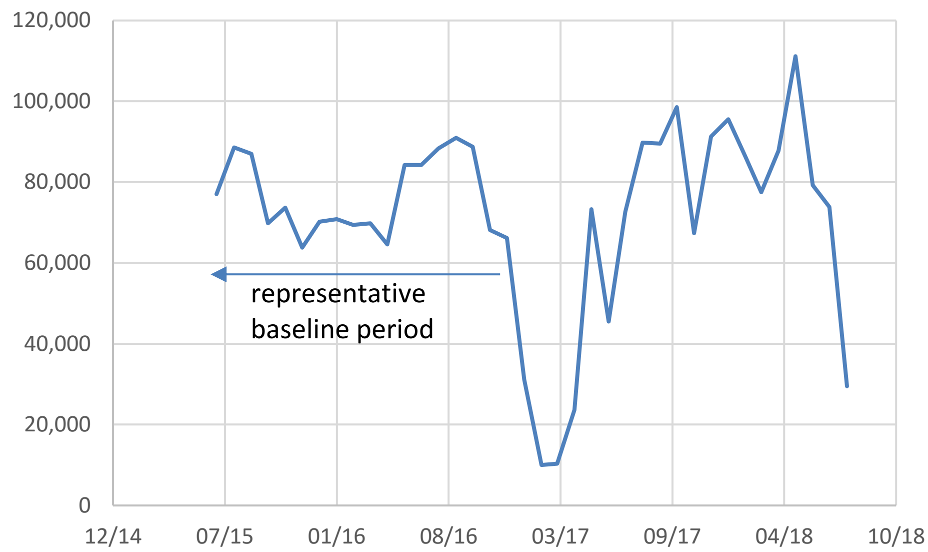
Baseline Gas Consumption

The evaluation uses the same period as the applicant to represent the baseline: 5/31/15 to 11/30/16. The average gas consumption during this period is the representative of the 12-month annual gas consumption in the baseline. The average daily gas use during the representative baseline period was multiplied by 365 days per year.

The new recuperative thermal oxidizer originally went online around January 1, 2017 and failed shortly after. There is a period in later 2017 and 2018 that also represents operation without the recuperative thermal oxidizer. The gas consumption during this later period is slightly increased compared to 2015 and 2016; however, this data is not used in the analysis because it may represent atypical pre-retrofit operation as the site resolved issues.

Evaluation observed the baseline annual gas use to be 914,392 therms and the installed consumption to be 219,451therms. The installed consumption is 25% of the baseline.

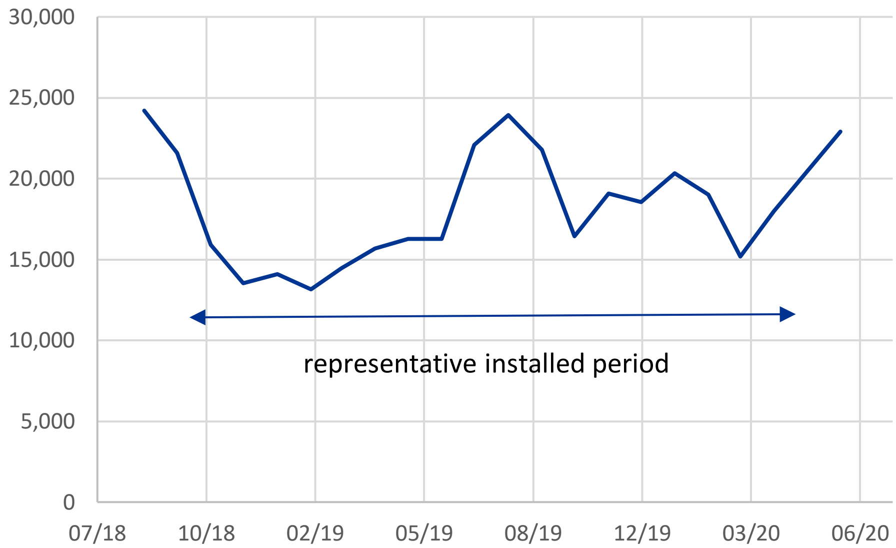
Figure 2-5 Baseline Plant Gas Consumption



Installed Gas Consumption

The evaluation uses August 2018 through May 2020 billing data to determine the installed case gas consumption. The average daily consumption during this period was multiplied by 365 to represent the annual installed gas consumption. Facility operators reported that this period is representative of typical operation. This data is also coincident with the SCADA system trends that were collected.

Figure 2-6 Installed Plant Gas Consumption



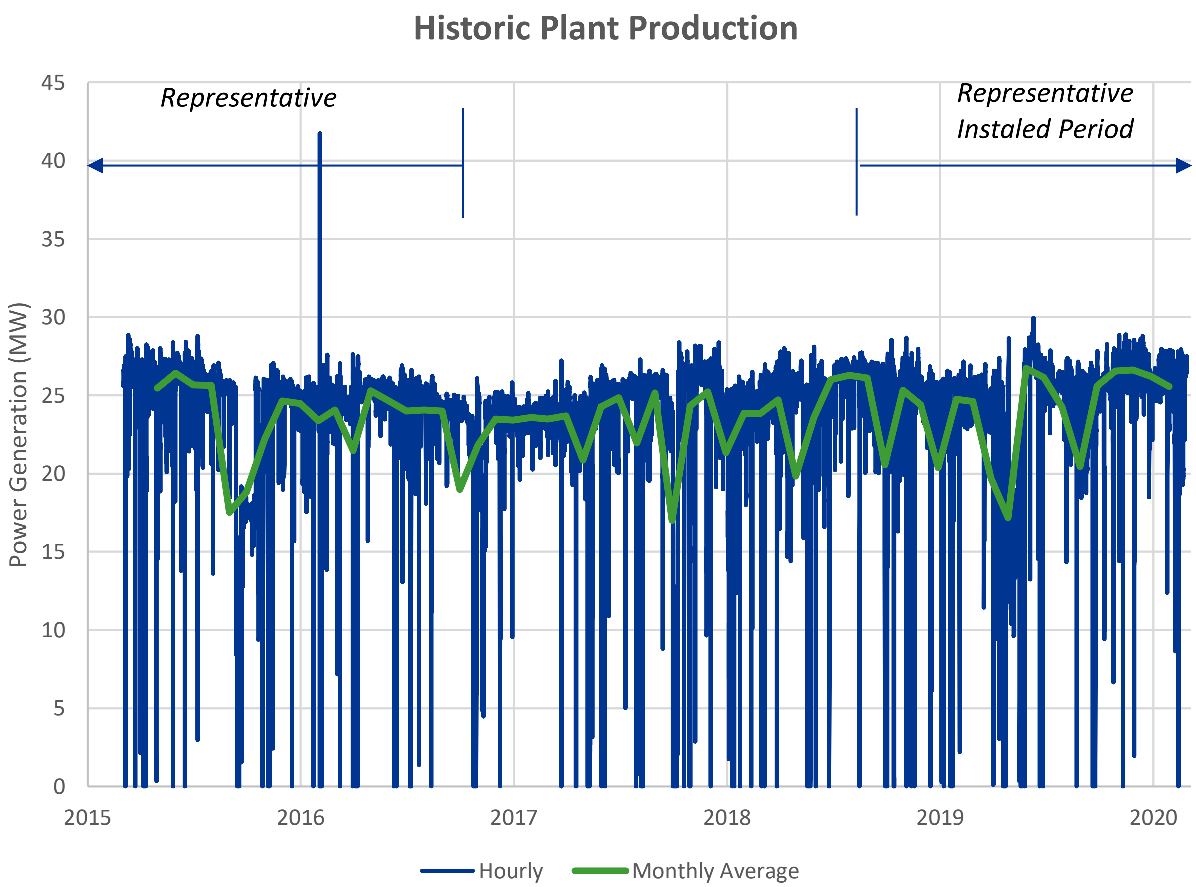
Plant Loads

SCADA trends included plant electrical generation for the previous 5 years, beginning in 2015. The generation data is shown below in Figure 2-7. Electrical generation is relatively constant over the 5 year period, which suggests that the oxidizer loads should be similar. The expectation is that more electrical generation would require more landfill gas, which would result in more bio-gas and siloxane removal. There should be some degree of relationship between the oxidizer/flare loads and electrical generation. Combustion fan speed and therefore airflow are relatively constant during the two operating modes, biogas vent only or bio gas vent with siloxane regen, which implies that the oxidizer loads are not sensitive to variations in electrical generation. The combustion fan speed is not being controlled such that it varies directly with electrical generation.

A review of the average generation output during the selected baseline and installed periods yields 23.2 MW and 24.0 MW, respectively. For comparison, the applicant Cx period was 7/4/18 to 10/11/18 in which the average plant generation was 24.2 MW.

The evaluation analysis does not account for this 6% difference in electrical generation between the selected baseline and installed periods since the impact on RTO loads are small and difficult to quantify. The evaluation analysis neglects any impact of the variation in electrical production in the baseline and installed cases.

Figure 2-7 Plant Electrical Generation



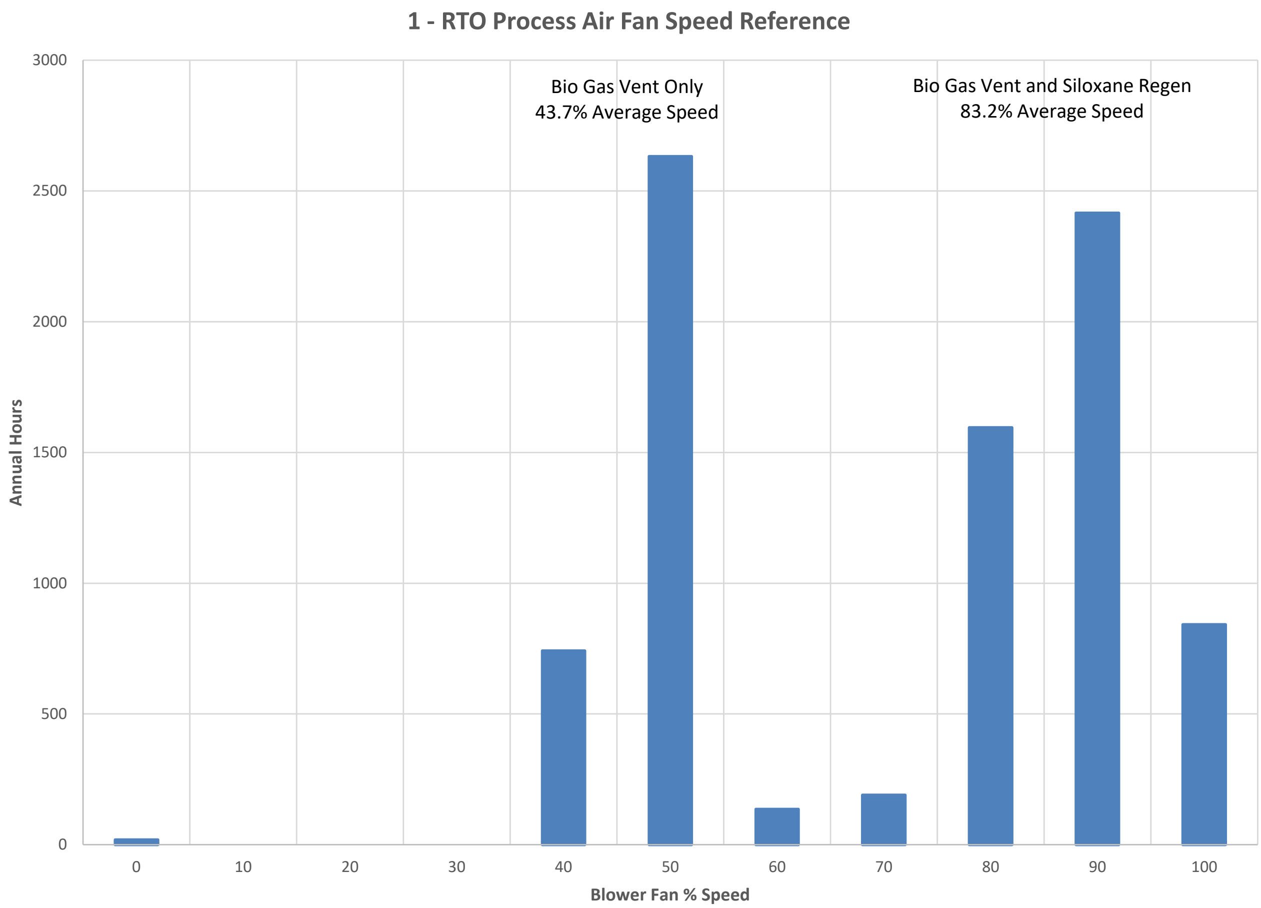
Installed Heat Flow

The evaluation collected trend data from the facility's SCADA system to verify parameters affecting the heat flow calculations. This data does not impact the total project savings, which is based only on the pre/post utility data. Evaluation included discussion of the heat flow calculations with the interest of better understanding deviations from the applicant's expected operation. The evaluation savings are very similar to the applicant savings; however, there are several factors that appear to be different than expected.

Trended process fan speed was used to estimate installed case airflow during periods when only the bio gas was active and when both the siloxane purge air was active as well. Figure 2-8 below summarizes the amount of time spent at the different operating speeds in a histogram. The process fan operates at an average of 43.7% speed when only bio gas is being served and 83.2% when siloxane is also being handled. The process fan and airflow are significantly lower when only the biogas vent process is active.

Siloxane regeneration occurs for 5,043 hours per year and bio gas venting occurs for 8,553 hours per year. Bio gas venting alone is the difference, 3,510 hours per year.

