energy & resource solutions

C1641: Impact Evaluation of the Business and Energy Sustainability Program

prepared for

CT Energy Efficiency Board (EEB)

Submitted:

September 5, 2018

Corporate Headquarters
120 Water St., Suite 350
North Andover, MA 01845
978-521-2550
Fax: 978-521-4588

This page intentionally left blank.

Contents

C1641: Impact Evaluation of the Business and Energy Sustainability Program

1 Executive Summary

This report presents the findings of an impact evaluation of the Business & Energy Sustainability suite of programs (BES, or "the programs"), comprised of the following four commercial and industrial (C&I) programs: the Operations & Maintenance Services (O&M) program, the Retro-Commissioning (RCx) program, the Process Reengineering for Increased Manufacturing Efficiency (PRIME) program, and the Business Sustainability Challenge (BSC). The BES programs are four of several programs and initiatives that the Connecticut Energy Efficiency Fund (CEEF) supports to advance energy efficiency throughout the state. Connecticut Light & Power, doing business as Eversource Energy (Eversource), and United Illuminating (UI) administer the programs on their own behalf and that of Connecticut Natural Gas and Southern Connecticut Gas.

ERS was contracted by the Connecticut Energy Efficiency Board (CT EEB) to conduct this impact evaluation under the oversight of the CT EEB Evaluation Administrator Team. Program stakeholders, including the EEB and the program administrators (PAs), prioritized this evaluation, as the O&M, RCx, and BSC programs have not been evaluated since 2012, and PRIME since 2007.

The BES impact evaluation, which examined the performance of projects completed from January 1, 2015, to December 31, 2015, included the following primary objectives:

1. Develop electric and natural gas energy savings estimates targeted to achieve ±10% relative precision at the 90% level of confidence for the BES suite of programs.
2. Develop program-level electric demand savings coincident with summer and winter on-peak and seasonal peak periods for the BES suite of programs, targeted to achieve ±10% relative precision at the 80% level of confidence.
3. Provide recommendations to support future iterations of the Connecticut Program Savings Document (PSD) as appropriate with measure-level findings from the study.
4. Estimate the non-energy impacts from the sampled projects.
5. Provide forward-looking realization rates that incorporate the most recent measure-level updates from the 2018 Connecticut PSD.

1.1 Program Descriptions

The BES suite of programs encompasses four former stand-alone programs, which each address sustainable practices, energy savings, and/or process improvements at C&I facilities. Brief descriptions of the four BES programs are provided below. Detailed descriptions of these programs are provided in Section 2 of this report.

- **The Operations and Maintenance Services (O&M) Program** provides financial and technical assistance for electrical and thermal efficiency improvements through operational changes and repairs instead of capital investments. All commercial, industrial, and municipal customers are eligible for participation.
- **The Retro-Commissioning (RCx) Program** works with customers to identify malfunctions and inefficiencies in building management systems (BMSs) that cause unnecessarily high energy use. The RCx program focuses primarily on low-cost heating, ventilating, and air-conditioning (HVAC) and control improvements among existing energy-using systems.
- **The Process Reengineering for Increased Manufacturing Efficiency (PRIME) Program** makes lean manufacturing training available to all manufacturing customers throughout the state, offering technical and financial assistance to apply lean techniques to their manufacturing processes.
- **The Business Sustainability Challenge (BSC) Program** provides training and education to participating businesses to improve their strategic energy management practices. The program works with the participating facility to develop a plan and timeline for implementing the sustainability strategy, leveraging benefits from other efficiency programs and external tools as needed. No savings were claimed through this program during the evaluation timeframe; therefore, the BSC program is not addressed in forthcoming sections of this report.

1.2 2015 Program Activity Summary

From January 1, 2015, to December 31, 2015, the Connecticut utilities United Illuminating (UI) and Eversource Connecticut provided financial incentive support for 136 energy efficiency projects[1] delivered via the BES suite of programs. The two program sponsors, Eversource and

[1] RCx measures typically claim both electric and natural gas impacts at the same facility. However, as the program tracks electric and natural gas savings as separate projects within the tracking database, the evaluators similarly considered such projects separately in the evaluation study.

UI, combined for a total of 9,037,272 kWh and 41,714 MMBtu saved in the 2015 program year, as broken out by program in Tables 1-1 and 1-2. No savings were claimed through the BSC program during the evaluation time frame.

Table 1-1. 2015 BES Program Activity (Electric Projects)

	Eversource		UI		Statewide	
Program	kWh (N=85)	% of Total	kWh (N=19)	% of Total	kWh (N=104)	% of Total
PRIME	1,950,093	25%	237,701	21%	2,187,794	24%
O&M	1,776,296	22%	227,711	21%	2,004,007	22%
RCx	4,200,843	53%	644,628	58%	4,845,471	54%
Total (kWh)	7,927,232		1,110,040		9,037,272	
Total (%)	85%		15%		100%	

Table 1-2. 2015 BES Program Activity (Gas Projects)

	Eversource		UI		Statewide	
Program	MMBtu (N=24)	% of Total	MMBtu (N=8)	% of Total	MMBtu (N=32)	% of Total
O&M	26,366	76%	6,886	100%	33,252	80%
RCx	8,463	24%	0	0%	8,463	20%
Total (MMBtu)	34,828		6,886		41,714	
Total (%)	83%		17%		100%	

1.3 Study Methods

ERS determined the evaluation results through an engineering assessment of 81 statistically sampled BES projects incentivized in 2015. For every project drawn in the sample, the impact evaluation team conducted site visits to verify measure installations, often deploying metering equipment over a period of a month or more, in accordance with International Performance Measurement and Verification Protocol (IPMVP) best practices.[2]

Project-level analyses and measurement and verification (M&V) reports were developed for each sampled project. A key metric from each project assessment is the realization rate (RR), or the ratio of project-level evaluated savings to reported savings. The 81 project-level RRs were combined in a statistical expansion analysis leading to the program-level RRs summarized in the next section. Aggregate analysis included quantitative review of the key differences

[2] "IPMVP Concepts and Options for Determining Energy and Water Savings: Volume 1," March 2002, https://www.nrel.gov/docs/fy02osti/31505.pdf.

between the reported and evaluated savings, in order to best inform the evaluation's recommendations to improve the programs.

1.4 Results

Table 1-3 provides the overall impact evaluation results for the BES projects claiming electric savings during program year 2015. Please note that PRIME projects, by design, do not claim peak demand savings, thereby making calculation of RRs impossible.

Table 1-3. Comparison of BES Reported and Evaluated Savings: Electric Projects

Program	Savings Metric	Total Reported Savings	Total Evaluated Savings	Evaluated Gross RR	Relative Precision[1]
PRIME	Annual energy savings (kWh)	2,187,794	1,180,245	0.54	29.4%
	Summer seasonal demand savings (kW)	0.0	38.9	N/A	N/A
	Winter seasonal demand savings (kW)	0.0	38.9	N/A	N/A
O&M	Annual energy savings (kWh)	2,004,007	1,589,436	0.79	18.1%
	Summer seasonal demand savings (kW)	74.1	141.8	1.91	28.67%
	Winter seasonal demand savings (kW)	45.6	117.7	2.58	21.1%
RCx	Annual energy savings (kWh)	4,845,471	5,092,974	1.05	6.9%
	Summer seasonal demand savings (kW)	505.8	636.2	1.26	17.4%
	Winter seasonal demand savings (kW)	251.6	440.4	1.75	4.6%
Total	**Annual energy savings (kWh)**	**9,037,272**	**7,987,201**	**0.88**	**8.7%**
	Summer seasonal demand savings (kW)	**579.9**	**832.0**	**1.43**	**14.3%**
	Winter seasonal demand savings (kW)	**297.2**	**586.3**	**1.97**	**5.7%**

[1] At 90% confidence interval for energy savings (kWh and MMBtu) and at 80% confidence interval for demand savings (kW)

The evaluators determined an overall annual electric energy savings gross RR of 88.4%, at a relative precision of ±8.7% at the 90% confidence interval. Table 1-3 shows that the program is saving 12% less kWh than anticipated. Electric energy RRs varied by program, with RCx achieving 5% higher evaluated kWh savings than reported, but O&M and PRIME achieving 21% and 46% lower kWh savings, respectively, than reported. The lower evaluated savings are primarily due to the lower-than-expected production levels in certain PRIME projects, which in turn reduced the savings.

The evaluators determined an overall summer seasonal demand savings gross RR of 143%, at a relative precision of ±14.3% at the 80% confidence interval, and an overall winter seasonal demand savings gross RR of 197%, at a relative precision of ±5.7% at the 80% confidence interval. Evaluators found a total of 6 O&M and PRIME projects[3] that did not claim peak demand savings but were confirmed to produce positive peak demand savings, leading to the high peak demand RRs in Table 1-3.

Table 1-4 provides the impact evaluation results by program for the BES projects claiming natural gas savings during the 2015 program year.

Table 1-4. Comparison of BES Reported and Evaluated Savings: Natural Gas Projects

Program	Total Reported Savings (MMBtu)	Total Evaluated Savings (MMBtu)	Evaluated Gross RR[1]	Relative Precision
O&M	33,252	23,265	0.70	10.0%
RCx	8,463	7,579	0.90	0.0%
Total	**41,714**	**30,716**	**0.74**	**7.9%**

[1] Evaluated gross RRs are calculated based on ex-ante savings that reflect the PSD algorithms at the time of project implementation (2015). The steam trap measure's savings algorithm has since been updated in the current CT PSD (2018). Therefore, evaluators calculated a forward-looking RR (FRR) that reflects the current steam trap savings algorithm. The O&M gas FRR of 0.94 should be applied by the program moving forward, as further explained in Section 4.6.

The evaluators determined a gross RR of 74%, at a relative precision of ±7.9% at the 90% confidence interval, for annual natural gas savings. Table 1-4 indicates that the program is saving 26% less natural gas than anticipated, for reasons that are further explained in Sections 4.3 and 4.4. Below are the results for specific BES program components.

1.4.1 Process Reengineering for Increased Manufacturing Efficiency (PRIME) Evaluation Results

Table 1-5 provides the impact evaluation results for the PRIME projects completed in 2015.

Table 1-5. Comparison of BES Reported and Evaluated Savings: PRIME

Savings Metric	Total Reported Savings	Total Evaluated Savings	Evaluated Gross RR	Relative Precision
Annual energy savings (kWh)	2,187,794	1,180,245	0.54	29.4%

For PRIME projects in the evaluation sample, the evaluators determined a gross kWh RR of 54%, at a relative precision of ±29.4% (±16% absolute precision) at the 90% confidence interval. The PRIME program does not report peak demand savings; however, the evaluators identified the peak demand savings for 3 of the 28 PRIME projects in the evaluation sample.

[3] As recommended by the CT PSD, PRIME projects do not claim peak demand savings.