Figure 2-8 RTO Process Fan Speed Histogram

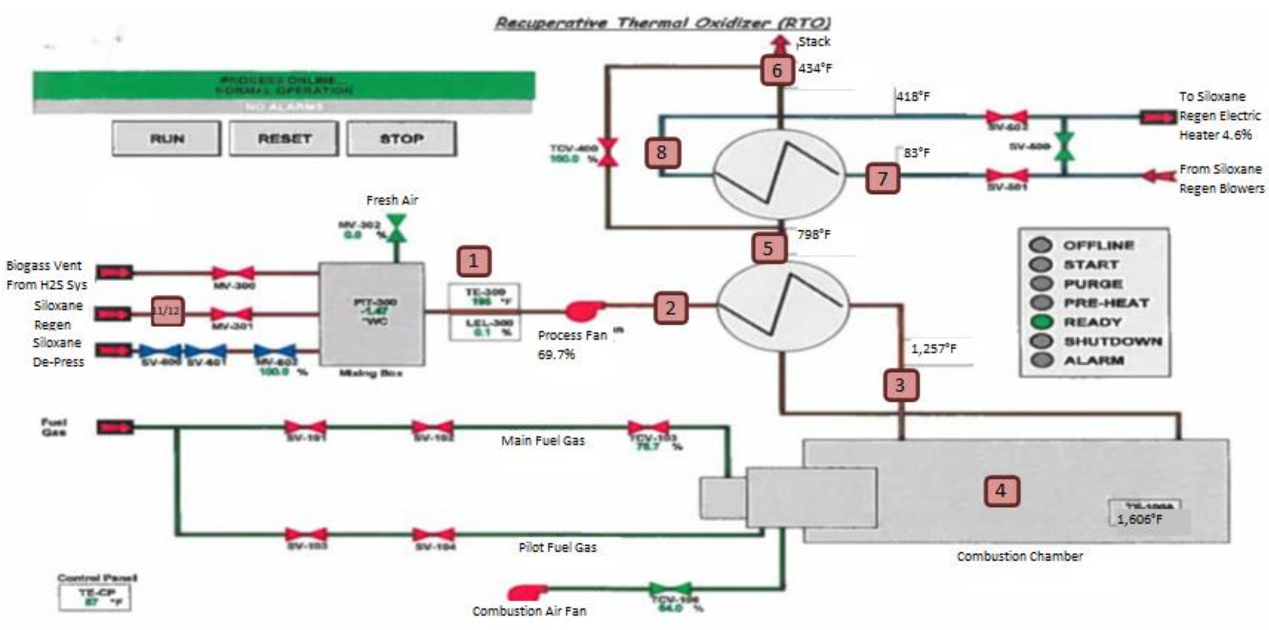


Temperatures at intermediate points of the thermal oxidizer vary similarly based on the fan speed. While the combustion temperature is the same during either operating condition (1,550°F), the intermediate temperatures vary somewhat because the inlet temperature coming off the siloxane beds is different than the bio gas vent. This difference affects the heat exchange effectiveness slightly. Figure 2-9 summarizes the average temperatures observed in the trend data. Figure 2-10 shows a system diagram with the locations of the corresponding RTO monitoring points.

Figure 2-9 Summary of Average Operating Conditions

Summary of Trend Data		Averages			
Point #	Point	Overall	Bio Vent	Sil Regen	Unit
1	RTO Process Air Fan Speed	66.5	43.7	83.2	%
2	RTO Process Fan Discharge Temp	114.1	91.2	131.0	°F
3	RTO Combustion Chamber Inlet Temp	1038.0	1,103	995	°F
4	RTO Combustion Chamber Temp	1538.9	1,533	1,549	°F
5	RTO HX-1 Outlet Temp	760.3	670	828	°F
6	RTO Stack Exhaust Temp	730.2	671	776	°F
7	RTO HX-2 Air Inlet Temp	163.3	175	155	°F
8	RTO HX-2 Air Outlet Temp	216.0	166	253	°F
9	Siloxane Regen Heater Output	10.7	1.2	17.7	kW
10	Siloxane Regen Heater Discharge Temp	188.9	83.5	265.7	°F
11	Siloxane Train A Regen Out Temp	116.8	89.0	137.2	°F
12	Siloxane Train B Regen Out Temp	117.9	89.3	138.9	°F

Figure 2-10 Installed System Diagram



Note: points 9 and 10 are part of the siloxane system and not shown on this schematic of the RTO

The recuperative thermal oxidizer effectiveness is calculated based on the entering and leaving temperatures of the heat exchanger. Based on the SCADA trend data, the evaluation calculates an average of 58% and 49% for bio gas vent and siloxane purge periods respectively, with an overall average of 53%. These values are calculated using the following expression for the mixture of biogas vent and siloxane regeneration streams:

RTO Effectiveness, % = 1 – [(RTO Outlet,°F - RTO Inlet,°F)/(RTO Combustion,°F – RTO Inlet,°F)]

Gas is consumed at the combustion chamber burner that raises the temperature from the RTO combustion inlet (point 3) to the combustion temperature (point 4). The gas input required is heat required to raise the air temperature minus the heat content of the pollutants. The evaluation makes the same assumptions about the pollutant heat content as the applicant that were provided by the site. Gas input is calculated using the following expressions:

Inlet Heat, Btu/h = Airflow, cf/h x Air density lb/cf x Specific Heat, Btu/lb·°F x (Comb. T, °F – Inlet T, °F)

Gas Input, Btu/h = [Inlet Heat, Btu/h – Pollutant Burnoff, Btu/h] / System Efficiency, %

Gas consumption is then calculated as follows:

Gas Consumption, therms = Gas Input, btu/h *Annual Hours

Note that this gas consumption is a separate calculation from the utility data analysis that is used as the primary method for the evaluated savings calculations. In theory this value should calibrate to the utility data. Model inputs were examined and those that are based on larger assumptions were adjusted to calibrate the heat flow model. The calibrated heat flow model offers additional insight into the RTO operation but does not impact the final project savings

There are two major inputs in these expressions that can't be measured: pollutant burn-off heat and system efficiency. By calibrating the energy model to billing data, the evaluation can estimate these values similar to how the applicant estimated these values. Since the calibration includes two independent variables, an assumption regarding one of the independent variables will affect the other.

Pollutant burn-off heat was determined by the applicant based on information provided by the site. The bio gas burn-off heat was estimated to be 1,225,920 Btu/h and no heat from the siloxane regeneration. These assumptions resulted in relatively low system efficiencies of approximately 50%.

The evaluation applied a similar methodology to the installed case RTO using the SCADA operating conditions and the utility data. Using the same burn-off heat assumption as the applicant results in a RTO system efficiency of 48%; however, if no burnoff heat is contributing to the final combustion temperature the RTU system efficiency is 90%. The latter is a more expected value for the RTO which has a near-100% combustion efficiency, but raises questions as to why the pollutant isn't contributing to the temperature rise. These questions can't be answered without additional data collection to examine pollutant burn-off. Since the reasoning would not impact the pre/post savings result it is unresolved in this evaluation analysis.

Baseline Heat Flow

In the baseline, the entering combustion temperature is the same as the process fan discharge temperature (point 2), or about 114°, since there is no heat recovery for either the bio gas vent or siloxane regeneration. In the installed case, the RTO and its associated heat exchangers increase the entering combustion temperature (point 3) to 1,038°F on average.

The applicant reported that the baseline combustion temperatures were 1,550°F and that value was used in its analysis. Conversely, the facility operators reported to the evaluator that the combustion temperature was previously 1,800°F in the baseline and that they lowered it to 1,550°F to reduce energy costs. There is no direct data available such as screenshots or trending data that confirm the 1,800°F combustion temperature was applicable to the baseline. While this value does not directly impact the savings calculation, it may be a useful in comparing the operating parameters.

Time of Day Analysis

The siloxane bed regeneration occurs as needed and is not based on a fixed schedule. As indicated by the relatively consistent process fan speeds across the week as shown in Figure 2-11. The evaluation analysis does not attempt to quantify savings for different periods during the week.

Figure 2-11 Process Fan Speed and Time of Week

Day of	Hour of Day																							
Week	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Monday	68	68	68	67	67	67	67	66	65	65	64	65	64	65	64	66	66	67	67	67	68	68	68	68
Tuesday	68	68	68	67	67	67	67	66	65	65	64	65	64	65	64	66	66	67	67	67	68	68	68	68
Wednesday	68	68	68	67	67	67	67	66	65	65	64	65	64	65	64	66	66	67	67	67	68	68	68	68
Thursday	68	68	68	67	67	67	67	66	65	65	64	65	64	65	64	66	66	67	67	67	68	68	68	68
Friday	68	68	68	67	67	67	67	66	65	65	64	65	64	65	64	66	66	67	67	67	68	68	68	68
Saturday	68	68	68	67	67	67	67	66	65	65	64	65	64	65	64	66	66	67	67	67	68	68	68	68

Electric Savings

Installed case trend data was collected to determine the siloxane electric resistance pre-heater energy use. This monitoring point included input kW on an hourly basis for one year. The 2019 pre-heater energy was observed to be 91,922 kWh.

Evaluation uses the same baseline pre-heater energy as metered by the applicant: 716,722 kWh. The applicant performed power metering of the pre-retrofit heater operation. The analysis of this data appears to be an accurate representation of the pre-retrofit heater energy use.

Electric savings are the baseline energy minus the installed pre-heater energy or 624,801 kWh.

1.3 Final Results

This section summarizes the evaluation results determined in the analysis above. Both the applicant and evaluation savings are based on billing data. The facility gas consumption figures shown below directly impact the evaluation results.

Table 5-48. Evaluation Results Summary

PA Application ID	Measure Name		Annual Savings (therms)
6795554	Recuperative Thermal Oxidizer and Secondary Heat Exchanger	Tracked	691,953
		Evaluated	694,942
		Realization Rate	100.4%

The evaluation observed 10% less airflow than the tracking analysis predicted, 4,021 cfm instead of 4,400 cfm. Operating temperatures were observed to be very similar to the tracking analysis. These values do not directly impact the savings calculation that is based on utility billing data.

The recuperative thermal oxidizer effectiveness was estimated to be operating an average of 53% system effectiveness, which is lower than the 70% effectiveness used in the tracking analysis. The evaluation RTO effectiveness was calculated based on trend data, which was not directly part of the savings calculation.

Operating hours were observed to be very similar to the tracking analysis.

The baseline gas consumption is slightly different in the evaluation. While both the evaluation and applicant baseline are based on 2015/2016 data, the applicant uses a more indirect approach. 2017/2018 consumption was determined, and an increase in consumption was deducted to determine the 2015/2016 consumption. This methodology included a unit conversion error that had a minor impact on the overall savings. The evaluation baseline consumption is a direct average of the 2015/2016 data.

The period in 2017 and 2018 after the RTO initially failed was considered atypical operation and not representative of baseline operation. This is discussed in further detail in Section 2.2.3.

Table 3-2 below is a summary of key tracking and evaluated parameters.

Table 5-49. Summary of Key Parameters

	BASELINE		PROPOSED / INSTALLED	
Parameter	Tracking Value(s)	Evaluation Value(s)	Tracking Value(s)	Evaluation Value(s)
Utility Meter Gas Consumption (therms)	959,856	914,392	267,903	219,451
RTO Process Fan Discharge Temp (°F)	132	114	132	114
RTO Combustion Chamber Temp (°F)	1,550	1,800	1,550	1,800
RTO Effectiveness (%)	N/A	N/A	70%	53%
Total Blower Airflow (cfm)	4,400	4,021	4,400	4,021
Annual Operating Hours	8,520	8,553	8,520	8,553
Pollutant Burnoff Heat (btu/h)	1,225,920	N/A	1,225,920	N/A
System Efficiency (%)	55%	58%	100%	90%

Note: Burnoff Heat and System Efficiency are model inputs that could not be measured. These values do not impact savings and are shown to help understand deviations. These values impact one another; lower burnoff heat results in higher system efficiency and vice versa.

1.3.1 Explanation of Differences

This section describes the key drivers behind any difference in the application and evaluation estimates of therm savings. Table 5-21 provides a summary of the differences between tracking and evaluated values.

Table 5-50. Summary of Deviations

End-use	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
Process	Operational	Operational differences include RTO effectiveness, airflow, baseline combustion temperature, pollutant burn-off heat, system efficiency	0.4%	Small increase in savings – Tracked savings were consistent with the applicant savings.

The utility data analysis showed a result very similar to the tracking analysis' commissioning effort, which was also based on utility data analysis. The evaluation collected trend data to demonstrate operating conditions to explain potential deviations. While the utility data analysis suggests that there were few overall deviations in claimed savings and some key parameters, there are some parameters that varied more significantly than others.

Evaluation observed RTO effectiveness of 53%, which is significantly less than the 70% effectiveness that was part of the original study. The impact of this deviation alone would reduce savings by 25%, so additional deviations are likely offsetting this factor.

Additionally, the 10% reduced airflow would reduce heat loads by 10%. If this reduction applied to both the baseline and installed case, savings would be 10% less. The tracking analysis baseline airflow was based on an email from a plant operator. If that airflow value was accurate, the evaluation finding of less airflow would increase savings by 10%.

Heat contribution from pollutant burn-off is a factor that is estimated and not measured. Evaluation initially made the same pollutant heat assumptions as the tracking analysis. This assumption resulted in an RTO system efficiency of 50%, which is difficult to explain or accept. Half of the gas input heat being lost through the RTO jacket would suggest poor insulation values. As the heat contribution of the pollutants approaches zero, the RTO system efficiency approaches 90%, which is a more expected value. More investigation would need to be performed to explain the pollutant heat contribution. Factors including the fuel-to-air mixture may be impacting the heat contribution differently in both the baseline and installed cases.