Figure 1-1 illustrates the key drivers behind the low kWh RR for PRIME, and their positive and negative impacts, organized into seven distinct categories.[4]

Figure 1-1. Key Drivers behind PRIME Electric Energy RR

Discrepancy Category	Negative Impact		Positive Impact		Overall	
	# Instances	Impact on RR	Impact on RR	# Instances	Impact on RR	# Instances
Differences in Production/Productivity	15	-77%	21%	7	-56%	22
Inaccurate breakdown of time/load-dependent kWh	8	-15%	47%	12	32%	20
Differences in utility billing data	9	-18%	7%	5	-10%	14
Revisions to process	1	-6%	0%	0	-6%	1
No evidence of production efficiency improvement	1	0%	0%	0	0%	1
Project not implemented	1	-5%	0%	0	-5%	1
Tracking savings discrepancy	1	-1%	0%	0	-1%	1
Total	**36**	**-121%**	**75%**	**24**	**-46%**	**60**

Differences in production/productivity between the evaluators' collected data and the applicant's assumptions most significantly impacted the PRIME kWh RR, leading to a 56% reduction in evaluated kWh savings, as illustrated above in Figure 1-1.

1.4.2 Operations and Maintenance (O&M) Evaluation Results

Table 1-6 provides the impact evaluation results for O&M projects incentivized during the 2015 program year.

Table 1-6. Comparison of Reported and Evaluated Savings: O&M Projects

Savings Metric	Total Reported Savings	Total Evaluated Savings	Evaluated Gross RR	Relative Precision
Annual energy savings (kWh)	2,004,007	1,589,436	0.79	18.1%
Summer on-peak demand savings (kW)	74.1	141.8	1.91	28.7 %
Summer seasonal demand savings (kW)	74.1	141.8	1.91	28.7 %
Winter on-peak demand savings (kW)	45.6	117.7	2.58	21.1%
Winter seasonal demand savings (kW)	45.6	117.7	2.58	21.1%
Annual natural gas savings (MMBtu)	33,252	23,265	0.70	10.0%

For electric O&M projects in the evaluation sample, the evaluators determined a gross kWh RR of 79%, at a relative precision of ±18.1% at the 90% confidence interval. O&M projects saved significantly more summer and winter peak demand than reported. Lighting O&M projects, which were most predominant in the O&M electric sample, generally featured lower evaluated

[4] Discrepancy categories for PRIME are defined in Appendix A.

savings than anticipated due to differences in the HVAC interactive savings calculations between the applicant and evaluator. The evaluators determined a gross MMBtu RR of 70%, at a relative precision of ±10.0% at the 90% confidence interval, for natural gas O&M projects in the evaluation sample. Since 18 of the 19 gas O&M projects sampled for evaluation involved steam trap repair/replacement measures, the evaluators focused the key drivers behind the low RR on that measure, as illustrated by Figure 1-2. The key drivers are organized into six distinct categories.[5]

Figure 1-2. Key Drivers behind O&M – Steam Trap Measures RR

Discrepancy Category	Negative Impact		Positive Impact		Overall	
	# Instances	Impact on RR	Impact on RR	# Instances	Impact on RR	# Instances
Decommissioned equipment	3	-7%	0%	0	-7%	3
Difference in operating hours	4	-2%	1%	2	-1%	6
Difference in calculation methodology	14	-35%	7%	1	-27%	15
Difference in steam properties	0	0%	11%	3	11%	3
Difference in boiler efficiency	11	-4%	0%	0	-4%	11
Documentation differences	2	-7%	8%	2	2%	4
Total	**34**	**-54%**	**28%**	**8**	**-26%**	**42**

The differences in the calculation methodology between the evaluator and applicant most significantly impacted the RR for steam trap projects, as described further in Section 3.3.2.1 and Appendix A. The evaluators used an alternative steam trap savings algorithm based on recent Massachusetts research[6] instead of the steam trap savings algorithm recommended in the CT PSD at the time of project implementation.

1.4.3 Retro-Commissioning (RCx) Evaluation Results

Table 1-7 provides the impact evaluation results for RCx projects incentivized during the 2015 program year.

---

[5] Discrepancy categories for steam trap O&M projects are defined in Appendix A.

[6] "Steam Trap Evaluation Phase 2 by ERS for Massachusetts (MA) Program Administrators and Energy Efficiency Advisory Council", March 18, 2017. This analysis derives algorithm variable values and savings based on billing analysis and engineering calculations of 24 office, health care, schools, municipal and industrial facilities. http://ma-eeac.org/wordpress/wp-content/uploads/Steam-Trap-Evaluation-Phase-II.pdf

Table 1-7. Comparison of Reported and Evaluated Savings: Electric RCx Projects

Savings Metric	Total Reported Savings	Total Evaluated Savings	Evaluated Gross RR	Relative Precision
Annual energy savings (kWh)	4,845,471	5,092,974	1.05	6.9%
Summer on-peak demand savings (kW)	505.8	636.2	1.26	17.4%
Summer seasonal demand savings (kW)	505.8	636.2	1.26	17.4%
Winter on-peak demand savings (kW)	251.6	440.4	1.75	4.6%
Winter seasonal demand savings (kW)	251.6	440.4	1.75	4.6%
Annual natural gas savings (MMBtu)	8,463	7,579	0.90	0.0%

The evaluators determined an annual RCx electric energy savings gross RR of 105%, at a relative precision of ±6.9% at the 90% confidence interval. The program achieved higher levels of kWh, summer peak demand, and winter peak demand savings than anticipated.

Figure 1-3 illustrates the key drivers behind the higher kWh RR for RCx, and their positive and negative impacts, organized into seven distinct categories.[7]

Figure 1-3. Key Drivers behind RCx Electric Energy RR

Discrepancy Category	Negative Impact		Positive Impact		Overall	
	# Instances	Impact on RR	Impact on RR	# Instances	Impact on RR	# Instances
Difference in baseline assumptions	7	-6%	12%	2	6%	9
Difference in calculation methodology	4	-2%	0%	0	-2%	4
Difference in installed quantity	3	-16%	0%	0	-16%	3
Documentation differences	1	0%	0%	0	0%	1
Measure not implemented	1	0%	0%	0	0%	1
Difference in equipment operation	10	-5%	24%	6	18%	16
Total	**26**	**-31%**	**36%**	**8**	**5%**	**34**

The differences in equipment operation estimated by the applicant and measured by the evaluators most significantly contributed to the 105% RR, leading to an 18% increase in the evaluated kWh savings, as illustrated above in Figure 1-3, but overall the positive and negative factors cancelled out, producing an RR close to 100%.

The evaluators determined an overall RCx summer seasonal demand savings gross RR of 126%, at a relative precision of ±17.4% at the 80% confidence interval, and an overall winter seasonal demand savings gross RR of 175%, at a relative precision of ±4.6% at the 80% confidence interval. For two of the largest sampled RCx electric projects, evaluators found significant differences between the equipment load profiles estimated by the applicant and measured by the evaluators, leading to the high peak demand RRs for electric RCx projects.

[7] Discrepancy categories for RCx are defined in Appendix A.

The evaluators determined an RCx gas RR of 90% at a relative precision of ±0%, since each RCx project claiming natural gas savings in 2015 was evaluated. Figure 1-4 illustrates the key drivers behind the 90% RR for natural gas RCx projects, and their positive and negative impacts, organized into six distinct categories.

Figure 1-4. Key Drivers behind RCx Natural Gas RR

	Negative Impact		Positive Impact		Overall	
Discrepancy Category	# Instances	Impact on RR	Impact on RR	# Instances	Impact on RR	# Instances
Difference in baseline assumptions	4	-5%	2%	7	-3%	11
Difference in calculation methodology	1	-5%	3%	1	-2%	2
Difference in installed quantity	1	0%	0%	0	0%	1
Difference in equipment operation	7	-17%	8%	6	-9%	13
Documentation differences	0	0%	3%	7	3%	7
Total	**13**	**-27%**	**16%**	**21**	**-10%**	**34**

Differences in equipment load profiles, as estimated by the applicant and measured by the evaluators, most significantly impacted the RCx gas RR, leading to a 9% reduction in evaluated natural gas savings, as illustrated above in Figure 1-4.

1.5 Conclusions and Recommendations

ERS analyzed the achieved electric and natural gas savings of the BES programs among a sample of 81 projects completed in 2015. The PRIME, O&M, and RCx programs were estimated to have generated significant savings, achieving 88% of the ex-ante reported electric energy savings and 74% of the ex-ante reported natural gas savings. The primary drivers of the lower-than-anticipated evaluated energy savings include the following: changes in site-specific operation or production levels, differences in calculation methodologies, removal or failure of previously repaired equipment, and differences in pre-project (baseline) and operating conditions. The O&M and RCx programs achieved significantly higher summer and winter peak demand savings than initially reported. Evaluators found a total of 6 O&M projects that did not claim peak demand savings but were confirmed to produce positive peak demand savings, as well as two RCx electric projects with significant differences between the equipment load profiles estimated by the applicant and measured by the evaluators. These differences primarily led to the high RRs for summer and winter peak demand savings.

Overall, the evaluators found that the programs' savings claims were reasonable, relying on the Connecticut PSD when possible (e.g., steam traps and lean manufacturing) or involving site-specific analysis when warranted (e.g., RCx projects). Many of the key contributors to the RRs involved facility- or equipment-specific operation that could not be precisely predicted by vendors a year or more in advance. The key drivers for discrepancies between the reported and evaluated savings are further examined in Sections 4.2, 4.3, and 4.4.

To maximize the value of this study for the BES programs moving forward, the evaluation team identified nine forward-looking recommendations to improve program effectiveness and savings estimations. These recommendations are explored further in Section 5 and summarized here.

1. The BES PAs should apply the evaluation RRs to PRIME and RCx projects moving forward, barring any significant changes in program design, measure offerings, or customers. Additionally, the PAs should apply the evaluation RR to electric O&M projects moving forward; however, the PAs should prospectively apply the forward-looking RR (FRR) of 0.94 to gas O&M projects[8]. The evaluators assessed changes in the PSD from the 2015 version to present (2018) and found that, of the measures addressed by the PSD and featured in this evaluation, only the steam trap measure has undergone changes that result in an FRR considerably higher than the evaluation RR. The evaluators found no such changes for electric measures, as summarized in Section 4.6.
2. Each BES program should implement pre- and post-project inspections and possible metering to more comprehensively document baseline conditions and most up-to-date facility operations. For PRIME projects, the standard practice involves a 90-day review of facility operations, compared to the savings assumptions calculated at the time of project implementation. This 90-day true-up is highly valuable for realistic savings claims but could not always be found for sampled PRIME projects in the project files supplied by the utility to the evaluator. Based on the project documentation provided by program staff, the evaluators could not confirm if the 90-day review occurred for 32% of the sampled PRIME projects. The kWh RR for these projects were 43% lower than projects with 90-day review documentation available to the evaluators. While pre- and post-project inspections are standard practice for RCx and O&M programs, the evaluators were unable to obtain the relevant inspection documentation for 42% of the sampled RCx and O&M projects. The kWh and natural gas RRs for these projects were 36% and 9% lower, respectively, than projects with relevant inspection documentation confirmed by the evaluators. In

[8] The current version of the PSD (2018) recommends two mutually exclusive approaches to calculating steam trap savings—Napier and Grashof. Without knowing which of these approaches will be utilized by the program to estimate steam trap savings, an explicit FRR cannot be calculated. Evaluators therefore recommend an FRR of 0.94 for gas O&M projects based on an assumption that the PAs will follow this report's Recommendation #9 and use only the PSD's Grashof algorithm to calculate steam trap savings moving forward. If Recommendation #9 is not adopted, an alternative FRR must be calculated.

order to reduce uncertainty in savings claims, the RCx and O&M programs should more frequently include pre- and post-project metering, particularly for the largest or most complex projects, in the calculation of reported savings and subsequent incentive amounts.