The baseline combustion temperature may also be contributing to the deviation in a positive manner. Facility personnel reported that the combustion temperature was previously 1,800°F and was reduced to save energy costs, which is contrary to the conditions reported in the application. The higher combustion temperature results in better system efficiencies for the baseline bio gas oxidizer and siloxane flare.

The higher baseline combustion temperature of 1,800°F would also help explain why more gas savings are being achieved despite the lower observed RTO heat recovery effectiveness and lower process fan airflow. The higher temperature would increase the baseline gas burner loads by 20%, increasing gas savings.

Regardless of the higher combustion temperature or pollutant burnoff heat value, the baseline system efficiency appears to have been much poorer than the new RTO. While the new RTO system efficiency appears to be about 90%, the baseline system efficiency appears to have been no better than 70%. This would represent a significant amount of heat in the form of jacket and distribution losses.

1.3.2 Lifetime Savings

The regenerative thermal oxidizer replaces equipment that was two years old and the evaluation classified the project as a single baseline retrofit replacement. The evaluators 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 smaller than the tracking lifetime savings because the evaluated first year savings are smaller than the tracking first year savings. Table 5-22 provides a summary of key factors that influence the lifetime savings.

Table 5-51. Measure 6795554 - Lifetime Savings Summary

Factor	Tracking	Application	Evaluator
Lifetime savings	12,455,154 therms	12,455,154 therms	12,508,949 therms
First year savings	691,953 therms	691,953 therms	694,942 therms
Measure lifetime	18 years	18 years	18 years
Baseline classification	Retrofit	Retrofit	Retrofit Single

The evaluation uses the same 18 year measure life as the applicant. Since the first-year savings are similar, the measure life savings are similar as well.

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

1.3.2.1 Ancillary impacts

This section explains the ancillary impacts associated with the electric savings. A second heat exchanger was installed to reclaim heat from the RTO discharge and use it pre-heat the siloxane bed purge air. This offset heat from a 500-kW electric resistance heater.

The original tracking analysis performed metering to determine that the baseline annual electric usage and anticipated savings of 716,722 kWh. The tracking analysis assumed that the need for electric heat would be eliminated with the use of the additional heat exchanger. During commissioning in 2018 it was observed that there was still significant electric heat being used and those savings were reduced to 199,156 kWh based on utility data review. Evaluation reviewed SCADA trends for 2019 and observed that the electric resistance heater energy use was 91,922 kWh. The evaluation electric savings are therefore 624,801 kWh, or 314% of the revised Cx electric savings. The Cx report noted that this secondary heat exchanger was not being fully utilized; commissioning efforts were undertaken, and that savings were expected to increase in the future – as they have done.

2018RIG55

Report Date: 9/27/20

Program Administrator	National Grid	
Application ID(s)	8038935, 8124543, 8898960, 8898962	
Project Type	Retrofit	
Program Year	2018	
Evaluation Firm	DNV GL	DNV·GL
Evaluation Engineer	Ryan Brown	
Senior Engineer	Glenn Gavi/Chad Telarico	

Future inclusion pending customer approval to publish.

2018RIG58

Report Date: 7/10/20

Program Administrator	National Grid	
Application ID(s)	7474075	
Project Type	Retrofit	
Program Year	2018	
Evaluation Firm	DNV GL	DNV·GL
Evaluation Engineer	Laengheng Khoun; Glenn Gavi	
Senior Engineer	Chad Telarico	

1 Evaluated Site Summary and Results

The project was implemented at a large military research facility and consisted of replacing or repairing 36 pre-existing steam traps that have failed. Failed traps were classified as leaking. The total project savings for this measure is 18,863 therms. The 36 pre-existing steam traps are in 16 different buildings in the research facility. According to an interview with the site contact, the steam traps are likely served by several different boilers, however, the site contact could not specify exactly how many as the boiler plant was located off-site and inaccessible to evaluators.

The evaluation results are presented in Table 5-9. The project is classified as a retrofit with a single baseline. Evaluators were permitted to access 3 buildings which consisted of 15 total steam traps. Of the 3 buildings visited, the evaluators visually inspected all 15 traps and metered 8 traps. The evaluators conducted ultrasonic leak checks, took infrared pictures with temperature readings, and installed thermocouple loggers where feasible. It was also found that the facility's heating season typically lasts from mid-October to mid-May.

Table 5-52. Evaluation Results Summary

PA Application ID	Measure Name	Annual Savings (therms)	
7474075	Steam Traps	Tracked	18,863
		Evaluated	16,387
		Realization Rate	86.9%

1.1 Explanation of Deviations from Tracking

The evaluated savings found a 13.1% decrease from evaluated savings to tracked savings. The key reason is a reduced pressure value from 200psi to 15 psi for one trap. The secondary and minor deviation from tracking are metered operating hours that were different than claimed in the applicant documentation.

1.2 Recommendations for Program Designers & Implementers

Overall, the tracker estimation and inputs to the calculator were well documented. The main discrepancy is a high-pressure value does not reflect onsite operating conditions. It is recommended that the parameters used to estimate savings (pressure, temperature etc.) in the tracking documentation mirror as close to operating conditions as possible.

1.3 Customer Alert

The customer was happy with the relatively minor upgrade project and is happy to continue to work with National Grid in the future.

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 with the information available.

The measure evaluated was implemented by the site to fix steam leaks in the facility's steam distribution system by replacing or repairing failed steam traps. The measure involves replacing (36) steam traps that were found to be leaking. This was a result of a facility-wide steam trap survey that was conducted. A total of (963) steam traps were inspected as part of the survey. The main function of steam traps is to remove condensate from the steam lines while reducing steam loss. A failed steam trap would result in leaking of pressurized steam from the steam lines either to the outside air or into the condensate lines. This could result in multiple problems such as water hammer, increased boiler load, reduced system efficiency, steam line rupture etc. Maintenance of steam traps is essential for proper functioning of equipment in the steam distribution system.

The tracking documentation lists the steam traps that were inspected as part of the survey and classifies them as fully operational, leaking, or not in service. The following sections present the applicant and evaluator approaches for determining the gas savings resulting from fixing the steam leaks.

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

The measure was classified as a retrofit measure. The pre-existing condition was described based on a steam trap survey conducted by a third-party steam specialist. In the survey, each trap was classified as fully operational, plugged, leaking, blowing by or not in service. A total of (963) traps were inspected as part of the survey. The steam distribution system consists of multiple boilers serving multiple heating systems (such as unit heaters, heat exchangers etc.) in multiple buildings throughout the facility. The pre-existing steam traps were of the following types:

- Float and Thermostatic
- Thermostatic
- Inverted Bucket

The traps were located between 3 and 20-feet above the ground. The steam pressure in the lines were ranging from 15 psi_g to 450 psi_g, depending on the application with the steam lines serving the facility's heating system which mainly consisted of unit heaters. Based on an interview with the site contact and verified for spring operation from metered data, the facility's heating season typically lasts between mid-October to mid-May. The 36 steam traps which were replaced are found in Table 5-53 organized by steam temperature.

Table 5-53. Steam Traps grouped by operating steam temperature

Steam Temperature (°F)	Number of Steam Traps
250	31
320	3
388	1
460	1
Total	**36**

Table 5-10 shows the list of traps that were proposed to be fixed during the steam leak survey and the steam trap characteristics.

Table 5-54. Summary of Baseline Equipment

Sl.No	Trap Tag	Trap Application	Pipe Dia (in)	Orifice Dia (in)	Steam Pressure (psig)
1	610	Unit Heater	0.75	7/32	15
2	651	Unit Heater	0.75	7/32	15
3	144	Drip Leg	0.75	5/16	15
4	145	Drip Leg	0.75	5/16	15
5	203	Drip Leg	0.75	7/32	15
6	407	Drip Leg	0.50	7/32	15
7	320	Unit Heater	0.75	7/32	15
8	243	Drip Leg	0.75	7/32	75
9	298	Drip Leg	0.50	5/16	15
10	149	Drip Leg	0.75	7/32	15
11	184	AHU	0.75	3/16	15

Sl.No	Trap Tag	Trap Application	Pipe Dia (in)	Orifice Dia (in)	Steam Pressure (psig)
12	185	AHU	0.75	3/16	15
13	187	AHU	0.75	3/16	15
14	188	Drip Leg	0.50	3/16	15
15	87	Drip Leg	0.75	5/16	200
16	621	Heat Exchanger	0.75	7/32	15
17	189	Drip Leg	0.75	3/16	15
18	67	Drip Leg	0.75	3/16	75
19	68	Drip Leg	0.75	7/32	75
20	231	Flash Tank	1.00	7/32	15
21	233	Drip Leg	1.50	1/2	15
22	234	Heat Exchanger	2.00	1/2	15
23	33	Drip Leg	0.75	7/32	15
24	307	Unit Heater	0.75	7/32	15
25	637	Drip Leg	0.75	7/32	15
26	643	Unit Heater	1.25	7/32	15
27	642	Drip Leg	0.75	7/32	15
28	641	Heat Exchanger	2.00	7/32	15
29	287	Drip Leg	0.75	3/16	15
30	283	Drip Leg	0.75	7/32	15
31	138	Drip Leg	0.50	1/8	450
32	76	Drip Leg	0.50	7/32	15
33	77	Drip Leg	0.75	7/32	15
34	81	AHU	1.50	7/32	15
35	217	Drip Leg	0.50	1/8	15
36	229	Heat Exchanger	2.00	13/32	15

2.1.2 Applicant Description of Installed Equipment and Operation

The site conducted a facility-wide steam trap survey to detect faulty steam traps. The site fixed the leaks by replacing (36) failed steam traps out of the (963) traps that were inspected as part of the survey. The steam traps that were fixed are shown in Table 5-10 above.

2.1.3 Applicant Energy Savings Algorithm

The applicant used the new state-wide 2017 Steam Traps calculator to calculate the savings for repaired or replaced failed traps. The custom savings equation developed through the referenced study has been adopted by the evaluators and is described below.

$$Svgs = \left(60 \times \frac{\pi}{4} D^2 \times (P + 14.7)^{0.97}\right) \times \frac{LF \times C_D \times (h_g - h_f) \times CR \times Hours}{100{,}000 \times \eta}$$

where,

$Svgs$	= Annual energy savings per year (therms)
60	= Empirically derived factor in Grashof equation ($lb_m/(in^{0.06}\text{-}lb^{0.97}\text{-}hr)$)
D	= Diameter of steam trap orifice (inches)
P	= Pressure of steam in line at trap (psig); add 14.7 to get psia
0.97	= Empirically derived factor in Grashof equation
LF	= Leak factor is determined through field testing and accounts for partially obstructed orifices or non-ideal steam flow. Plugged traps use a value of 0% (i.e. no savings result from fixing a plugged trap), leaking traps use a value of 26% and blowing by traps use a value of 55%
C_D	= Discharge coefficient (70%) due to trap hole not being a perfect orifice
h_g, h_f	= Enthalpy of saturated steam and liquid, respectively; associated with specified trap operating pressure (Btu/lb)
CR	= Condensate return factor accounting for energy returned from leaking/blowing by traps via a condensate return line. (36.3%)
$Hours$	= Hours per year that a trap is pressurized and operating
$100{,}000$	= Therms per Btu conversion
η	= Boiler plant efficiency

2.1.4 Evaluation Assessment of Applicant Methodology

The applicant used the state-wide 2017 Steam Traps calculator which is the standard template used by the Program Administrator to calculate the savings for repaired the failed traps. The evaluator approves of the calculator and will modify the calculator with adjusted inputs in accordance with findings on site to calculate the evaluator savings.

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

A site visit was conducted in February 2020 to verify the steam traps were replaced. Spot measurements were conducted (temperature checks and ultrasonic readings) and HOBO thermocouple loggers were installed to confirm the operation of the steam traps that were claimed to be replaced as part of the project. The site visit involved a combination of visual inspection, measuring temperature readings, and using an ultrasonic leak detector to determine if the traps operate as intended.

The site is a military facility that consists of multiple buildings. The facility's steam distribution system has a central steam plant that serves all the facility's steam requirements. The steam is used for space heating purposes and the different steam lines serve multiple end-use applications such as unit heaters, heat exchangers, and other heating systems. The operating pressure of the steam varies between 15 and 450 psi_g. The evaluators could not visit all buildings due to facility restrictions and were only permitted by the site personnel to visit (3) buildings in the facility that contained (15) steam traps that were claimed as part of the project in the applicant documentation.

During the site visit, the evaluators visually inspected 15 steam traps. The evaluators conducted ultrasonic leak checks, took infrared pictures, documented temperature readings, and installed thermocouple loggers where feasible. The evaluators found that 2 of the steam traps were not energized during the time of the initial visit, i.e. there was no steam passing through the lines on which the two traps were located. However, the two traps were verified as operational after reviewing logger data for the steam traps where the traps were not operable during the site visit. The evaluators confirmed that all the metered traps were supplied by the same central steam plant. The site contact confirmed that the heating season is typically from October to May.

Table 5-11 summarizes the measures verified after project installation and the changes found during verification.

Table 5-55. Measure Verification

Measure Name	Verification Method	Verification Result
Steam Traps	Conduct ultrasonic leak checks, take infrared pictures, document temperature readings, and install thermocouple loggers	Steam traps are operating as expected. Operation hours vary compared to applicant estimations.