3. The evaluators believe that the BES programs are best suited as a cost-effective gateway to build relationships with Connecticut commercial and industrial customers that may lead to additional capital improvement projects down the road. However, among the sampled RCx projects, the evaluators identified multiple instances of equipment replacements or add-ons, such as variable frequency drives. Among the twelve sampled electric O&M projects, five involved the upgrade to more efficient lighting systems. The evaluators recommend that the CT EEB and utilities more carefully reassess if such equipment replacement or add-on measures should be classified as O&M or RCx improvements. The BES PAs should collaborate more closely with other Connecticut commercial and industrial programs that can offer complementary capital improvement measures at facilities participating in BES programs.
4. The BES programs' vendors should more comprehensively train the staff of participating facilities to maintain the implemented operational improvements. For example, the evaluators found that the poorest-performing RCx projects involved facility staff who were unaware of the controls improvements and the process of restoring them if overridden. The PRIME program sponsors five-day lean manufacturing events, but the program should follow up with similar supplementary training at the 90-day review to ensure that facility staff members become experts on optimizing the operation of the equipment used every day. The evaluators recommend that the closeout process for PRIME, O&M, and RCx projects is supplemented to include "handoff" paperwork and best practices documentation before incentive payout, in order to maximize the savings persistence of the incented improvements.
5. BES programs should more frequently consider peak demand savings, as some do not. The PRIME program does not consider peak demand impacts in site-specific savings estimations. However, the evaluators found that 3 of the 28 sampled PRIME electric projects caused a total of 38.9 kW savings.
6. The BES PAs should more carefully organize and archive relevant project files such as pre- and post-installation inspection reports, pre-project trended or metered data, and vendor analysis spreadsheets. For 27% of the sampled projects, the evaluators encountered difficulties in obtaining these relevant files, requiring three separate data request submittals that spanned 5 months and delayed evaluation activities for an estimated 6

months. Project files are often not stored in a central depository but on individual computers. The evaluators recommend that the utilities adopt a more comprehensive method to digitally archive all relevant project files. These systems will provide more transparency and will allow the utilities to more quickly and cost-effectively deliver project files in future evaluations.

7. For the PRIME program, the evaluators recommend that the lean manufacturing savings algorithm is updated with evaluation results on load dependence factors. The evaluators recommend that the existing load dependence factors for constant loads (65% as recommended in the current PSD), time-dependent loads (20%), and time- and production-dependent loads (15%) are updated to reflect evaluated values of 41%, 41%, and 18%, respectively. The evaluated results reflect weighted averages among the sample of 28 projects completed in 2015.
8. The PRIME program, like other BES programs, offers an attractive, low-cost gateway for industrial customers to become more familiar with efficiency offerings in Connecticut. Eversource has indicated that 8 of 12 PRIME participants in 2015 went on to complete additional energy efficiency projects through other C&I programs. The evaluators recommend that the utilities continually revisit the PRIME benefits and costs, examining in particular if PRIME participants are more likely to engage other C&I programs as a result of their experience with PRIME, to ensure that the program is contributing towards overall C&I portfolio cost-effectiveness.
9. The current version of the PSD (2018) recommends two mutually exclusive approaches to calculating steam trap savings—Napier and Grashof—each of which generally reflect the evaluator's savings approach based on recent Massachusetts research on actual steam trap performance through analysis of utility data.[9] Evaluators believe that the condensate return factor of 0.45 currently recommended in the PSD's Napier algorithm is appropriate for low-pressure steam systems (5 psig or below), as it accounts for the overstatement in flow in the Grashof-based equation. However, for steam system pressures over 5 psig, evaluators believe that the Grashof method is most appropriate, as the 0.45 condensate return factor will result in overestimated savings using the Napier approach. Therefore, to

[9] "Steam Trap Evaluation Phase 2 by ERS for Massachusetts (MA) Program Administrators and Energy Efficiency Advisory Council," March 18, 2017. This analysis derives algorithm variable values and savings based on billing analysis and engineering calculations of 24 office, health care, school, municipal, and industrial facilities. http://ma-eeac.org/wordpress/wp-content/uploads/Steam-Trap-Evaluation-Phase-II.pdf.

simplify steam trap savings calculation moving forward, the evaluators recommend that the PAs use only the PSD's Grashof algorithm.

2 OVERVIEW

This report describes the methodology and results for an impact evaluation of the Connecticut Business & Energy Sustainability suite of programs (BES, or "the programs"). Descriptions of the four BES programs are provided below.

- **The Operations and Maintenance Services (O&M) Program** provides financial and technical assistance for electrical and thermal efficiency improvements through operational changes and repairs instead of capital investments. All commercial, industrial, and municipal customers are eligible for participation. The program is not intended for normal preventive maintenance or repetitive procedures. Common measures include compressed air improvements (e.g., leak repair and controls upgrades), repairs/conversions of economizers, and repair/replacement of defective steam traps.
- **The Retro-Commissioning (RCx) Program** works with customers to identify malfunctions and inefficiencies in a building management system (BMS) that cause unnecessarily high energy use. The RCx program focuses primarily on low-cost HVAC and control improvements among existing energy-using systems, such as shedding non-essential loads during periods of peak energy use. Program involvement includes building-level screening and surveying, in-depth investigation including diagnostic monitoring, a retro-commissioning report with operations and maintenance strategies, and implementation of selected improvements.
- **The Process Reengineering for Increased Manufacturing Efficiency (PRIME) Program** makes lean manufacturing training available to all manufacturing customers throughout the state, offering technical and financial assistance to apply lean techniques to their manufacturing processes. A verified contractor completes a no-cost survey of the participating customer's manufacturing process to determine opportunities for process optimization and subsequent energy savings. If opportunities are identified, the program then funds lean manufacturing training events at the participating facility as well as the implementation of the identified process changes. After 90 days, the contractor revisits the participating facility to verify that the process improvements have persisted and to refine the energy savings claim.
- **The Business Sustainability Challenge (BSC) Program** provides training and education to participating businesses to improve their strategic energy management practices. The program works with the participating facility to develop a plan and timeline for implementing the sustainability strategy, leveraging benefits from other efficiency programs and external tools as needed. All commercial, industrial, and municipal

customers of UI and Eversource are eligible to participate in the BSC program. No savings were claimed through this program during the evaluation time frame; therefore, the BSC program is not addressed in forthcoming sections of this report.

A previous impact evaluation study of the O&M, RCx, and BSC programs was performed on 2008–2010 measure installations and was completed in 2013.[10] PRIME was previously evaluated in 2007 through a pilot assessment of the newly created program.[11]

Eversource Energy (Eversource) and United Illuminating (UI) administer the BES Programs on their own behalf and that of Connecticut Natural Gas and Southern Connecticut Gas. This impact evaluation examines projects completed during the program period from January 1, 2015, through December 31, 2015, through on-site M&V of the electric and natural gas savings claimed among the programs.

2.1 Purpose and Objectives of the Study

The primary objectives of the BES impact evaluation are to determine program impacts and to refine related aspects of Connecticut's Program Savings Document (PSD) where feasible. More specifically, the objectives include the following:

1. Develop electric and natural gas gross energy savings estimates, targeting a statistical objective of two-tailed 90% confidence with an error tolerance of ±10% relative precision for the BES suite of programs. Within the site-specific savings analyses, identify discrepancies in the savings estimates between the program tracking or reported savings estimates and the final gross savings estimates.
2. Develop program-level summer peak demand savings estimates, targeting a statistical objective of two-tailed 80% confidence with an error tolerance of ±10% relative precision. Develop program-level winter peak demand savings estimates, targeting a statistical objective of one-tailed 80% confidence with an error tolerance of ±10% relative precision, due to a relatively higher error ratio anticipated for winter peak demand savings. Identify

[10] "Impact Evaluation of the Retrocommissioning, Operations and Maintenance and Business Sustainability Challenge Programs Impact Evaluation," January 2013. https://www.energizect.com/sites/default/files/RCx-OM-%20BSC%20Final%20Report%2001-21-13.pdf

[11] "Process Reengineering for Increased Manufacturing Efficiency (PRIME) Program Evaluation," March 2007. https://www.energizect.com/sites/default/files/CL&P%20PRIME%20Evaluation%20Report%20-%20FINAL%2003-26-07_0.pdf

and quantify discrepancies between the tracking demand savings estimates and the final gross demand savings estimates.

3. Provide inputs to update the current PSD as appropriate with findings from the study, including metering results, installation results, and other parameters.
4. Estimate the non-energy impacts from the sampled projects, including other fuels, water, cost, and productivity.
5. Provide forward-looking realization rates that incorporate the most recent measure-level updates from the 2018 Connecticut PSD.

2.2 Program Population Summary

From January 1, 2015, through December 31, 2015, the Connecticut utilities UI and Eversource Connecticut provided financial incentive support for 136 energy efficiency projects[12] delivered via the BES suite of programs. The two utilities combined for a total of 9,037,272 kWh and 41,714 MMBtu saved in the 2015 program year, as broken out by program in Tables 2-1 and 2-2.

Table 2-1. 2015 BES Program Activity (Electric Projects)

	Eversource		UI		Statewide	
Program	kWh (N=85)	% of Total	kWh (N=19)	% of Total	kWh (N=104)	% of Total
PRIME	1,950,093	25%	237,701	21%	2,187,794	24%
O&M	1,776,296	22%	227,711	21%	2,004,007	22%
RCx	4,200,843	53%	644,628	58%	4,845,471	54%
Total (kWh)	**7,927,232**		**1,110,040**		**9,037,272**	
Total (%)	**85%**		**15%**		**100%**	

Table 2-2. 2015 BES Program Activity (Gas Projects)

	Eversource		UI		Statewide	
Program	MMBtu (N=24)	% of Total	MMBtu (N=8)	% of Total	MMBtu (N=32)	% of Total
O&M	26,366	76%	6,886	100%	33,252	80%
RCx	8,463	24%	0	0%	8,463	20%
Total (MMBtu)	**34,828**		**6,886**		**41,714**	
Total (%)	**83%**		**17%**		**100%**	

[12] RCx measures typically claim both electric and natural gas impacts at the same facility. However, as the program tracks electric and natural gas savings as separate projects within the tracking database, the evaluators similarly considered such projects separately in the evaluation study.

3 METHODOLOGY

This section provides the detailed methodology behind the selection of BES projects for evaluation, the techniques used by the evaluators to collect relevant equipment-level data, the analysis of measure-level savings, and the aggregation of electric and gas savings by site leading to program-level realization rates.

The major evaluation objectives are addressed in this study through site-level M&V and analysis among a statistically representative sample of participants. For every project drawn in the sample, the impact evaluation team conducted site visits to verify measure installations, often deploying metering equipment over a period of a month or more, in accordance with International Performance Measurement and Verification Protocol (IPMVP) best practices.[13] The site-level M&V supplied the data to calculate the annual measure-level savings and site-level impacts. Program-level results were determined through statistical expansion analysis based on the sample design discussed in the next section.

3.1 Sample Design

ERS employed an evaluation sampling approach that reflects the industry-standard method of stratified ratio estimation (SRE), as outlined in the 2004 California Evaluation Framework.[14] This approach allows for efficient sample design and generally requires a lower sample size for a targeted level of precision if there is a strong correlation between the program-reported savings and the evaluated gross savings. SRE generally works well for realization rates (RRs), defined as the ratio of evaluated savings to program-reported (or tracked) savings, as there is usually a strong correlation between these two variables.

The evaluators designed the on project-level kWh and MMBtu savings, targeting ±10% relative precision at the 90% confidence interval for each fuel source. Based on the expected variability of results, the evaluators anticipated that the energy-based sample also would achieve the targeted ±10% relative precision at the 80% confidence interval for summer and winter peak demand savings.[15] Table 3-1 summarizes the sample design.

[13] "IPMVP Concepts and Options for Determining Energy and Water Savings: Volume 1," March 2002, https://www.nrel.gov/docs/fy02osti/31505.pdf.

[14] "The California Evaluation Framework," June 2004, pages 328–340, http://www.calmac.org/publications/California_Evaluation_Framework_June_2004.pdf.

[15] The summer peak demand savings targeted ±10% relative precision at the two-tailed 80% confidence interval, while winter peak demand savings targeted ±10% relative precision at the one-tailed 80% confidence interval.

Table 3-1. BES Impact Evaluation Sample Design Summary

Sample Design Parameter	Basis of Estimation or Approach
Population frame definition	BES participants with projects completed in 2015
Sampling unit	Project
Population	136 projects
Key variables for design	Annual electric energy savings (kWh) Annual natural gas savings (MMBtu)
Additional variables to estimate	Summer on-peak demand savings (kW) Summer seasonal demand savings (kW) Winter on-peak demand savings (kW) Winter seasonal demand savings (kW)
Sampling method	Stratified ratio estimation (SRE)
Upper-level stratification variables	Fuel source Program
Lower-level stratification variable	Project-level annual energy savings (kWh or MMBtu)
Target relative precision	10% at 90% confidence
Assumed realization rate error ratios	0.50 kWh 0.60 kW N/A gas (census)

The electric sample design was based on a population of projects defined by tracking data from the utilities, covering the period from January 1 to December 31, 2015. Based on the tracking data provided by UI and Eversource, the evaluators identified 174 measure instances with non-zero electric savings from 104 projects completed during the evaluation time frame. Of the 104 projects, 59 were multiple-measure projects. The evaluation team planned to assess all measures when performing on-site M&V for a project, maximizing the cost-effectiveness of the evaluation. Therefore, the base sampling unit for this evaluation effort was an individual project.

The evaluators segmented the population by program in order to provide greater resolution into the individual program-level impacts. Given the relatively low populations for RCx and O&M programs in 2015 – 16 and 21 kWh saving projects, respectively – the stratum designation for each of these programs was as follows:

- Stratum 1: RCx and O&M each had a stratum featuring low-saving projects – 2 and 5 projects for RCx and O&M, respectively – with kWh savings contribution of less than 3% of each of the programs' total kWh savings. Stratum 1 was excluded to improve the cost-effectiveness of the evaluation study, emphasizing larger and more impactful projects. In the aggregate analysis, the population realization rates for Stratum 2 were applied to Stratum 1 projects.

- Stratum 2: RCx and O&M each had a stratum for projects not in Stratum 1, containing 14 and 16 projects for RCx and O&M, respectively. Stratum 2 represented greater than 97% of each programs' total kWh savings, from which a random sample was drawn.

For the PRIME program, which includes 67 projects claiming kWh savings in 2015, the evaluation team stratified the population into 3 distinct strata as follows:

- Stratum 1: This stratum represents 5 projects with a combined kWh contribution of less than 3% of the total PRIME kWh savings. Similar to RCx and O&M, Stratum 1 sites were omitted to improve the cost-effectiveness of the evaluation study.
- Stratum 2: This stratum represents 45 "medium-saver" projects with a combined representation of 51% of the total PRIME kWh savings from which a random sample was drawn. The breakpoint between Stratum 2 and 3 was based on an observed inflection point in the tracking savings estimate at 30,000 kWh, as illustrated in Figure 3-1, below.
- Stratum 3: This stratum represents the 17 largest-saving projects with a combined representation of 47% of the total PRIME kWh savings, from which a random sample was drawn.

Figure 3-1. PRIME kWh Savings Distribution and Stratum 2 Bounds

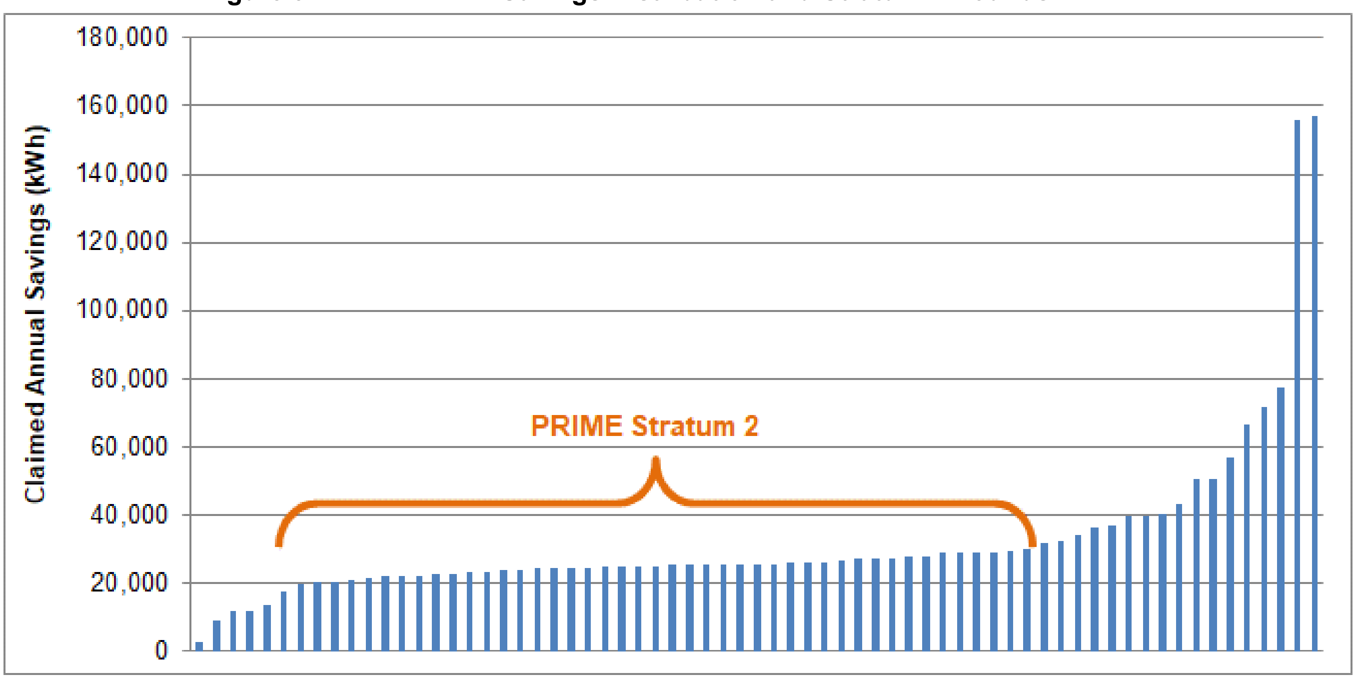


Table 3-2 presents the sample sizes and anticipated relative precision by program for a total electric sample of 52 projects.

Table 3-2. BES Sample Design for Electric Savings

Program	Stratum	Project Quantity	Sampling	Total Reported Savings kWh	Total Reported Savings Summer kW	Relative Precision On kWh Savings[1]	Relative Precision On Summer kW Savings[2]	Case Weights	Sample Size
PRIME	1	5	None	48,628	0.0	N/A	N/A	N/A	0
PRIME	2	45	Random[3]	1,117,705	0.0	18%	N/A	3.21	14
PRIME	3	17	Random	1,021,461	0.0	9%	N/A	1.21	14
PRIME Subtotals		**62**	**N/A**	**2,187,794**	**0.0**	**13%**	**N/A[4]**	**N/A**	**28**
O&M	1	5	None	43,405	7.0	N/A	N/A	N/A	0
O&M	2	16	Random	1,960,602	67.2	12%	11%	1.33	12
O&M Subtotals		**21**	**N/A**	**2,004,007**	**74.2**	**12%**	**11%**	**N/A**	**12**
RCx	1	2	None	141,908	91.1	N/A	N/A	N/A	0
RCx	2	14	Random	4,703,563	414.7	9%	8%	1.17	12
RCx Subtotals		**16**	**N/A**	**4,845,471**	**505.8**	**9%**	**8%**	**N/A**	**12**
Grand Total		**104**	**N/A**	**9,037,272**	**580.0**	**6%**	**7%**	**N/A**	**52**

[1] At the 90% confidence interval.

[2] At the 80% confidence interval.

[3] Assuming an error ratio of 0.6, as no error ratio was available from prior PRIME evaluations.

[4] As PRIME projects do not claim kW savings, no relative precision can be calculated.

The gas sample design was based on a population of projects defined by tracking data from the utilities, covering the period from January 1 to December 31, 2015. Based on the tracking data provided by UI and Eversource, the evaluators identified 64 measure instances with non-zero gas savings from 32 projects completed during the evaluation time frame. Of the 32 projects, 20 were multiple-measure projects. As with the electric sample, the base sampling unit for the gas evaluation was an individual project.

The RCx and O&M programs report gas savings, but PRIME does not. After excluding the three smallest projects representing 463 MMBtu/yr (1%) of savings, all in O&M, the remaining 29 gas saving projects were selected without sampling. The design is summarized in Table 3-3. Census sampling was needed to achieve the original precision targets due to the small populations.

Table 3-3. BES Sample Design for Gas Savings

Program	Stratum	Project Quantity	Sampling	Total Reported Gas Savings (MMBtu)	Relative Precision	Case Weights	Sample Size
O&M	2	19	Census	32,789	0%	1.00	19
RCx	2	10	Census	8,463	0%	1.00	10
Total		**32**	**N/A**	**41,714**	**0%**	**N/A**	**29**

In total, 7 of the 29 gas projects were at facilities also selected in the electric sample.

3.2 Recruitment

Field engineers and analysts recruited the facility representatives of sampled electric and gas projects using utility-provided contact information. For all of the sampled projects, the recruitment involved scheduling a date and time for field engineers to visit the facility, inspect and inventory the installed equipment incented by the program, and deploy short- and long-term measurement devices on impacted equipment. ERS received additional recruiting assistance from the utilities for sites with facility representatives who were non-responsive during the initial contact attempts. For non-census sites for which backup sites were available, each non-responsive customer received at least six calls at different times of the day and week and follow-up email prompts before the evaluators moved on to a backup site. Overall, the recruitment led to an 88% response rate. This is a high value that mitigates concerns about nonresponse bias.

3.3 Data Collection and Analysis

This section describes the methods used by the evaluation team to collect site-level data for the calculation of evaluated impacts, from collecting relevant project information, to deploying measurement equipment, to analyzing the metered and trended performance data and calculating savings. As the methods varied by measure type, the following sections are divided by program.