2.2.2 Measured and Logged Data

The tasks completed by the evaluators during the site visit is summarized below:

- Visually inspect at least 15 (sampled) new/repaired steam traps
- Take infrared pictures with temperature readings of new/repaired steam traps
- Perform ultrasonic leak checks using an ultrasonic leak detector on a sample of (15) new/repaired steam traps
- Install thermocouple loggers to meter temperature data on sampled steam traps where feasible (installed 8 loggers)

The steam trap sample subgroups were created based on steam trap type, pipe size, and steam trap pressure. A summary of the sample groups, the characteristics used to group steam traps, and the amount of steam traps spot measured or metered are found in Table 5-14. The steam trap grouping numbers for each steam trap in the population of replaced/repaired steam traps are found in Table 5-13 along with other steam trap characteristics.

Table 5-56. List of Steam Traps with Ultrasonic Readings

Group	Properties			Steam Trap Count	Spot Checked Steam Trap Count	Metered Steam Trap Count
	Type	Pipe Size (in)	Pressure (psig)			
1	Float and Thermostatic	0.5,0.75,1.00	15	15	4	4
2	Float and Thermostatic	1.25,1.5,2	15	6	3	1
3	Inverted Bucket	0.5,0.75	15	6	6	2
4	Thermodynamic	0.5	15	1	0	0
5	Thermostatic	0.5,0.75	15	3	0	0
6	Float and Thermostatic	All	75	2	0	0
7	Inverted Bucket	0.75	75	1	0	0
8	Thermostatic	0.75	200	1	1	0
9	Thermodynamic	0.5	450	1	1	1[16]

Table 5-57. Steam Trap Groups

Sl.No	Trap Tag #	Sample Group #	Trap Application	Trap Type	Pipe Dia (in)	Orifice Dia (in)	Steam Pressure (psig)
1	610	1	Unit Heater	Float & Thermostatic	0.75	7/32	15
2	651	1	Unit Heater	Float & Thermostatic	0.75	7/32	15
3	144	5	Drip Leg	Thermostatic	0.75	5/16	15
4	145	5	Drip Leg	Thermostatic	0.75	5/16	15
5	203	1	Drip Leg	Float & Thermostatic	0.75	7/32	15
6	407	1	Drip Leg	Float & Thermostatic	0.50	7/32	15
7	320	1	Unit Heater	Float & Thermostatic	0.75	7/32	15
8	243	6	Drip Leg	Float & Thermostatic	0.75	7/32	75
9	298	5	Drip Leg	Thermostatic	0.50	5/16	15
10	149	1	Drip Leg	Float & Thermostatic	0.75	7/32	15
11	184	3	AHU	Inverted Bucket	0.75	3/16	15
12	185	3	AHU	Inverted Bucket	0.75	3/16	15
13	187	3	AHU	Inverted Bucket	0.75	3/16	15
14	188	3	Drip Leg	Inverted Bucket	0.50	3/16	15

16 Logger did not log properly and data was not collected.

Sl.No	Trap Tag #	Sample Group #	Trap Application	Trap Type	Pipe Dia (in)	Orifice Dia (in)	Steam Pressure (psig)
15	87	8	Drip Leg	Thermostatic	0.75	5/16	200
16	621	1	Heat Exchanger	Float & Thermostatic	0.75	7/32	15
17	189	3	Drip Leg	Inverted Bucket	0.75	3/16	15
18	67	7	Drip Leg	Inverted Bucket	0.75	3/16	75
19	68	6	Drip Leg	Float & Thermostatic	0.75	7/32	75
20	231	1	Flash Tank	Float & Thermostatic	1.00	7/32	15
21	233	2	Drip Leg	Float & Thermostatic	1.50	1/2	15
22	234	2	Heat Exchanger	Float & Thermostatic	2.00	1/2	15
23	33	1	Drip Leg	Float & Thermostatic	0.75	7/32	15
24	307	1	Unit Heater	Float & Thermostatic	0.75	7/32	15
25	637	1	Drip Leg	Float & Thermostatic	0.75	7/32	15
26	643	2	Unit Heater	Float & Thermostatic	1.25	7/32	15
27	642	1	Drip Leg	Float & Thermostatic	0.75	7/32	15
28	641	2	Heat Exchanger	Float & Thermostatic	2.00	7/32	15
29	287	3	Drip Leg	Inverted Bucket	0.75	3/16	15
30	283	1	Drip Leg	Float & Thermostatic	0.75	7/32	15
31	138	9	Drip Leg	Thermodynamic	0.50	1/8	450
32	76	1	Drip Leg	Float & Thermostatic	0.50	7/32	15
33	77	1	Drip Leg	Float & Thermostatic	0.75	7/32	15
34	81	2	AHU	Float & Thermostatic	1.50	7/32	15
35	217	4	Drip Leg	Thermodynamic	0.50	1/8	15
36	229	2	Heat Exchanger	Float & Thermostatic	2.00	13/32	15

Most steam traps are grouped in sample group numbers 1-3. They account for 27 of the 36 steam traps repaired or replaced at the facility. These three sample groups were spot checked more than others and had meters placed to capture enough operating hour schedules. Groups without spot checks or meters were not seen during the site visit due to building access restrictions.

The thermocouple loggers were installed to estimate the operating hours of the steam traps, i.e. the total hours the steam lines were energized during the metering period. The table below shows the list of HOBO thermocouple temperature loggers that were installed during the site visit:

Table 5-58. List of Thermocouple temperature loggers installed

Sl.No	Logger Type	Metering Period	Logger ID	Metering Interval	Steam Trap Tag #	Group #
1	HOBO Thermocouple	02/06/20 – 06/18/20	20531923	5-Minutes	642	1 & 2[17]
2	HOBO Thermocouple	02/06/20 – 06/18/20	20531924	5-Minutes	87	8
3	HOBO Thermocouple	02/06/20 – 06/18/20	20550138	5-Minutes	621	1
4	HOBO Thermocouple	02/06/20 – 06/18/20	20550140	5-Minutes	185	3
5	HOBO Thermocouple	02/06/20 – 06/18/20	20550205	5-Minutes	637	1
6	HOBO Thermocouple	02/06/20 – 06/18/20	20556574	5-Minutes	184	3
7	HOBO Thermocouple	02/06/20 – 06/18/20	20580013	5-Minutes	77	1
8	HOBO Thermocouple	02/06/20 – 06/18/20	20557180	5-Minutes	138	9

The loggers captured surface temperature of the steam line and ambient air temperature in 5-minute intervals. One logger (installed on Trap# 138 in sample group 9) failed and did not record any data. Another logger (installed on Trap# 642 in sample group 1&2) showed steam trap temperatures similar to ambient temperatures while the steam trap was energized during the site visit with a surface temperature spot measurement of 248°F. The logger data was therefore ignored for evaluation purposes due to possible inaccuracy in data collection (tape with thermocouple came off pipe, meter fell, etc.). The metering of the 8 steam traps provided valid data for 6 traps.

2.3 Evaluation Methods and Findings

This section describes the evaluator methods and findings.

2.3.1 Evaluation Description of Baseline

The evaluation baseline is a retrofit with a single baseline. The evaluator agrees with the applicant baseline based on data collected during the site visit and the results of the steam trap survey conducted. Discussion with the site contact confirmed that the pre-existing traps were leaking and that a total of (36) traps were fixed, which agrees with the number claimed in the applicant documentation.

17 Meter monitored drip leg steam trap on main line that fed the heat exchanger steam trap

2.3.2 Evaluation Calculation Method

The evaluated savings for this site were calculated using the state-wide 2017 Steam Trap calculator used by PAs.

Spot temperature measurements were taken to confirm the inlet steam pressure, using the saturated steam properties. Ultrasonic decibel readings were taken before and after each trap, as well as in proximity to each trap's orifice, to determine whether the trap appears to function. Traps that are failed open typically have a decibel reading at the orifice that is higher than the decibel reading before or after the trap. None of the traps tested exhibited that characteristic, so all the traps were found to be functioning properly. The following table shows the temperature and ultrasonic readings taken at the following steam traps:

Table 5-59. List of Steam Traps with Temperature and Ultrasonic Readings with Metered Hours

Sl. No	Trap Tag #	Evaluator Inlet Pressure (psi_g)	Evaluated Hours (hr)	Temperature (°F)			Ultrasonic (dB)			[Max(In,Out) - Orifice]>0?	Trap Functional from Ultrasonic
				Inlet temp (°F)	Outlet Temp (°F)	Orifice Temp (°F)	Inlet (dB)	Outlet (dB)	Orifice (dB)		
1	184	15	5,570	236	209	234	19	11	10	9	YES
2	185	15	5,570	236	234	211	23	23	21	2	YES
3	187	15	5,570	231	219	225	22	18	18	4	YES
4	188	15	5,570	252	212	238	11	12	10	2	YES
5	87	15	3,075	292	215	272	36	22	25	11	YES
6	621	N/A[18]	4,554	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/V
7	189	15	5,570	230	173	221	5	6	3	3	YES
8	637	15	4,554	242	219	244	40	21	21	19	YES
9	643	15	4,764	241	206	238	19	15	18	1	YES
10	642	15	4,554	248	159	212	23	15	18	5	YES
11	641	N/A[19]	4,764	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/V
12	138	450	4,764	302	212	199	12	3	7	5	YES
13	76	15	4,554	239	213	246	31	15	16	15	YES
14	77	15	4,554	232	185	229	18	14	12	6	YES
15	81	15	4,764	230	221	221	8	12	6	6	YES

The evaluators metered a sample of the total number of traps (8) and classified the traps into subgroups based on steam trap type, pipe size, steam pressure. The loggers were installed to capture the maximum number of steam traps that were classified based on the sample groups and access at the facility. The thermocouple loggers confirm traps are energized until mid-May as stated by the site

18 Trap was found to unenergized at the time of the visit but was found to be working based on logger data
19 Trap was found unenergized at the time of the visit

contact. Figure 5-3 and Figure 5-4 shows the constant energized period until boiler shutdown for the main steam line and the on/off behaviour for calls of heat during the shoulder months of March, April, and May for space heating. Annual hours are calculated from the number of hours during the heating season (October – May) and multiplied by the percentage of energized period calculated from metered data.

Results from the sampled steam traps in each subgroup are extrapolated to the population from the results found onsite. Onsite engineers found all sampled steam traps were functioning correctly. Therefore, the properly functioning results were extrapolated to show all steam traps in the population are functioning correctly.

Total operational hour results from logger data are extrapolated to the groups based on the sample group the logger represents. Hours for groups that were not metered are the average of all metered steam traps. The estimated tracking hours of operation estimated 4,752 annual hours, and the average of all metered steam traps is 4,764. Evaluators believe the average steam trap hours of operation for non-metered steam traps is representable.

Evaluators reduced the steam trap pressure for tag #87 as both the temperature spot measurement and logger data were both lower than the estimated 200psi. The average temperature of operation and spot measurement provide a steam trap operating pressure of 15psi. Evaluation engineers placed a logger on the 450psi steam trap; however, the logger did not log correctly. Therefore, engineers will leave the 450psi operating pressure in lieu of lowering the operating temperature since a measurement from a more accurate measurement tool is not available and the high probability the steam trap is installed on a high-pressure line (i.e. verified by higher surface temperature from IR gun spot check, several other surveyed steam traps operate at 450psi, the steam trap is a drip leg likely on the main line).

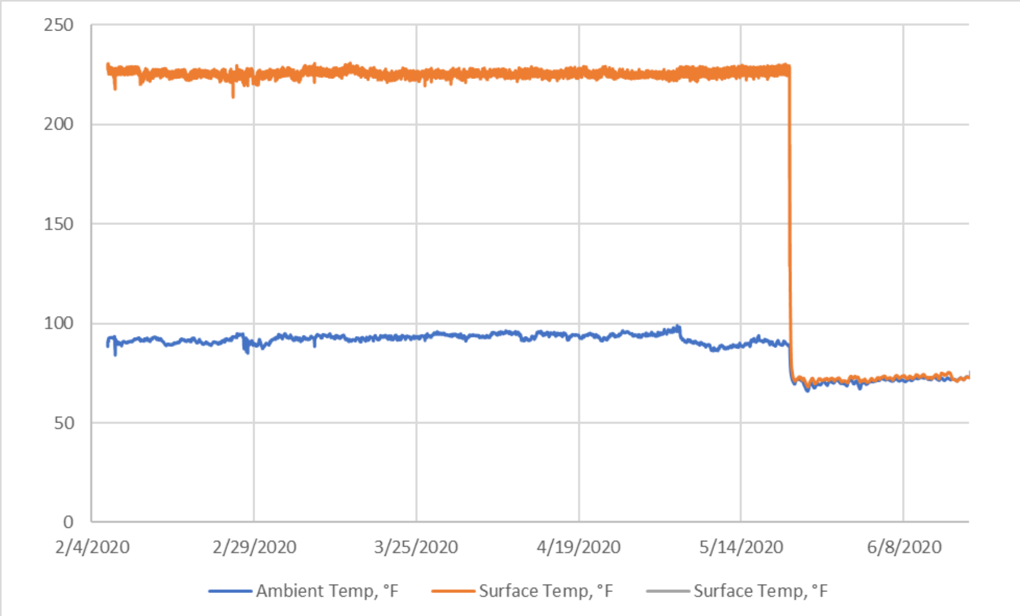


Figure 5-7. Steam trap operation for tag #77 in group 1

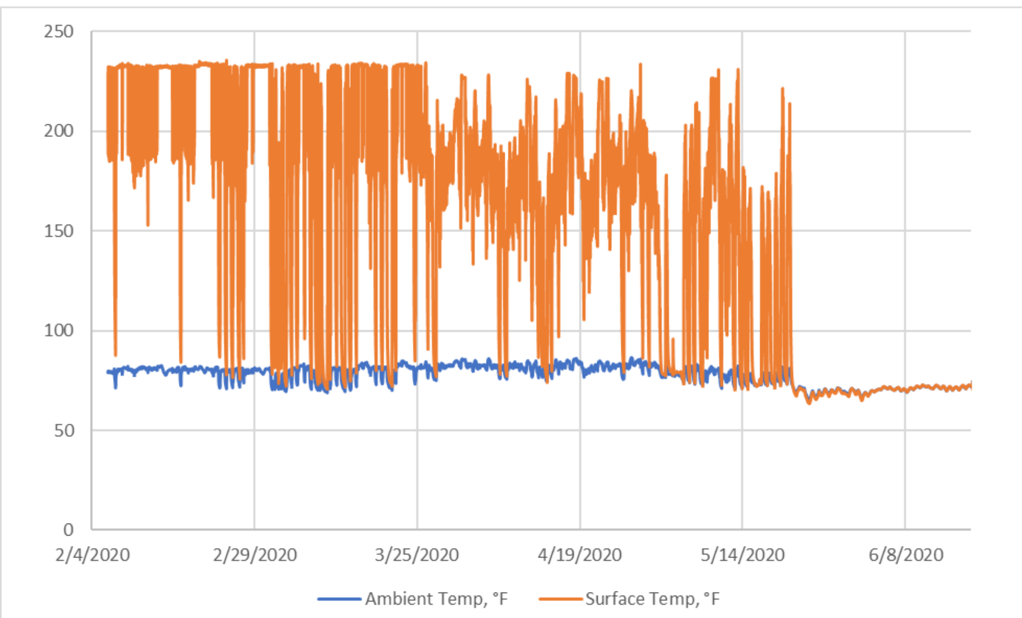


Figure 5-8. Steam trap operation for tag #87 in group 8

2.4.3 Gas Billing Analysis

The evaluators analysed the site's billing data for a period of 17 months prior to the installation and 16 months post the installation of the project and the time during the project's installation. The natural gas consumption (in therms) obtained for this site from the utility billing data was plotted against the heating degree days (HDD) as shown in Figure 5-9.