3.3.1 PRIME

The PRIME program provides training and consulting to implement lean manufacturing techniques. To determine the energy consumption impacts of these lean techniques, the program’s contractors identify and classify the types of equipment impacted by the lean measures. Based on a prior pilot program evaluation of PRIME in 2007, equipment at participating manufacturing facilities can be grouped into five categories:

A. Manufacturing equipment with energy use independent of production hours and production throughput (e.g., quantity of widgets produced)

B. Manufacturing equipment with energy use dependent on production throughput but independent of production hours

C. Manufacturing equipment with energy use dependent on production hours but independent of production throughput

D. Manufacturing equipment with energy use dependent on production hours and throughput

E. Office equipment

The reported energy savings for all PRIME projects were calculated using algorithms provided in the CT PSD, which incorporates the following inputs:

- Pre-event annual electric energy consumption based on billing history
- Percentage of facility's electricity consumption affected by PRIME event
- Pre-event production quantity
- Post-event production quantity
- Annual electric energy usage independent of production hours and production quantity (Type A , B, and office equipment)
- Annual electric energy usage dependent on hours of production (Type C equipment)
- Annual electric energy usage dependent on production quantity (Type D equipment)

In general, reported energy savings from PRIME projects are based on an assumption that production throughput will increase as a result of the project, but will not require as proportional an increase in required electric consumption (i.e., the normalized kWh-per-unit will decrease). These savings occur from Type B and Type D equipment only.

Per CT PSD recommendations, PRIME projects do not claim peak demand savings. However, evaluators independently assessed each project to determine if peak savings resulted from the PRIME event. In general, evaluators corroborated the program's claim of zero peak demand savings, save for 3 projects. The evaluators found that the following patterns suggest demand savings from PRIME projects: 1) The facility's typical work day does not fully cover the on-peak summer weekday hours of 1:00 p.m. through 5:00 p.m., and expanded production without the program intervention would result in increased peak usage; 2) The impacted equipment operates at a lower load; and 3) The event resulted in the removal or shutdown of electric equipment that previously operated during the on-peak hours. Additional details on the energy savings algorithm and definitions of terms in the CT PSD are provided in Appendix E.

Field engineers conducted site visits at all sampled PRIME projects, independently inspecting the lean techniques detailed in the project documents and interviewing the site contact to verify that the facility's operating conditions have remained consistent (or if not, how they have changed). Information about the facility's pre- and post-event production throughput were also gathered by the field engineers during the site visits.

While on-site, the engineers attempted to isolate the production line(s) and key equipment impacted by the lean techniques sponsored by the program. Field engineers collected nameplate data and specification sheets for key equipment to estimate load and interviewed facility staff to determine equipment run hours and active/idle load factors. When affected equipment was accessible, the field engineers deployed motor on/off loggers to determine the actual post-project operating profiles. The field engineers also requested trended or sub-metered data on power draw of key equipment from facility staff, if available.

For PRIME projects, the standard practice involves a 90-day review of facility operations, compared to the savings assumptions calculated at the time of project implementation. This 90-day true-up is highly valuable, as it allows for an adjustment to the reported savings based on actual project performance and facility production levels. However, based on the project documentation provided by program staff, the evaluators could not confirm if the 90-day review occurred for 32% of the sampled PRIME projects.

Field engineers obtained pre- and post-event facility electric billing data from the utilities and site contacts and estimated the portion of billed electricity consumption affected by the lean manufacturing improvements. Each electric component affected by the project was then classified into one of the equipment categories described above. The engineers developed comprehensive data collection templates (see Appendix D) for all PRIME projects in the sample to characterize the key equipment affected by the project. The collected data was then analyzed to inform the best available option for evaluation analyses as shown in Figure 3-2 (below), in terms of priority.

- ❑ **Option #1 – Billing analysis** was utilized by engineers for only 4 projects in the evaluation sample. While billing analysis is preferable, it requires sufficient pre- and post-event utility billing data, verification that impacted equipment is covered by specific utility meter(s), and sufficiently high reported savings as compared with the overall facility electricity consumption (minimum 10% as a rule of thumb, but the actual minimum depends on how well facility electricity use correlates with production rates and other independent variables).
- ❑ **Option #2 – Detailed inventory of equipment** was utilized for 17 projects in the evaluation sample. This method involves collecting detailed information on operating schedules, operating power, and time and/or load dependency for each impacted piece of

equipment in order to calculate the annual energy impacts from changes in production using the same spreadsheet analysis methodology recommended in the PSD.

- **Option #3 – Utility bill disaggregation by end use** was utilized for 5 projects in the evaluation sample. This method involves disaggregation of the facility's billed electricity consumption into different equipment categories and assignment of time/throughput dependencies to those categories to calculate the energy impacts from the event. During the site visit, field engineers worked with facility staff to identify the different equipment categories contributing to the utility meter's overall consumption and estimated contribution from each equipment category. These equipment-specific consumption estimates were then used to inform the savings that would occur from the implemented PRIME measures.
- **Option #4 – Verification** was utilized for only 2 projects in the evaluation sample when field engineers couldn't collect any information required for adopting Options #1, #2, or #3, or when the PRIME project was not found to be implemented on-site. The vendor's savings analysis was updated for these sites with the latest on-site estimates for production impact and kWh dependency on time/production.

It should be noted that for some Option #2 or Option #3 projects, an analysis of pre- and post-event billing data (Option #1) was used to sanity-check or refine the equipment-based savings calculations. For example, if the normalized utility bills indicated a facility-wide energy usage increase between pre/post periods, but the Option #2 or #3 approach indicated positive savings from the PRIME event, the evaluators investigated the facility-wide increase through interviews with facility staff. In some such cases, the increase could be justified (e.g., an equipment addition on an unrelated manufacturing line), but in other cases the utility bill sanity check confirmed zero evaluated savings.

Figure 3-2. Evaluation Options for PRIME Based on Available Collected Data

Option	Utility Meter	Affected Equipment	Production
#1 – Billing analysis	✓ Pre/post utility bills available ✓ Project impacts can be isolated and observed on specific meter(s) ✓ Usage shows an annual pattern (not intermittent or random) ✓ No other projects/factors with kWh impacts over pre/post period ✓ Savings > 10% of annual usage	✓ Can verify that affected systems/components are covered by the analyzed meters	✓ Production impact can be quantified: ✓ Pre/post production data available ✓ Alternatively, proxy data available (e.g., pre/post hours of op., revenue, number shifts, number employees, shipment tonnage)
#2 – Detailed inventory of equipment	✓ Pre/post utility bills available ✖ But project impacts not observable in utility bills: ✖ Savings too low ✖ Other kWh impacts ✖ Usage too intermittent	✓ Project affects a discrete set of systems or components ✓ Affected equipment is accessible ✓ Detailed data can be gathered: quantities, wattage, hours of op. ✓ Affected systems can be grouped as dependent/independent on production/hours	✓ Production impact can be quantified: ✓ Pre/post production data available ✓ Alternatively, proxy data available (e.g., hours of operation, revenue, number shifts, number employees, tonnage)
#3 – Utility bill disaggregation by end use	✓ Pre/post utility bills available ✓ Project impacts can be isolated on specific meter(s) ✖ But, project impacts not observable in utility bills: ✖ Savings too low ✖ Other kWh impacts ✖ Usage too intermittent	✖ Cannot collect detailed data on affected equipment ✓ Can work with facility staff to estimate annual kWh % contributions by equip. categories ✓ Can group categories as dependent/independent on production/hours	✓ Production impact can be quantified: ✓ Pre/post production data available ✓ Alternatively, proxy data available (e.g., hours of operation, revenue, number shifts, number employees, tonnage)
#4 – Verification only	✖ Pre/post utility bills not available ✖ Or, project impacts not observable in utility bills: ✖ Savings too low ✖ Other kWh impacts ✖ Usage too intermittent	✖ Project impacts cannot be isolated to specific systems or components ✖ Or, affected equipment is inaccessible or too time-consuming to verify ✖ Or, cannot disaggregate the bill or group as dependent/independent	✖ Production data not available ✓ But production % change can be estimated

For all PRIME evaluation options except Option #1 (billing analysis), the evaluators updated the CT PSD's PRIME algorithm with verified, site-specific data for the facility's pre-event annual electricity consumption, percentage of facility's electricity consumption affected by the project, production improvement, and classification of key equipment categories by time/throughput dependence (Type A, B, C, D, and office) to calculate the evaluated energy savings.

3.3.2 O&M

The following sections describe data collection and analysis methodologies for the predominant natural gas and electric O&M measures in the evaluation sample.

3.3.2.1 *Steam Trap O&M (Natural Gas)*

Field engineers independently inspected and inventoried all repaired and replaced steam traps during the site visit, verifying operation using thermal imaging, infrared temperature measurements, or ultrasound frequency detectors. Field engineers also gathered information on steam pressure, trap size, failure types, and annual operating hours for each affected trap. To estimate the steam generation efficiency, field engineers spot-measured the boiler efficiency using a combustion flue gas analyzer or obtained boiler efficiency test reports from the facility contacts when measurement was not possible. An example steam trap inventory form is provided in Appendix B.

The O&M program followed the steam trap savings algorithm provided in the 2015 CT PSD[16] for calculation of reported savings. The evaluators used a different algorithm based on recent Massachusetts research.[17] The MA algorithm has a similar structure and variables to the PSD version but was based on evaluated results and in aggregate had a net effect of estimating lower savings for the studied facilities. Additional details on the evaluation energy savings algorithms for steam traps are provided in Appendix C.

According to a recent memo titled *Short Life Measure Savings Adjustment*[18] submitted to the Energy Efficiency Advisory Council (EEAC) in Massachusetts, discounting savings due to high failure rates for short-life measures such as steam traps should only be made in exceptional circumstances. One such exception is a markedly high failure rate (>15% worse) as compared with the anticipated failure rate from a simple linear survival rate curve based on the steam trap measure's effective useful life (EUL) of 6 years. The anticipated linear failure rate for steam traps at the time of the evaluator's visit was compared to the actual failure rate observed. If the observed failure rate was not 15% greater than the expected failure rate, the evaluators did not discount savings for the failed traps as the failure rate is reasonably characterized by the steam trap measure's EUL of 6 years. For this evaluation, no projects had a failure rate higher than the

[16] The reported savings for steam traps were calculated using the algorithms provided in the 2015 CT PSD document. The savings algorithms for steam traps have now been updated in the 2018 CT PSD document to more closely reflect the evaluator's approach that incorporates steam loss adjustment factors for failed and leaking traps as well as a condensate return factor based on the MA research referenced below.

[17] "Steam Trap Evaluation Phase 2 by ERS for Massachusetts (MA) Program Administrators and Energy Efficiency Advisory Council," March 18, 2017. This analysis derives algorithm variable values and savings based on billing analysis and engineering calculations of 24 office, health care, schools, municipal, and industrial facilities. http://ma-eeac.org/wordpress/wp-content/uploads/Steam-Trap-Evaluation-Phase-II.pdf

[18] "Factoring in Rates of Failure for Measures with A Short Life", ERS, May 18, 2018

expected failure rate based on the measure life and no savings were subtracted for any projects with failed traps.

3.3.2.2 *Lighting O&M (Electric)*

The evaluation sample included 5 O&M projects that involved lighting upgrades; however, it is unclear to the evaluators why equipment replacement projects like lighting upgrades were considered under the O&M program during the time of this project. Utilities have acknowledged that since 2017, lighting equipment is no longer installed as part of the O&M program and limited re-tubing was occasionally done under O&M prior to 2017, as it was in some cases considered a standard O&M activity to replace tubes. Field engineers inventoried the replaced fixture types and quantities and measured lighting hours of operation in accordance with IPMVP Option A. To characterize the operation of impacted lighting fixtures, field engineers deployed a total of 26 lighting status or level loggers[19] among the 5 project locations for this study. Upon retrieving the loggers, engineers processed the interval run-time data into hourly operating profiles for representative usage groups[20] among the replaced lighting fixtures. Field engineers also interviewed the facility's manager, owner, or other knowledgeable representative, to identify characteristics that affect the facility's annual energy use for lighting operation, such as seasonal changes in facility use, observed holidays, and characteristics of HVAC systems and setpoints.

Since lighting operation is typically most dependent on facility schedule, the evaluators examined patterns among each usage group's run-time data by hour of day and day of week. For each metered usage group, engineers extrapolated operation by hour and by day of week over a full year. The pre- and post-project lighting fixture wattages[21] and quantities were

---

[19] Lighting status loggers use photocell sensors to record hourly average percentages of a light fixture's operating time over a metering period. Light-level loggers use photocell sensors to record the actual illumination magnitude at specified intervals.

[20] A usage group can be defined as a distinct facility space or collection of spaces that feature similar lighting use throughout the year. Some example usage groups in this study include offices, warehouses, manufacturing spaces, hallways, and mechanical rooms.

[21] The Connecticut PSD does not feature a standard fixture wattage table. Therefore, ERS referenced the standard fixture wattage table in the New York Technical Reference Manual's (TRM's) Appendix C to assess the reasonableness of the vendor's fixture wattage estimates. Unless significant differences were found between the vendor assumptions and the NY TRM's Appendix C, the evaluators adopted the same fixture wattages as estimated by the vendors. http://www3.dps.ny.gov/W/PSCWeb.nsf/96f0fec0b45a3c6485257688006a701a/72c23decff52920a85257f1100671bdd/$FILE/ATTESQKL.pdf/TRM%20-%20Version%204.0-April%202016.pdf.

matched with annual full-load operating hours to determine lighting energy savings in accordance with the CT PSD's recommended algorithm for C&I lighting retrofits.[22]

3.3.2.3 *Compressed Air Leaks Repair O&M (Electric)*

The evaluation sample included 4 O&M projects with compressed air leak repair measures. Field engineers independently verified the repaired compressed air leaks using ultrasonic frequency detectors and inventoried operating parameters at each leak location, including line pressure and line temperature in order to quantify the reduced air leakage rates.

The field engineers used a combination of metered data and manufacturer performance data on the air compressor to calculate the impacted air compressor's average operating efficiency in kW/cfm. Engineers used verified system characteristics, the estimated operating hours at leak locations, and the air compressor's verified average operating efficiency to calculate the evaluated savings.

3.3.3 RCx

The following sections describe data collection and analysis methodologies for the predominant RCx measures in the evaluation sample.

3.3.3.1 *Water-Side and Air-Side Measures (Gas & Electric)*

The following water-side and air-side retro-commissioning measures were predominant within the sampled RCx projects:

- Installation of variable frequency drives (VFDs) on HVAC pump and fan motors
- HVAC pump speed reset
- Hot water temperature reset
- Chilled water temperature reset
- Supply air fan speed controls
- Ventilation airflow controls
- Optimal start/stop

[22] "Connecticut Program Savings Document: 2017," October 2016, page 71. https://www.energizect.com/sites/default/files/2017%20CT%20Program%20Savings%20Document_Final.pdf.

All RCx projects involved improvements or repairs to HVAC equipment monitored by a BMS. While most of the RCx measures featured control strategy optimizations, evaluators are unclear why equipment installations like VFDs were considered under the RCx program.

Field engineers independently confirmed that the reported control strategy optimizations programmed within the impacted BMSs were implemented and remained operational during the site visit. For nearly all RCx projects in the evaluation sample, the field engineers were able to obtain trended data on key parameters such as VFD speeds, HVAC pump and fan power draws, hot water and chilled water supply and return temperatures, supply and return airflows, and chiller load and power draw. When the trended data was insufficient or warranted independent verification, field engineers performed supplementary M&V, including the deployment of current transducers (CTs) in the electrical panels serving the affected motors, along with spot-measurements of the voltage, amperage, power factor, and wattage at time of deployment. The CTs were retrieved after a sufficient range of performance was observed, typically 4–6 weeks.

Upon retrieval of the trended or metered data, the engineers cleaned, processed, and correlated the data with key independent variables such as hourly outside air temperature (OAT) and/or facility schedule. Such correlations allowed the evaluators to extrapolate performance from the metering period to a full year in the calculation of annual savings values. Through project file requests with the utilities, the evaluators obtained the vendor analysis spreadsheets for all RCx projects in the sample. The evaluators assessed the completeness and accuracy of the applicant analyses, which were typically performed using a temperature bin analysis that calculates savings at various OAT ranges throughout a typical year. To allow for the most unbiased comparison of reported and evaluated savings, the evaluators generally revised the vetted vendor’s analysis approach with trended and metered data. In some cases, the evaluators created an original analysis approach when the vendor analysis was deemed insufficient or impractical to update.

3.3.3.2 *Refrigeration Head Pressure Controls (Electric)*

The evaluation sample included 4 RCx projects with refrigeration head pressure optimization measures at grocery stores. During the site visits, field engineers inspected refrigeration control panels to document setpoints such as suction pressure, condenser pressure, and condensing temperature differential with the ambient temperature. Temperature loggers were deployed on refrigerant pipes located at compressor discharge or condenser drop leg, and trended data was gathered from the facility’s refrigeration control system on outdoor air temperature, condensing temperature setpoint, and actual condensing temperature.

The evaluators obtained the vendors' savings analyses, which leveraged a custom software tool developed for modeling refrigeration systems. The software simulates the hourly energy use of the compressors and condensers based on thermodynamic and heat transfer calculations. The evaluators reviewed the applicant software analysis methodology and determined it to be appropriate for this measure category. For the most unbiased comparison of savings, the evaluated energy savings were calculated using the applicant's savings analysis software tool, updated with actual compressor and condenser system performance metrics from trended and metered data.

3.4 Discrepancy Analysis

The primary objectives of this study include identifying why the evaluated gross savings estimates differ from the program-reported savings estimates. The evaluators completed separate discrepancy analyses for the following five program-measure combinations: Steam trap O&M, RCx Electric, RCx Gas, PRIME, and Electric O&M projects. The various discrepancy categories considered within each discrepancy analysis are summarized in Table 3-4 and are defined further in Appendix A. The discrepancy categories are customized for the various BES programs and measures to most appropriately tailor the evaluation findings and recommendations to the programs.

Table 3-4. Discrepancy Categories for BES Programs and Measures

Program / Measure Category	Discrepancy Categories
Steam Trap O&M	Documentation differences Differences in operating hours Differences in calculation methodology Differences in steam conditions Differences in boiler efficiency Failed or removed equipment
Electric RCx Gas RCx Electric O&M	Documentation differences Differences in calculation methodology Differences in installed quantity Differences in baseline assumptions Differences in equipment operation
PRIME	Tracking savings discrepancy Differences in utility billing data Differences in production/productivity Inaccurate breakdown of time/load dependent kWh Revisions to process No evidence of production efficiency improvement Project not implemented

The discrepancy analysis quantifies each category's contribution to the total difference between the reported and evaluated savings.

3.5 Expansion Analysis

After all project-level results were calculated using the methods in Sections 3.3, the evaluators calculated program-level evaluation results through statistical expansion analysis. Section 4 includes results of the study's program-wide RRs, or the ratio of evaluated savings to program-reported savings. RRs were calculated for all sampled projects as the ratio of project-level evaluated savings to reported savings. Program-wide RRs for electric and natural gas energy savings, as well as for summer and winter coincident demand, were calculated using the following formula:

$$RR_{Program} = \frac{\sum_{i=1}^{n} w_i y_i}{\sum_{i=1}^{n} w_i x_i}$$

where,

$RR_{Program}$ = Program-wide realization rate

w_i = Case weight for each project in the sample (see Tables 3-2 and 3-3)

y_i = Evaluated savings for each project in the sample

x_i = Reported savings for each project in the sample

Within the expansion analysis, the evaluators also calculated the relative precision and error ratio of the realization rates, overall and by segment. Case weights were also used to compute results stratified by other variables besides those in the sample design, such as utility-specific RRs.

4 RESULTS

This section examines the evaluation results for electric and natural gas savings claimed by the BES suite of programs, as well as the key drivers among the program-specific RRs. The section concludes with evaluation results by utility, discussion on forward-looking realization rates, and an examination of non-energy impacts associated with BES sampled projects.

4.1 BES Overall Results

The following sections provide overall realization rates and statistical results achieved for the PRIME, O&M, and RCx programs comprising the BES suite.

4.1.1 Electric Results

Table 4-1 provides the overall impact evaluation results for the BES projects claiming electric savings during the 2015 program year. Further discussion of site-level RRs is provided in Appendices G and H for individual projects.

Table 4-1. Comparison of BES Reported and Evaluated Savings: Electric Projects

Program	Savings Metric	Total Reported Savings	Total Evaluated Savings	Evaluated Gross RR	Relative Precision
PRIME	Annual energy savings (kWh)	2,187,794	1,180,245	0.54	29.4%
	Summer seasonal demand savings (kW)	0.0	38.9	N/A	N/A
	Winter seasonal demand savings (kW)	0.0	38.9	N/A	N/A
O&M	Annual energy savings (kWh)	2,004,007	1,589,436	0.79	18.1%
	Summer seasonal demand savings (kW)	74.1	141.8	1.91	28.7%
	Winter seasonal demand savings (kW)	45.6	117.7	2.58	21.1%
RCx	Annual energy savings (kWh)	4,845,471	5,092,974	1.05	6.9%
	Summer seasonal demand savings (kW)	505.8	636.2	1.26	17.4%
	Winter seasonal demand savings (kW)	251.6	440.4	1.75	4.6%
Total	**Annual energy savings (kWh)**	**9,037,272**	**7,987,201**	**0.88**	**8.7%**
	Summer seasonal demand savings (kW)	**579.9**	**832.0**	**1.43**	**14.3%**
	Winter seasonal demand savings (kW)	**297.2**	**586.3**	**1.97**	**5.7%**

The evaluators determined an overall annual electric energy savings gross RR of 88.4%, at a relative precision of ±8.7% at the 90% confidence interval. Table 4-1 (above) shows that the program is saving 12% less kWh than anticipated. The lower evaluated savings are mostly due to the lower-than-expected production levels in certain PRIME projects, which in turn reduced the savings. Other contributing factors to the kWh RR are discussed in Sections 4.2, 4.3, and 4.4

by program. The evaluated results for kWh achieved the ±10% relative precision bound targeted in the electric sample design for the BES suite overall.

Table 4-1 shows that the programs save higher levels of summer and winter peak demand than anticipated, primarily due to multiple instances of positive evaluated peak savings for O&M and PRIME projects reported as zero in the tracking data. As described in Section 3.3.1, PRIME projects by design do not claim peak demand savings. Section 4.3 and 4.4 further investigate higher evaluated savings for large O&M and RCx projects, respectively, leading to RRs higher than 100%.