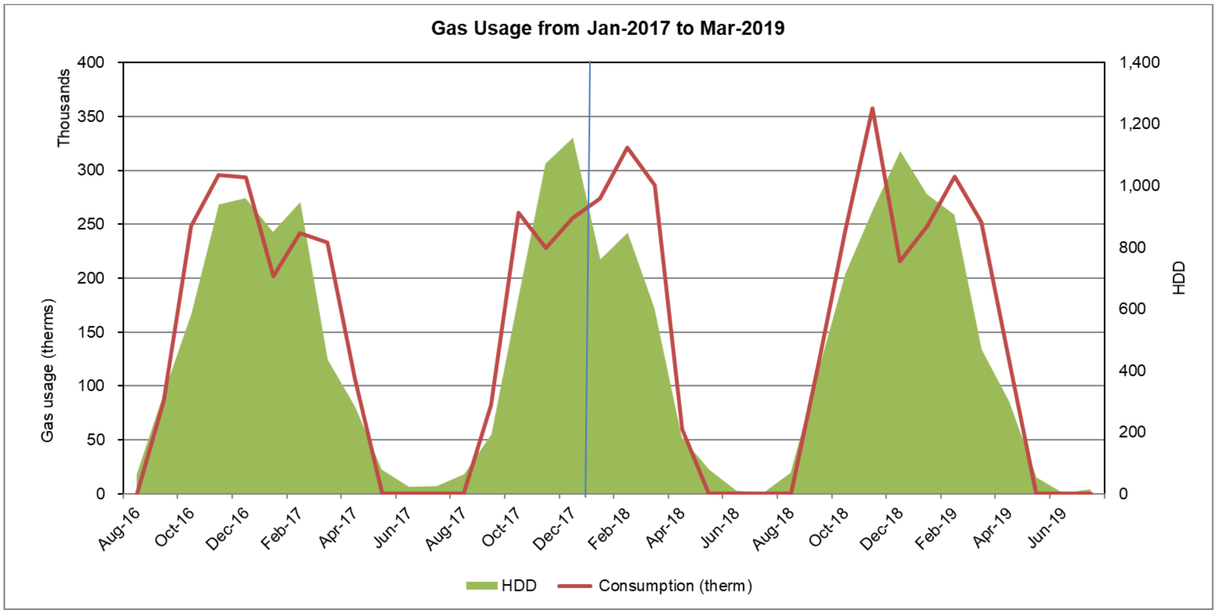


Figure 5-9. Therms consumption vs. HDD from utility billing data

The therms obtained from the billing data was normalized using actual and TMY3 weather data for both the pre and post case therms consumption data to ascertain if the billing data reflected the changes in the site's gas consumption profile resulting from the implementation of the project, in this case, fixing the steam leaks by replacing faulty steam traps. As shown in Figure 5-10, the billing data does not reflect the reduced gas consumption in the post case following the implementation of the project. The billing analysis shows a large amount of additional gas usage estimated after normalizing to billing data. It is likely that 36 steam traps would not show considerable change in a facility as large as this research campus, but it is also possible there were additional loads placed on the facility as a new building was constructed. The savings percentage of the steam traps is approximately 1% of the total gas annual consumption at the facility.

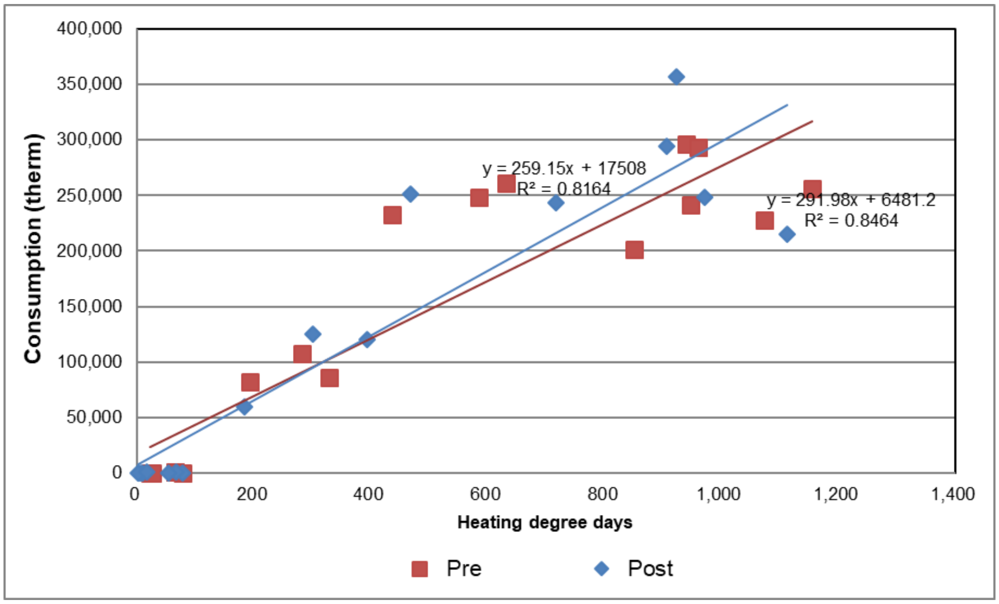


Figure 5-10. Pre- and post-installation correlation with degree days

3 Final Results

This section summarizes the evaluation results determined in the analysis above. Both the applicant and evaluation savings are based on the new state-wide 2017 Steam Traps calculator. The total evaluation results and realization rate are found below in Table 5-19.

Table 5-60. Evaluation Results Summary

PA Application ID	Measure Name	Annual Savings (therms)	
7474075	Steam Traps	Tracked	18,863
		Evaluated	16,387
		Realization Rate	86.9%

The evaluation observed 13.1% less savings than the tracking analysis predicted. Operating pressure from 1 steam trap resulted in the largest discrepancy with operating hours as a minor discrepancy.

Table 3-2 below is a summary of key tracking and evaluated parameters.

Table 5-61. Summary of Key Parameters

	BASELINE		PROPOSED / INSTALLED	
Parameter	Tracking Value(s)	Evaluation Value(s)	Tracking Value(s)	Evaluation Value(s)

Tag #87 Steam Pressure	200 psi	15 psi	200 psi	15 psi
Average Operating Hours	4,752	4,764	4,752	4,764

3.1 Explanation of Differences

This section describes the key drivers behind any difference in the application and evaluation estimates of therm savings. Table 5-21 provides a summary of the differences between tracking and evaluated values.

Table 5-62. Summary of Deviations

End-use	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
Operating Pressure	Operational	The operating pressure of steam trap tag #87 was reduced from 200psi to 15psi	-9.4%	Decrease in savings due to lower operating pressure
Hours of Operation	Operational	The average hours of operation for the repaired steam traps is different than the applicant estimation. Even though average is higher, the lower operating hours has the highest impact on tag #87 from 4,752 annual hours to 3,075 hours.	-3.7%	Decrease in savings due to change in hours of operation

3.2 Lifetime Savings

The replaced equipment is classified as a single baseline retrofit replacement. The evaluators 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 smaller than the tracking lifetime savings because the evaluated first year savings are smaller than the tracking first year savings. Table 5-22 provides a summary of key factors that influence the lifetime savings.

Table 5-63. Lifetime Savings Summary

Factor	Tracking	Application	Evaluator
Lifetime savings	18,863 therms	18,863 therms	16,387 therms
First year savings	113,178 therms	113,178 therms	98,324 therms
Measure lifetime	6 years	6 years	6 years
Baseline classification	Retrofit	Retrofit	Retrofit Single

The evaluation uses the same 6-year measure life as the applicant.

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

3.2.1 Ancillary impacts

There are no ancillary impacts from this retrofit measure.

2018RIG64

Report Date: 10/02/2020

Program Administrator	National Grid
Application ID(s)	7454434
Project Type	New Construction – Lost Opportunities
Program Year	2018
Evaluation Firm	DMI
Evaluation Engineer	Mickey Bush
Senior Engineer	Mickey Bush

Evaluated Site Summary and Results

This project consists of the replacement of an existing laundry washing machine with a new Xeros washing machine at a laundromat. Xeros washing machines reduce the amount of hot water required for the washing process by using a nylon polymer bead technology.

The claimed annual gas savings for the reduction in domestic hot water load was 3,687 therms. The project was classified as a New Construction project with a 15 year measure. A 472,602 gallon reduction in annual hot water use was also claimed as part of the project.

This site includes drop off laundry services, dry cleaning, and a self-serve laundromat. The drop off laundry and dry cleaning services are open weekdays from 7am to 6pm and Saturdays from 8am to 3pm (62 hours / week). The laundromat is open daily from 7am to 8pm (with the last new load of laundry started by 7pm.)

The site already had two Xeros washing machines in use, so after this project they have a total of 3 Xeros machines. The customer reports that they have three standard washing machines with the same capacity (lbs of clothes) as the Xeros machines. Additionally, the customer reported that they have twenty other laundry machines of different sizes on-site.

The evaluator was not able to conduct a site visit; therefore the evaluator has not completed a full M&V for this site. The evaluator has calculated baseline, methodology, admin/tracking, installed quantity and technology adjustments to the tracking savings, but has not calculated an operational adjustment.

A summary of the history of the evaluator's discussions with the site and attempts to set up a site visit is below.

- The evaluator contacted the site in early 2020 (pre-Covid) and the site contact answered some questions and made the evaluator aware of the availability of trend data from the vendor.
- The evaluator spoke with the vendor who services the sites laundry machines, who was able to provide trend data. As part of the equipment installation the vendor had installed data logging to capture the number of machine cycles and water use. The vendor uses that information to provide the customer with estimates of the gas and water savings they are achieving with the Xeros machines.
- The evaluator also spoke with the consultant who assisted the customer with the incentive process. The consultant was able to confirm that the proposed Xeros washing machine was installed. He has experience working with the Xeros washing machines and was able to answer questions about the technology.
- The evaluator was working with the customer to determine a site visit date in early March 2020, but the site visit was put on hold due to Covid.
- The evaluator attempted to re-engage the customer multiple times in the summer of 2020, but was not able to speak with the main site contact and therefore could not conduct an in person or virtual site visit or gather additional information on operation of the installed machine.

- The program administrator attempted to assist with contacting the customer, but was not able reach him.

The evaluation results developed from the data collected are presented in Table 1-1. These results are developed from the baseline, methodology, admin/tracking, quantity and technology adjustments.

Table 5-64. Evaluation Results Summary

PA Application ID	Measure Name		Savings (Therms/yr)	Measure Life (years)	Lifetime Savings (Therms)
7454434	High Performance Xeros Washing Machines	Tracked	3,687	15	55,309
		Evaluated	3,687	15	55,309
		Realization Rate	100%	N/A	100%

Explanation of Deviations from Tracking

The evaluator has not identified any deviations from the tracking savings.

Recommendations for Program Designers & Implementers

The evaluator has not identified any recommendations for the program designers or implementers.

Customer Alert

There is no customer alert at this time.

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 new high performance Xeros washing machine.

Application Information and Applicant Savings Methodology

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

Applicant Description of Baseline

The applicant classified the measure as New Construction – replaced failed equipment measure type. The base case is a new conventional washer which uses 88 gallons of hot water per load of laundry. Table 2-1 presents the main parameters of the baseline as defined by the applicant.

Table 5-65. Applicant Baseline Summary

Operation Description	Value
Washer – Hot Water per Load	88 gallons/load is based on a study completed by applicant, which included metered data provided by the vendor. 88 gallons/load is the average for bath towels (5 cycles were metered and each provided similar hot water usage results). Separate hot water use values were determined for white and colored linens. Linens use more hot water per cycle than towels. This application uses the baseline value for bath towels in the calculations.
Washer – Total Water per Pound of Linen[1]	2.30 gallons of water / lb of linen

[1]The values for gallons/lb of linen are based on a metering study performed by the equipment vendor at a different location. The value used is based on metering for towels.

Applicant Description of Installed Equipment and Operation

The proposed Xeros washer utilizes nylon polymer beads within the washer which allow for cleaning of linens and towels without hot water. The machines also use less cold water in the washing process.

Table 5-66. Applicant Installed Summary

Operation Description	Value
Washer – Hot Water per Load	0 gallons
Washer – Total Water per Load[1]	0.64 gallons of water / lb of linen

[1]The values for gallons/lb of linen are based on a metering study performed by the equipment vendor at a different location. The value used is based on metering for towels.

Applicant Energy Savings Algorithm

The applicant savings calculations were performed using a spreadsheet calculation. The calculations assumed that the proposed washer would not use any hot water; therefore, the annual savings are calculated as the base case system annual water heating load.

The applicant assumes the customer will use the new machine for an average of 13 loads of linen each day for 365 days per day or total of 4,745 loads/year. The applicant assumes each load uses 88 gallons of 140°F water (and 64% of the total water use would be hot water). The assumed average incoming city water temperature is 50°F.

The assumption for loads per day and gallons per load are direct inputs into the calculations but the basis for this value is not provided with the documentation. The hot water gallons per load input is based on a study completed by applicant at a different location, which included metered data provided by the vendor. 88 gallons of hot water per load is the average metered usage for bath towels (5 cycles were metered and each provided similar hot water usage results). Separate hot water use values were determined for white and colored linens. Linens use more hot water per cycle than towels. This application uses the baseline value for bath towels in the calculations.

Annual savings are calculated using the following formula:

> Annual Hot Water Heating Savings (therms) = Annual Hot Water Use (gallons/year) × Gas Usage per Gallon (therm/gallon) ÷ Water Heater Efficiency
>
> = (13 loads/day × 365 days/year × 88 gallons HW/load) × (8.34 lb/gallon × (140°F-50°F) × 1 Btu/lb-°F ÷ 100,000 BTUs/therm) ÷ 85% thermal efficiency = 3,687 therms

Water

In addition to gas savings, the project BCR includes water savings. The calculated total (hot and cold) water savings are shown below in Table 5-67 with a summary of the water savings in the formula below. The values for gallons/lb of linen are based on a metering study performed by the equipment vendor at a different location. The values used are based on metering of bath towel loads. The total water savings are divided between hot and cold water in Table 5-68.

> Total Water Savings = (Baseline Gallons/Load – Proposed Gallons/Load) × (Loads/day × Days/year)
>
> = (138.0 gallons/load – 38.4 gallons/load) × (13 Loads/day × 365 Days/year) = 472,602 gallons/year

Table 5-67. Total (Hot and Cold) Water Savings

Measure Case	Loads/ Day	Lbs/ Load	Gallons/ lb	Gallons/ load	Gallons/ day	Days/ Year	Gallons/ Year
Base	13	60	2.30	138	1,794	365	654,810
Proposed	13	60	0.64	38	499	365	182,208
Savings	13	60	1.66	100	1,295	365	472,602

Table 5-68. Breakdown of Water Gallons per Load

Case	Total	Hot	Cold	% Hot	% Cold
Base	138	88	50	64%	36%
Proposed	38	0	38	0%	100%
Saved	100	88	12	88%	12%
% Saved	72%	100%	23%	-	-

Evaluation Assessment of Applicant Methodology

The applicant calculated the installed case natural gas consumption using an excel spreadsheet. This is appropriate because the laundry loads are independent of ambient conditions. However, the applicant could have verified whether the facility anticipates seasonality with respect to anticipated laundry loads throughout the year and verified the breakdown of loads between sheets and towels.

On-Site Inspection and Metering

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

Summary of On-site Findings

As discussed above, the evaluator did not conduct a site visit, but was able to confirm that the measure was installed through conversations with the customer, the vendor who services the laundromat equipment, and an energy consultant who assisted with the incentive process. The site contact is the laundromat owner.

Table 5-69. Measure Verification

Measure Name	Verification Method	Verification Result
High Performance Xeros Washing Machines	Phone call with the customer (laundromat owner), vendor and energy consultant	A new Xeros washing machine was installed.

Measured and Logged Data

The evaluator has spoken with the site contact as well as the equipment service vendor. When the proposed machine was installed, the equipment vendor installed monitoring to be able to provide water and gas savings estimates from the Xeros machine to the site.

The equipment service vendor shared the available data with the evaluator. The data provides monthly summary of the following information from March 2019 through February 2020:

- Xeros machine hot water use in gallons
- Xeros machine cold water use in gallons
- Number of wash cycles or loads for each cycle type. It appears that the installed Xeros machines include 24 unique cycle types.

The data also provides monthly estimates for gallons of water saved and therms of gas saved along with a running total of water and gas saved since the original installation. The evaluator was able to calculate the assumptions used to determine the water and gas savings. These appear to be assumptions built into the vendor's software and the basis for these values is not clear. Details of the assumptions are:

- The water savings assume that a baseline machine would use five times as much water as the proposed washer. The average estimated total water savings are 143 gallons/cycle. The vendor's data does not appear to break down the total water savings between hot and cold water. The applicant calculated total water savings of 100 gallons/cycle as shown in Table 2-5.
- The gas savings shown in the vendor's data appears to be based on 0.0034 therms/total gallon of water saved, which is 43% of the applicant's savings of 0.0078 therms/total gallon of water saved. The discrepancy between these values could be caused by differences in assumption in the breakdown of water savings between hot and cold water, hot water supply temperature, or hot

water heater efficiency, Since the basis for the vendor's therms/total gallon of water saved is not provided the reason for the difference in the vendor's and applicant's values cannot be determined.

After installation of the machine covered in this application the site has a total of three Xeros machines on-site. The evaluator discussed the cycle data with the service provider and he thought the data provided is the total water use and loads for all three machines, but the evaluator was not able to confirm whether the data is for a single or multiple machines with the site based on their reported machine use.

Evaluation Methods and Findings

This section describes the evaluator methods and findings.

Evaluation Description of Baseline

The evaluator agrees with the applicant's new construction measure type because the project is either an end of life equipment replacement or expanded operation project type if the new machine is adding capacity or replacing a machine at the end of its life and not replacing an existing machine.

It is not clear from the applicant documentation if the total laundry machines in use remained constant after this project because the new machine replaced a standard type washing machine at the end of its life, or if the number of machines increased resulting in additional capacity on-site. The impact of replacing a pre-existing standard type washing machine at the end of its life compared to increased capacity would not impact the gas savings.

The evaluator is not aware of an industry standard practice for laundry machines, but agrees that the baseline would be a machine that does not use the Xeros nylon bead technology.

Evaluation Calculation Method

The evaluator did not complete a full M&V for this site. The goal of additional data collection would have been to verify the following calculation inputs.

- Loads per day – The trend data shows an average of 14.5 loads/day, but it is not clear if this is for all three Xerox machines or the machine covered by this application. If the data is for all three machines it is not clear how the loads are divided between the three machines. According to the energy consultant who assisted with the application process some loads will not come out fully clean and will required a 'redo' cycle with hot water. The evaluator was not able to confirm with the site if the reported loads includes some 'redo' cycles with hot water.
- Hot Water supply temperature – The goal was to verify the water heater supply temperature setpoint during a site visit.
- Hot water heater thermal efficiency – The goal as to identify the water heater type and model to confirm the efficiency.

Cross-Check with Utility Billing Data

The program administrator provided monthly gas use for the site from 12/22/15 to 12/23/19. The claimed savings are ~10% of the whole building use.

It is difficult to draw conclusions about the impact of the machine installed as part of this application on the whole building gas data because the data does not include coincidental data on the loads of laundry. The new machine appears to have been installed in the spring / summer of 2018. The post inspection of this application occurred on 7/23/18. As shown in Table 2-8, there does not appear to be a clear drop in monthly gas use or average gas use/day after the summer of 2018, which may be a sign that the new machine added capacity opposed to replacing a pre-existing standard washing machine but the evaluator was not able to determine if that is the case.

Table 5-70. Building Gas Use

Billing Period		Days	Therms
12/22/15	12/23/16	367	39,113
12/23/16	12/27/17	369	37,485
12/27/17	12/26/18	364	37,322
12/26/18	12/23/19	362	37,176

Final Results

The project consisted of the installation of a high performance Xeros washing machine. The parameters impacting the analysis are summarized in Table 3-1.

Table 5-71. Summary of Key Parameters

Baseline	Applicant	Evaluator
Washer – Quantity	1	1
Washer – loads per day	13 loads/day (across three machines)	Could not be confirmed
Washer – hot water per load	88 gallons/load	88 gallons/load
Incoming water temperature	50°F	50°F
Supply water temperature to washer	140°F	Could not be confirmed
Water heater efficiency	85%	Could not be confirmed
As-Built	**Applicant**	**Evaluator**
Washer – Quantity	Same as baseline	Same as baseline
Washer – loads per day	Same as baseline	Could not be confirmed
Washer – hot water per load	0 gallons/load	Could not be confirmed
Incoming water temperature	50°F	Same as baseline
Supply water temperature to washer	140°F	Could not be confirmed
Water heater efficiency	85%	Could not be confirmed
Savings	**Applicant**	**Evaluator**
Annual natural gas savings (therms)	3,687	3,687
Natural gas realization rate	100%	

Explanation of Differences

The evaluator has not made any adjustments to the tracking savings. A summary of the evaluator's review of the potential sources of discrepancies is below.

Baseline – As noted in section 2.4.1 the evaluator agrees with the applicant baseline. The evaluator is not aware of an industry standard practice for laundry machines, but agrees that the baseline would be a machine that does not use the Xeros nylon bead technology.

Methodology – As noted in section 2.2.3 the evaluator agrees with the applicant methodology. The applicant calculated the installed case natural gas consumption using an excel spreadsheet. This is appropriate because the laundry loads are independent of ambient conditions.

Admin/Tracking – The tracking savings match the applicant documentation

Technology/Quantity – The site, the vendor and the site's energy consultant confirmed that the installed machines is the Xeros washing machines, which reduce the amount of hot water required for the washing process by using a nylon polymer bead technology. The evaluator has confirmed through review of a metering study performed at a different location by the equipment vendor that the Xeros machine does result in reduced hot water consumption.

Operational – The evaluator obtained trend data for monthly water use and washing machine loads, but did not have enough background on the data in order to complete a full measurement and verification with an operational savings adjustment. The reasons that the provided trend data was determined to not be sufficient are:

- The evaluator was not able to confirm if the water use and load data provided is for all three Xeros machine used at the site or only for the machine covered by this application. If the data is for all three machines the evaluator would need to determine how to isolate the loads per day for only the machine covered by this application.
- The evaluator was not able to confirm the hot water supply temperature provided by the hot water heater to the baseline type machines.
- The evaluator was not able to confirm the hot water heater type and efficiency.

Lifetime Savings

The evaluated first year savings and measure life are the same as the tracking and applicant values.

Table 5-72. Application 7454434 - Lifetime Savings Summary

Factor	Tracking	Applicant	Evaluator
Lifetime savings	55,309 therms	55,309 therms	55,309 therms
First year savings	3,687 therms	3,687 therms	3,687 therms
Measure lifetime	15 years	15 years	15 years
Baseline classification	New Construction	New Construction	New Construction

Ancillary impacts

The measure also included 472,602 gallons of water savings. Similar to the gas savings the evaluator has not adjusted the water savings.

Based on feedback from the energy consultant involved with the project and a review of a previous energy study for Xeros machines there is potential for an increase in maintenance costs due to either a service contract or the cost of chemicals associated with the polymer beads, but the maintenance cost impact was not determined for this site.

2018RIG78

Report Date: 05/18/2020

Program Administrator	National Grid	
Application ID(s)	7031427 Parent / 8766309 Child	
Project Type	New Construction – Lost Opportunities	
Program Year	2018	
Evaluation Firm	DMI	
Evaluation Engineer	Patrick Terrio	
Senior Engineer	Mickey Bush	

Evaluated Site Summary and Results

The evaluated project was to be installed at a newly constructed hotel. The proposed scope of work included two natural gas measures: the installation of three high performance Xeros laundry washing machines and three high performance Xeros dryers. The applicant calculated measure savings for the two measures by comparing the natural gas usage of the proposed unit to baseline washers and dryers. The washer measure saves gas because it uses less water and eliminates the need to use hot water in the washing process. The dryer measure saves gas because there is less moisture to be removed due to the Xeros washing machine and the proposed dryer removing moisture more efficiently.

Through discussions with the site contact and a walkthrough at the facility, it was determined that the measure was not installed at the facility. The customer installed two washers and two dryers representative of baseline units resulting in zero savings. The evaluation results are presented in Table 1-1.

Table 5-73. Evaluation Results Summary

PA Application ID	Measure Name		Savings (Therms/yr)	Measure Life (years)	Lifetime Savings (Therms)
7031427 / 8766309 (#1)	High Performance Xeros Washing Machines	Tracked	11,608	15	174,123
		Evaluated	0	15	0
		Realization Rate	0%	N/A	0%
7031427 / 8766309 (#2)	High Performance Xeros Dryers	Tracked	6,017	15	90,254
		Evaluated	0	15	0
		Realization Rate	0%	N/A	0%
Totals		**Tracked**	**17,625**	**15**	**264,378**
		Evaluated	**0**	**15**	**0**
		Realization Rate	**0%**	**N/A**	**0%**

Explanation of Deviations from Tracking

The evaluator found that there are no gas savings because the proposed washer and dryer type were not installed at the facility, and the installed equipment is representative of baseline performance.