Below, Figure 4-1 compares program-reported and evaluated annual kWh savings for the sample of BES projects studied. Ideally, the evaluated savings would always match the reported savings; this ideal is shown as a solid black line on the charts. Figure 4-2 illustrates a close-up of the shaded portion of Figure 4-1.

Figure 4-1. Comparison of BES Reported and Evaluated Electric Energy Savings

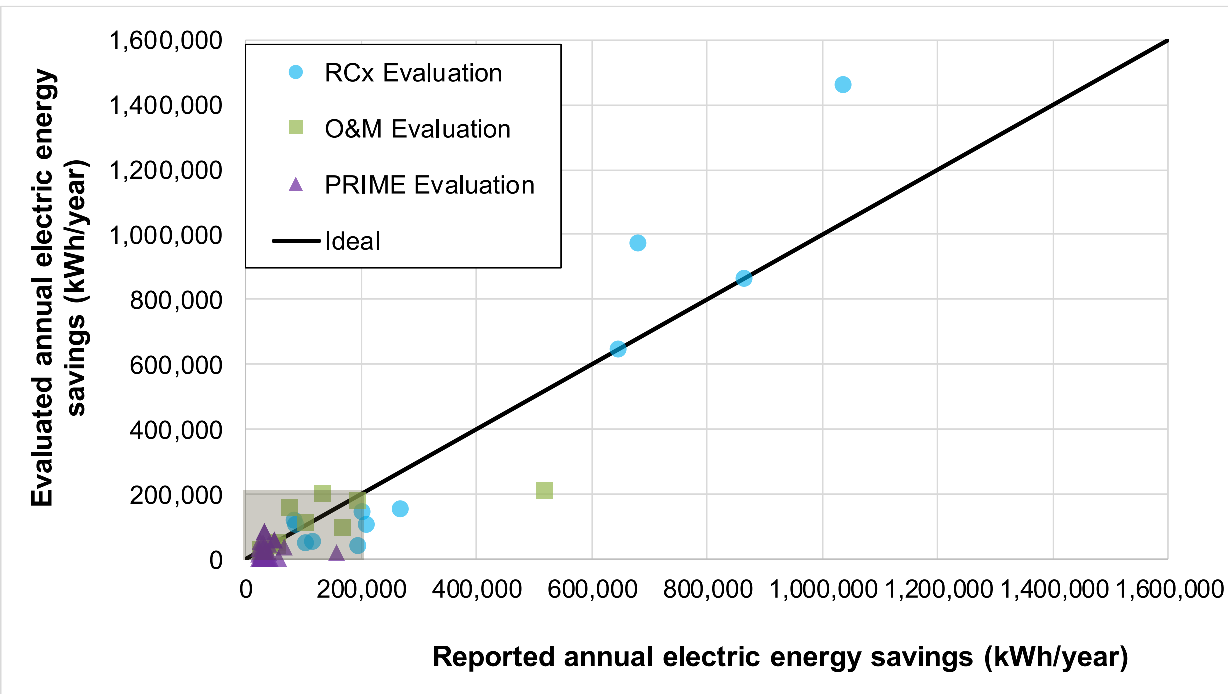


Figure 4-2. Comparison of BES Reported and Evaluated Electric Energy Savings – Close-Up

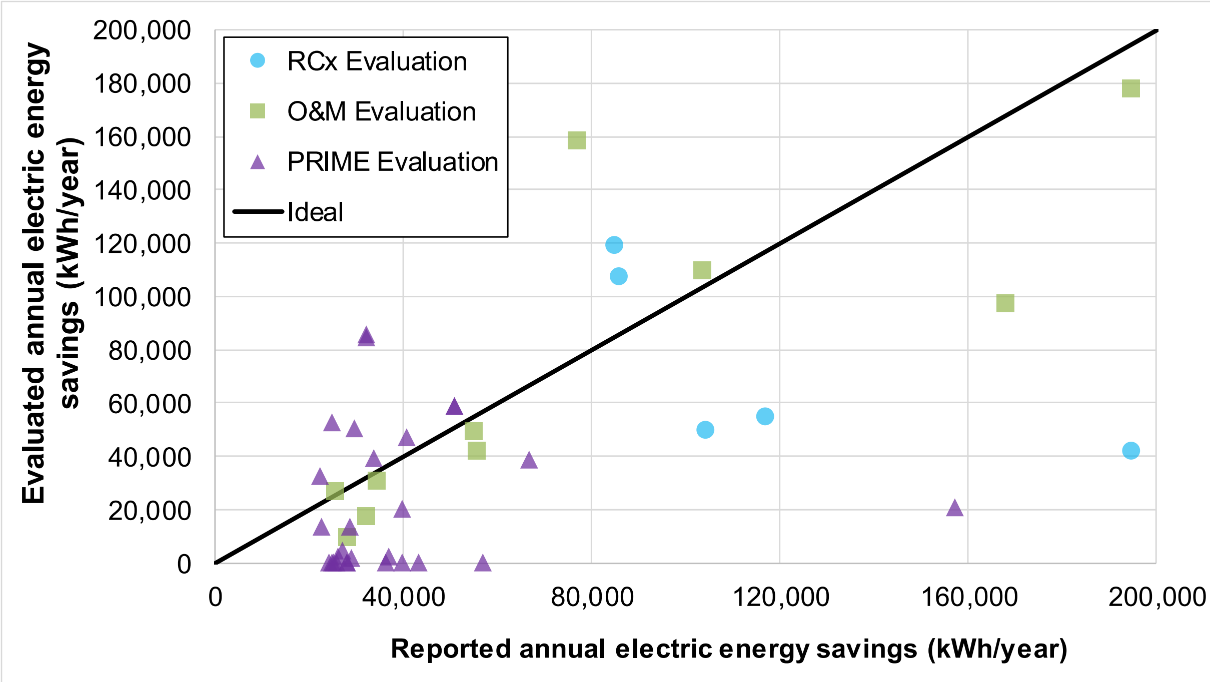


Figure 4-2 shows 10 of the smaller PRIME projects, in the range of 25,000 to 60,000 reported annual kWh savings, with little or no evaluated savings. On the other hand, as illustrated in Figure 4-1, the four largest kWh-saving projects in the sample, all from the RCx program, led to significantly higher evaluated savings for two projects and near-ideal RRs for the other two projects.

Figures 4-3 through 4-6 illustrate similar comparisons for summer and winter peak demand, respectively.

Figure 4-3. Comparison of BES Reported and Evaluated Summer Peak Demand Savings

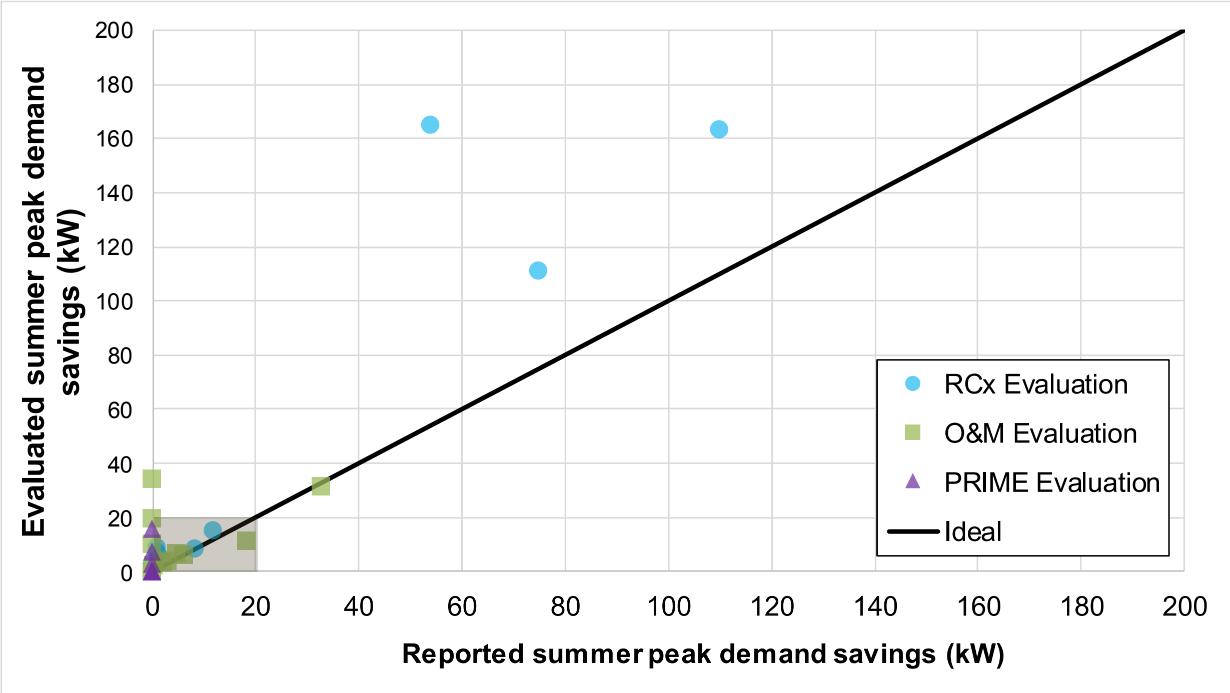


Figure 4-4. Comparison of BES Reported and Evaluated Summer Peak Demand Savings – Close-Up

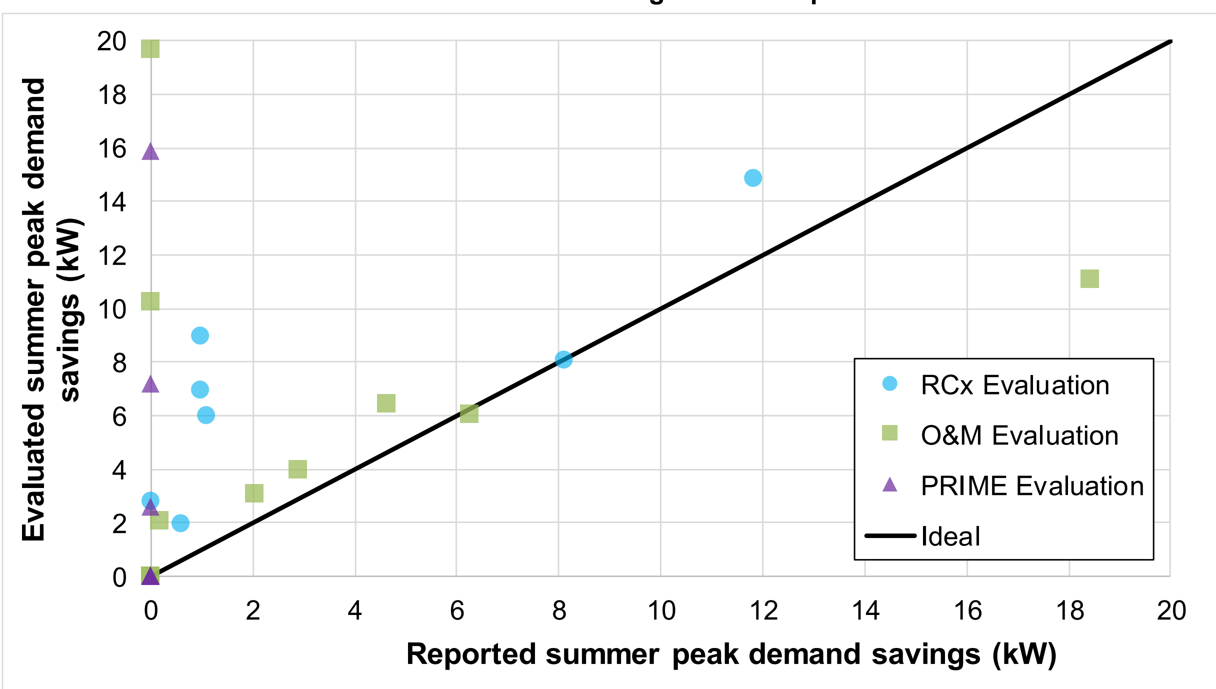


Figure 4-5. Comparison of BES Reported and Evaluated Winter Seasonal Peak Demand Savings