Recommendations for Program Designers & Implementers

The evaluator discussed the project implementation process for this specific application with the PA.

The evaluator noted that this project was performed at the same time as a larger CDA project for the hotel, but included in a separate Parent/Child application. The CDA project included typical HVAC and lighting measures, e.g. building envelope, VRF systems, etc. A post-inspection and utility commissioning was performed for the measures included in the larger CDA project, but reviewing the washers and dryers was not included in the post inspection. The washer/dryer applications should have been post-inspected.

In addition, the claimed savings appear to be based upon three washers and three dryers. The project documentation includes a revised memo where the applicant re-calculated savings for two washers and two dryers. It does not appear that the application was updated with these values. The customer installed two of each unit, not three of each unit. The application should have been updated to include the revised savings calculations.

Customer Alert

There is no customer alert at this time.

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 new three high performance Xeros washing machines and three new high performance Xeros dryers. However, it was determined that these units were not installed at the facility.

Application Information and Applicant Savings Methodology

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

Applicant Description of Baseline

The applicant classified both measures as new construction – lost opportunities measures. The applicant baseline are washers and dryers with standard performance. Table 2-1 presents the main parameters of the baseline as defined by the applicant.

Table 5-74. Applicant Baseline Summary

Operation Description	Value
Washer – hot water per load	88 gallons/load is based on a study completed by applicant, which included metered data provided by the vendor. 88 gallons/load is the average for bath towels (5 cycles were metered and each provided similar hot water usage results). Separate hot water use values were determined for white and colored linens. Linens use more hot water per cycle than towels. This application uses the baseline value for bath towels in the calculations.
Dryer – Moisture retention (Lbs of water to remove / lbs of dry clothes)	Sheets - 50% (30 lbs water / 60 lbs linen) Towels - 60% (51 lbs water / 85 lbs linen)
Dryer – gas usage per lb of water to be removed[1]	Sheets - 2,500 btu input / lb of water Towels - 2,700 btu input / lb of water
Washer – Total Water per Load[2]	2.30 gallons of water / lb of linen

[1]The btu of gas / lb of water are direct inputs into the calculations and it is not clear why different values are used for sheets and towels.
[2]The values for gallons/lb of linen are based on a metering study performed by the equipment vendor at a different location. The value used is based on metering for towels.

Applicant Description of Installed Equipment and Operation

The proposed Xeros washer utilizes nylon polymer beads within the washer which allow for cleaning of linens and towels without hot water. The machines also use less cold water in the washing process.

The Xeros dryers have lower load (moisture to be removed) and remove moisture ~25% more efficiently than baseline equipment.

Table 5-75. Applicant Installed Summary

Operation Description	Value
Washer – hot water per load	0 gallons
Dryer – Moisture retention (Lbs of water to remove / lbs of dry clothes)	Sheets - 35% (21 lbs water / 60 lbs linen) Towels - 45% (38 lbs water / 85 lbs linen)
Dryer – gas usage per lb of water to be removed[1]	Sheets – 1,830 btu input / lb of water Towels - 2,000 btu input / lb of water
Washer – Total Water per Load[2]	0.64 gallons of water / lb of linen

[1]The btu of gas / lb of water are direct inputs into the calculations and it is not clear why different values are used for sheets and towels.
[2]The values for gallons/lb of linen are based on a metering study performed by the equipment vendor at a different location. The value used is based on metering for towels.

Applicant Energy Savings Algorithm

The project documents include two spreadsheet calculation files: one for the Xeros washers and one for the Xeros dryers.

Washers

The applicant calculated the savings for the Xeros washer measure as a fuel offset of the baseline gas consumption.

The applicant assumes the hotel must launder 39 loads of linen each day. The applicant assumes each load uses 88 gallons of 150°F water. This water must be heated up from city water at 50°F. Annual savings are calculated using the following formula:

Xeros Washer Savings = (39 loads/day × 365 days/year × 88 gallons HW/load) × (8.34 lb/gallon × (150°F-50°F) × 1 Btu/lb-°F) ÷ 90% thermal efficiency ÷ 100,000 BTUs/therm = 11,608 therms

Dryers

The applicant calculated the Xeros dryer measure savings as a decrease in moisture load (lbs of water / lb of linen) and an improvement in performance (Btu / lb of water). Baseline and proposed dryer performance in gas usage per lb of water removed appears to be extracted from cutsheet data (manually entered into spreadsheet) and is used with moisture load, and dry linen load to convert to BTU input per lb of dry linen being washed in order to calculate savings based on the assumed linen wash load.

The washer calculations are based on hot water usage per load for towels, but the dryer calculations assume that 75% of the loads are towels and 25% of the loads are sheets.

The following tables demonstrate this calculation.

Table 5-76. Baseline Dryer Performance

Product	lbs linen	lbs water	btu/lb water	btu/lb-linen	Avg Btu/lb-linen	% Loads	Weighted Avg
Towels	85	51	2,730	1,638	1,629	75%	1,222
Towels	60	36	2,700	1,620	-		
Sheets	60	30	2,550	1,275	1,263	25%	316
Sheets	40	20	2,500	1,250	-		
Weighted Average Btu/lb-linen			-	-	-	-	1,537

Table 5-77. Proposed Dryer Performance

Proposed Dryer with Lower Load from Xeros Washer							
Product	lbs linen	lbs water	btu/lb water	btu/lb-linen	Avg Btu/lb-linen	% Loads	Weighted Avg
Towels	85	38	2,080	936	918	75%	689
Towels	60	27	2,000	900	-		
Sheets	60	21	1,910	669	641	25%	160
Sheets	40	14	1,750	613	-		
Weighted Average Btu/lb-linen			-	-	-	-	849

Annual savings are calculated using the following formula where the lbs of linen washed per day is a direct input into the calculations:

> Xeros Dryer Savings = 2,400 lbs of linen washed/day × (1,537.4 BTU gas input/lb of linen baseline − 848.6 BTU gas input/lb of linen installed) × 364 days/year ÷ 100,000 BTUs/therm = 6,017 therms

Water

In addition to gas savings, the project BCR includes water savings. The calculated total (hot and cold) water savings are shown below in Table 5-67. The values for gallons/lb of linen are based on a metering study performed by the equipment vendor at a different location. The values used are based on metering of bath towel loads. The total water savings are divided between hot and cold water in Table 5-68.

Table 5-78. Total (Hot and Cold) Water Savings

Measure Case	Loads/ Day	Lbs/ Load	Gallons/ lb	Gallons/ load	Gallons/ day	Days/ Year	Gallons/ Year
Base	39	60	2.30	138	5,382	365	1,964,430
Proposed	39	60	0.64	38	1,498	365	546,624
Savings	39	60	1.66	100	3,884	365	1,417,806

Table 5-79. Breakdown of Water Gallons per Load

Case	Total	Hot	Cold	% Hot	% Cold
Base	138	88	50	64%	36%
Proposed	38	0	38	0%	100%
Saved	100	88	12	88%	12%
% Saved	72%	100%	23%	-	-

Applicant Update

The original applicant calculations as described in this section were based on three washers and three dryers with load inputs of 39 loads per day for the washers and 2,400 lbs/day for the dryers. The applicant updated the calculations to reflect the installation of two washers and two dryers, but the tracking savings were not updated to reflect the updated calculations. Table 5-80 summarizes the updated calculations.

Table 5-80. Savings for 2 Washers and 2 Dryers

Measure	3 Machines		2 Machines	
Type	therms	loads or lbs/day	loads or lbs/day	therms
Washer	11,608	39	20	5,953
Dryer	6,017	2,400	1,200	3,008
Total	17,625			8,961

Evaluation Assessment of Applicant Methodology

The applicant calculated the installed case natural gas consumption using an excel spreadsheet. This is appropriate because the laundry loads are independent of ambient conditions. However, the applicant could have verified whether the hotel anticipates seasonality with respect to occupant density, anticipated laundry loads throughout the year and breakdown of loads between sheets and towels.

On-Site Inspection and Metering

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

Summary of On-site Findings

The evaluators conducted a site visit on February 26, 2020. During the site visit, the evaluators interviewed the facility's Chief Engineer and observed the washers and dryers at the facility. A summary of the on-site verification is provided in Table 2-2.

Table 5-81. Measure Verification

Measure Name	Verification Method	Verification Result
High Performance Xeros Washing Machines	Observe installed equipment	The evaluator observed UniMac washers without nylon polymer beads. Washer 1: UniMac UWN65T4VQU4001, 65 lb max load Washer 2: UniMac UWN105T4VQU4001, 105 lb max load
High Performance Xeros Drying Machines	Observe installed equipment	The evaluator observed UniMac dryers. Dryer 1: UniMac UT170NRUF6A2S01, 170 lb max load Dryer 2: UniMac UT120NRUF6A2S02, 120 lb max load

The customer claimed they did not install the high performance Xeros washing machines or Xeros dryers. The installed equipment appears to be representative of baseline performance. These machines are original to the building and the site contact was not familiar with any plans to install Xeros machines.

Figure 5-11 & Figure 5-12 show photos the evaluator took of the washer nameplates. Figure 5-13 & Figure 5-14 show photos the evaluator took of the dryer nameplates.

Figure 5-11. On-site Photos of Washer 1 Nameplate & Front

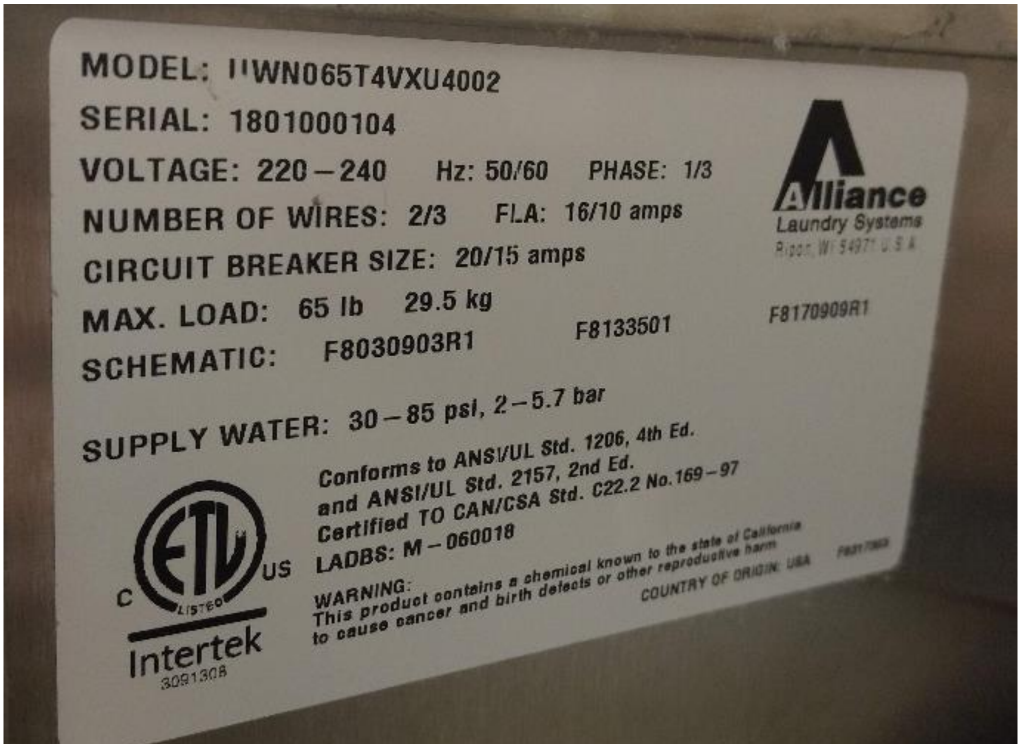


Figure 5-12. On-site Photo of Washer 2 Nameplate

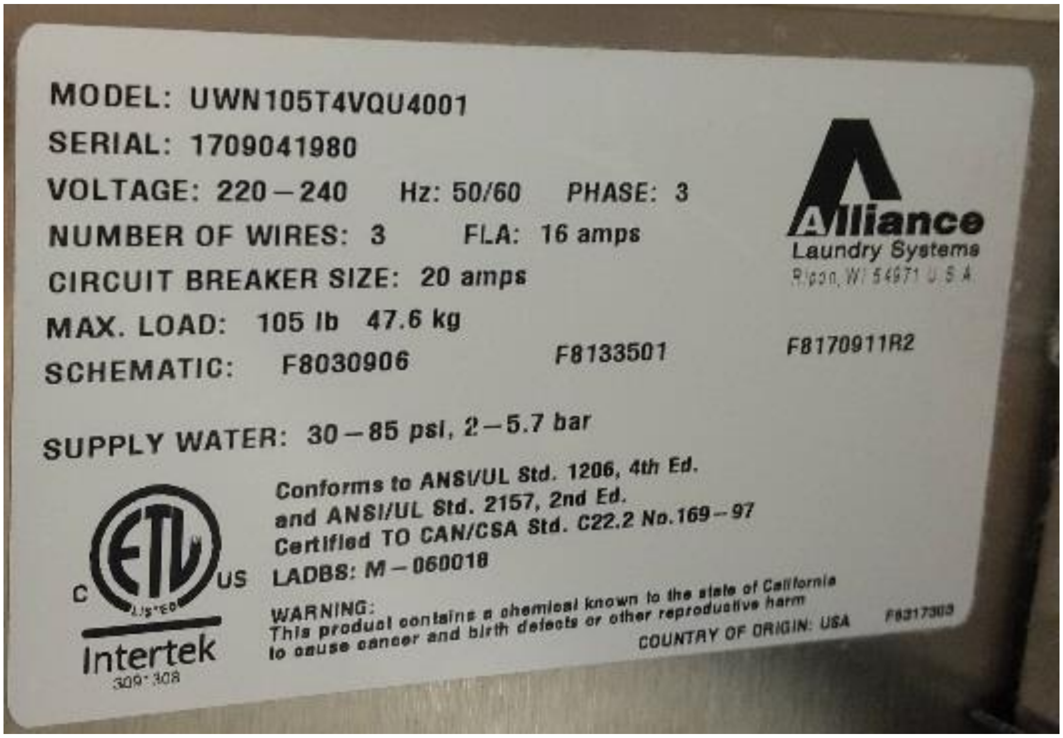


Figure 5-13. On-site Photo of Dryer 1 Nameplate

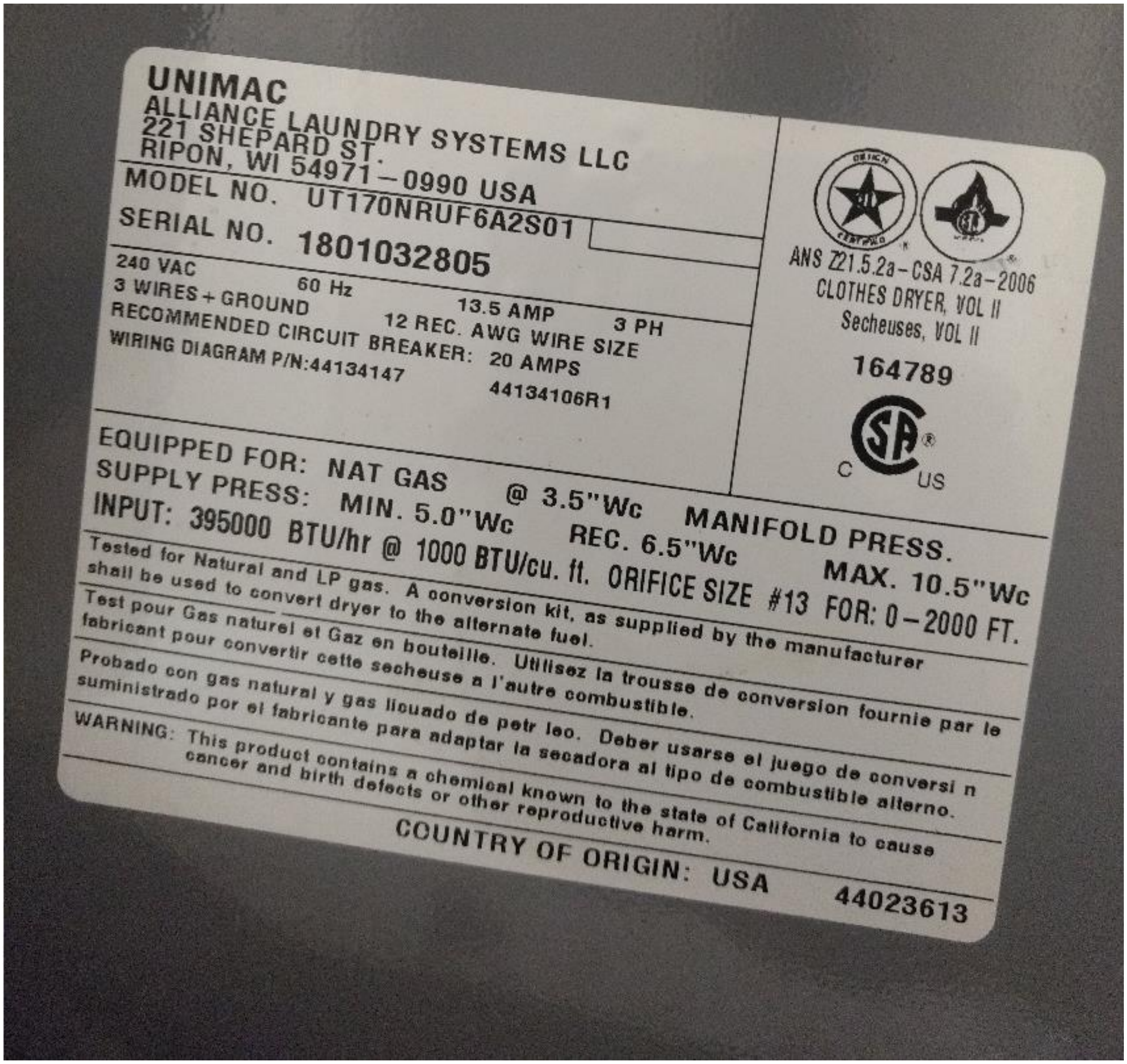
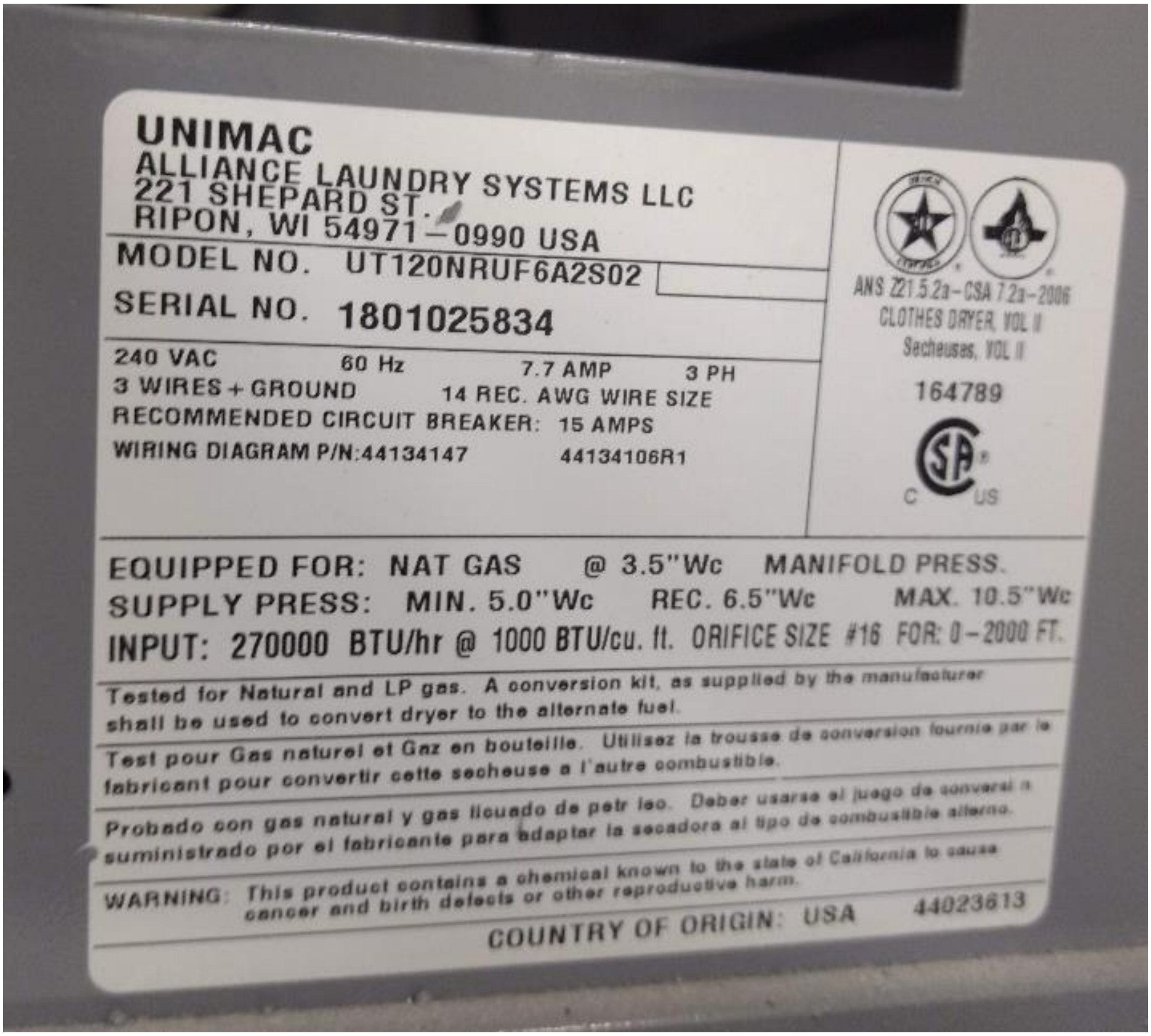


Figure 5-14. On-site Photo of Dryer 2 Nameplate



Measured and Logged Data

The evaluator did not perform any data logging because the measure was not installed. The evaluator did find data on site which differed from the applicant calculation inputs.

- The hot water heater at the facility produces 140°F hot water (which is less than the 150°F value as assumed by the applicant).
- The washing machines and dryers included information on number of loads at the machine control panels. The data suggests there are approximately 15 loads per day (which is less than the 39 loads per day assumed by the applicant).

Evaluation Methods and Findings

This section describes the evaluator methods and findings.

Evaluation Description of Baseline

The evaluator agrees with the applicant's baseline of new construction – lost opportunities because this is a ground up new building.

Evaluation Calculation Method

The installed washers and dryers were not Xeros units. The installed washers did not have nylon polymer beads. Upon review of the installed UniMac washers and dryers, the evaluator did not find any energy savings features. The evaluator did not perform savings calculations.

Cross-Check with Utility Billing Data

The project is a new construction building for which there was no existing gas usage to compare.

Final Results

The project was to consist of the installation of high performance Xeros washers and high performance Xeros dryers. Instead, the customer installed baseline-comparable equipment.

Table 3-82. Evaluation Results Summary

PA Application ID	Measure Name		Savings (Therms/yr)	Measure Life (years)	Lifetime Savings (Therms)
7031427 / 8766309 (#1)	High Performance Xeros Washing Machines	Tracked	11,608	15	174,123
		Evaluated	0	15	0
		Realization Rate	0%	N/A	0%
7031427 / 8766309 (#2)	High Performance Xeros Dryers	Tracked	6,017	15	90,254
		Evaluated	0	15	0
		Realization Rate	0%	N/A	0%
Totals		**Tracked**	**17,625**	**15**	**264,378**
		Evaluated	**0**	**15**	**0**
		Realization Rate	**0%**	**N/A**	**0%**

The parameters impacting the analysis are summarized in Table 3-2.

Table 5-83. Summary of Key Parameters

Baseline	Applicant	Evaluator
Washer – Quantity	3	2
Washer – loads per day	39 loads/day (across three machines)	15 loads/day (across two machines)
Washer – hot water per load	88 gallons/load	88 gallons/load
Incoming water temperature	50°F	50°F
Supply water temperature to washer	150°F	140°F
Water heater efficiency	90%	90%
Dryer – Quantity	3	2
Dryer – linens dried/day	2,400 lbs/day	N/A
Dryer – Moisture Retention	50-60%	N/A
Dryer – gas usage per pound water	2,500 – 2,700 BTUs/lb	N/A
As-Built	**Applicant**	**Evaluator**
Washer – Quantity	Same as baseline	Same as baseline
Washer – loads per day	Same as baseline	Same as baseline
Washer – hot water per load	Same as baseline	Same as baseline

Incoming water temperature	50°F	Same as baseline
Supply water temperature to washer	50°F	Same as baseline
Water heater efficiency	90%	Same as baseline
Dryer – Quantity	Same as baseline	Same as baseline
Dryer – linens dried/day	Same as baseline	Same as baseline
Dryer – Moisture Retention	35-45%	Same as baseline
Dryer – gas usage per pound water	1,750 – 2,000 BTUs/lb	Same as baseline
Savings	**Applicant**	**Evaluator**
Annual natural gas savings (therms)	17,522	0
Natural gas realization rate	0%	

Explanation of Differences

There are no savings because the proposed equipment was not installed, and the installed equipment is no better than baseline.

The evaluator also found that the applicant savings are different than the tracking savings. The tracking savings appear to be based upon three washers and three dryers. The project documentation includes a revised memo where the applicant re-calculated savings for two washers and two dryers. It does not appear that the tracking savings were updated with these values. The customer installed two of each unit, not three of each unit.

If the tracking savings had been updated to reflect the quantity of machines installed the savings would have decreased by 50%. Although the quantity of installed machines is 33% lower the tracking savings (2 units vs 3 units) the savings decrease by 50% because the applicant calculates the load (loads/day for washers and lbs of linens/day for dryers) for 2 machines to be 50% the load of 3 machines.

Table 3-2 provides a summary of the differences between tracking and evaluated values.

Table 5-84. Summary of Deviations

End-use	Discrepancy	Parameter	Impact of Deviation	Discussion of Deviations
Other	Installed Quantity		-100%	Decreased savings – The proposed equipment was not installed and the installed equipment is no better than baseline.

Lifetime Savings

The measure was not installed, thus there are not lifetime savings to be claimed.

The tracking savings appear to be based upon three washers and three dryers. The project documentation includes a revised memo where the applicant re-calculated savings for two washers and two dryers. It does not appear that the tracking savings were updated with these values. The *customer installed two of each unit, not three of each unit. The applicant savings in Table 5-22 reflect the calculations for two washers and two dryers.

Table 5-85. Application Parent 7031427 / Child 8766309 - Lifetime Savings Summary

Factor	Tracking	Applicant	Evaluator
Lifetime savings	264,378 therms	134,415 therms	0 therms
First year savings	17,625 therms	8,961 therms	0 therms
Measure lifetime	15 years	15 years	N/A
Baseline classification	N/A	N/A	N/A

Ancillary impacts

The measure also included 1,417,806 gallons of water savings. There are no water or sewer savings since the project was not installed.