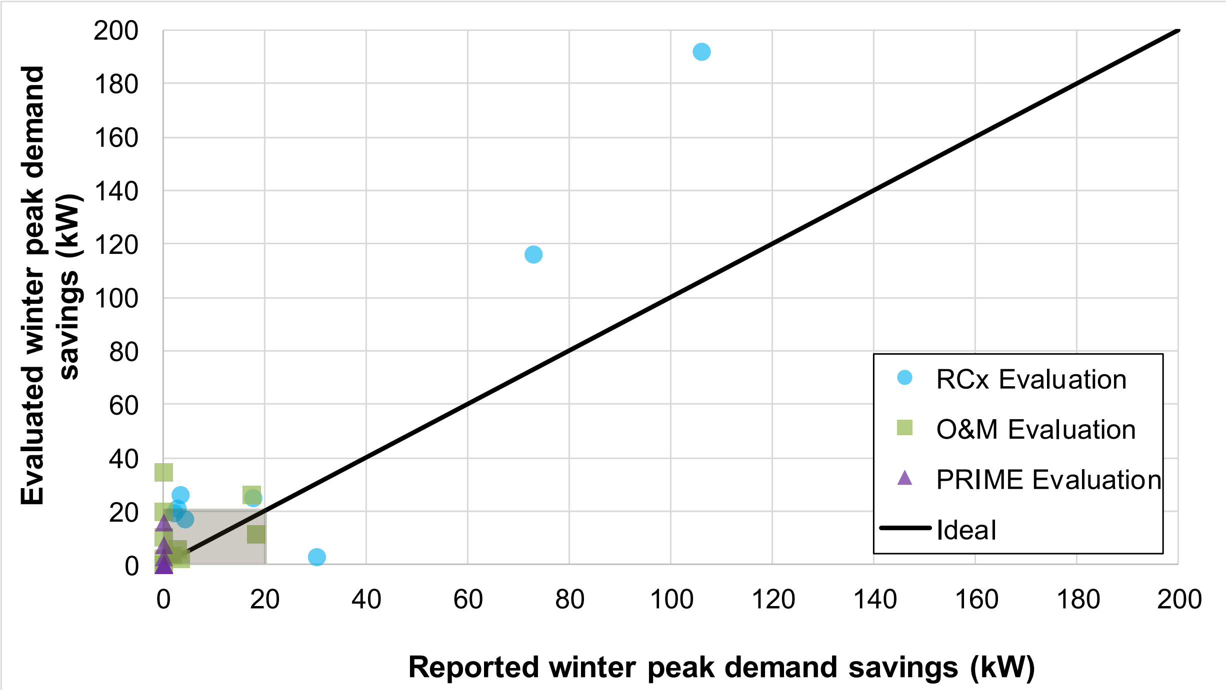
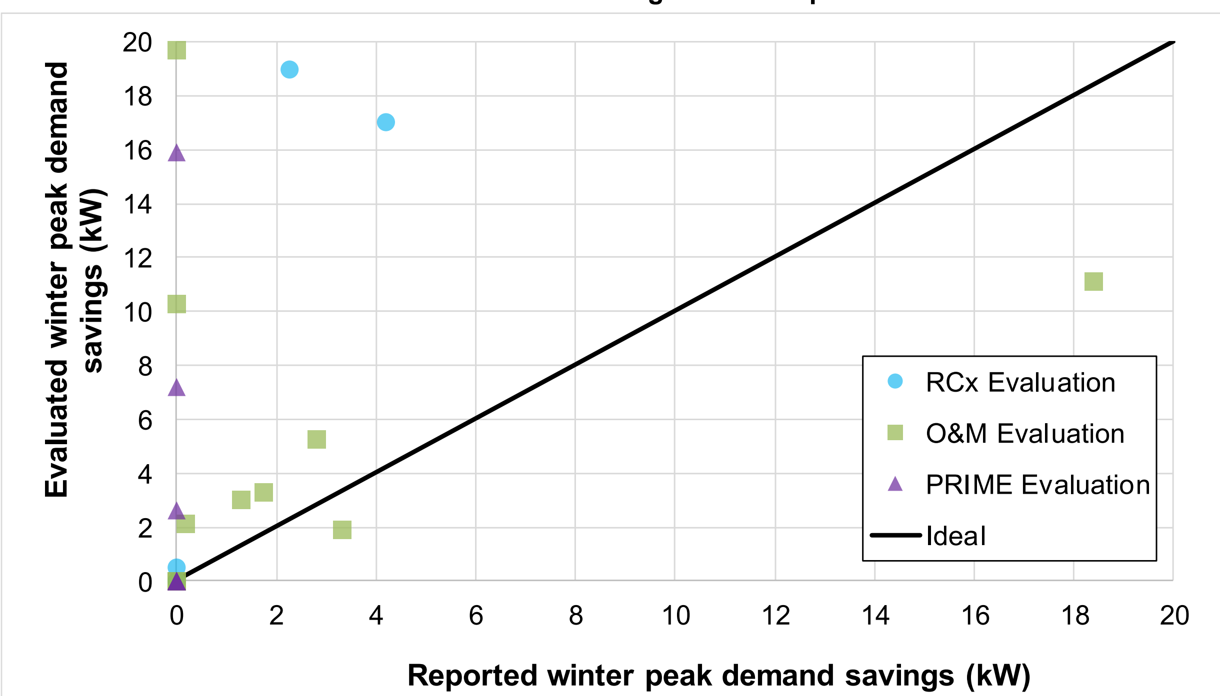


Figure 4-6. Comparison of BES Reported and Evaluated Winter Seasonal Peak Demand Savings – Close-Up



Figures 4-3 through 4-6 illustrate that most projects resulted in peak kW RRs greater than one (points above the ideal line), leading to overall summer and winter seasonal peak demand RRs of 143% and 197%, respectively. Evaluators found a total of 6 O&M and PRIME projects[23] that did not report peak demand savings but were confirmed by the evaluators to produce positive peak demand savings. This finding was the primary contributor to the high peak demand RRs indicated in Table 4-1. These points are illustrated on the y-axis in both left-hand and right-hand figures. Overall, the figures illustrate that more projects resulted in higher evaluated demand savings than reported.

4.1.2 Natural Gas Results

Table 4-2 provides the impact evaluation results by program for the BES projects claiming natural gas savings during the 2015 program year. PRIME projects did not claim natural gas impacts and are therefore not included in Table 4-2.

Table 4-2. Comparison of BES Reported and Evaluated Savings: Natural Gas Projects

Program	Total Reported Savings (MMBtu)	Total Evaluated Savings (MMBtu)	Evaluated Gross RR[1]	Relative Precision
O&M	33,252	23,265	0.70	10.0%
RCx	8,463	7,579	0.90	0.0%
Total	**41,714**	**30,716**	**0.74**	**7.9%**

[1] Evaluated gross RRs are calculated based on ex-ante savings that reflect the PSD algorithms at the time of project implementation (2015). The steam trap measure's savings algorithm has since been updated in the current CT PSD (2018). Therefore, evaluators calculated a forward-looking RR (FRR) that reflects the current steam trap savings algorithm. The O&M gas FRR of 0.94 should be applied by the program moving forward, as further explained in Section 4.6.

The evaluators determined a gross RR of 74%, at a relative precision of ±7.9% at the 90% confidence interval, for annual natural gas savings. Table 4-2 indicates that the program is saving 26% less natural gas than anticipated, for reasons that are explained in Sections 4.3 and 4.4. Figures 4-7 and 4-8 (the close-up) compare the program-reported and evaluated annual natural gas savings for the sample of BES projects studied.

[23] As recommended by the CT PSD, PRIME projects do not claim peak demand savings.

Figure 4-7. Comparison of BES Reported and Evaluated Natural Gas Savings

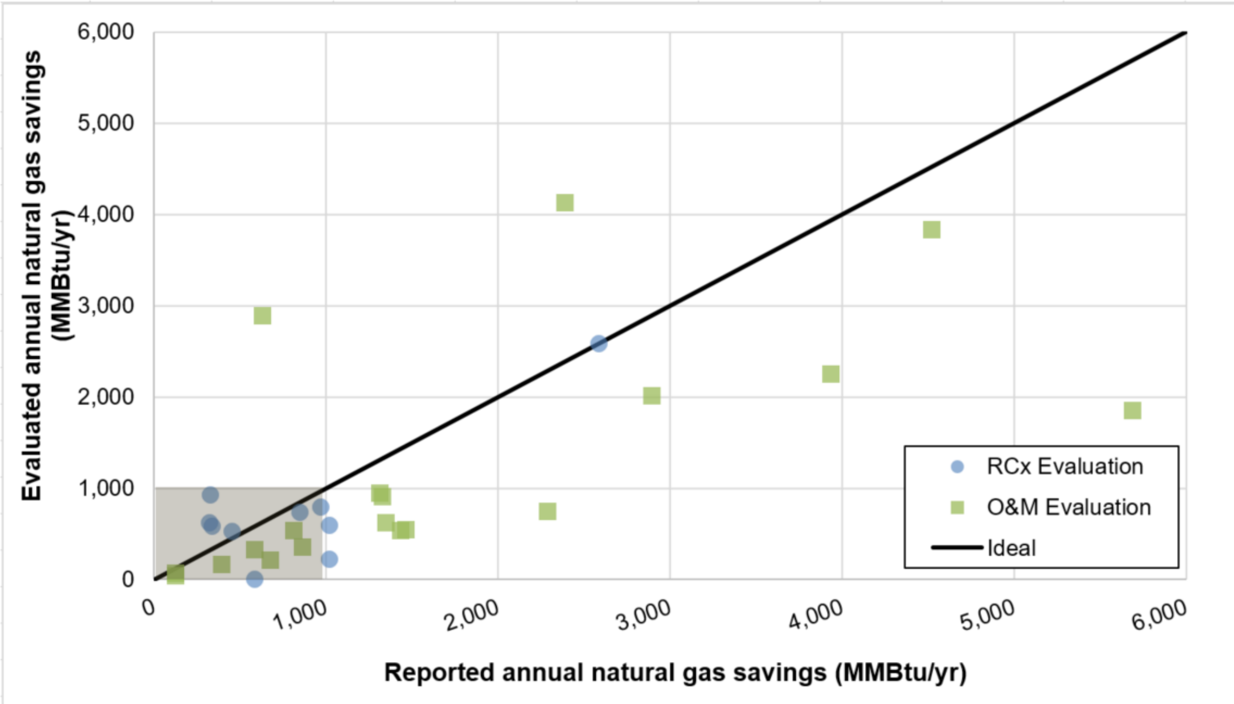
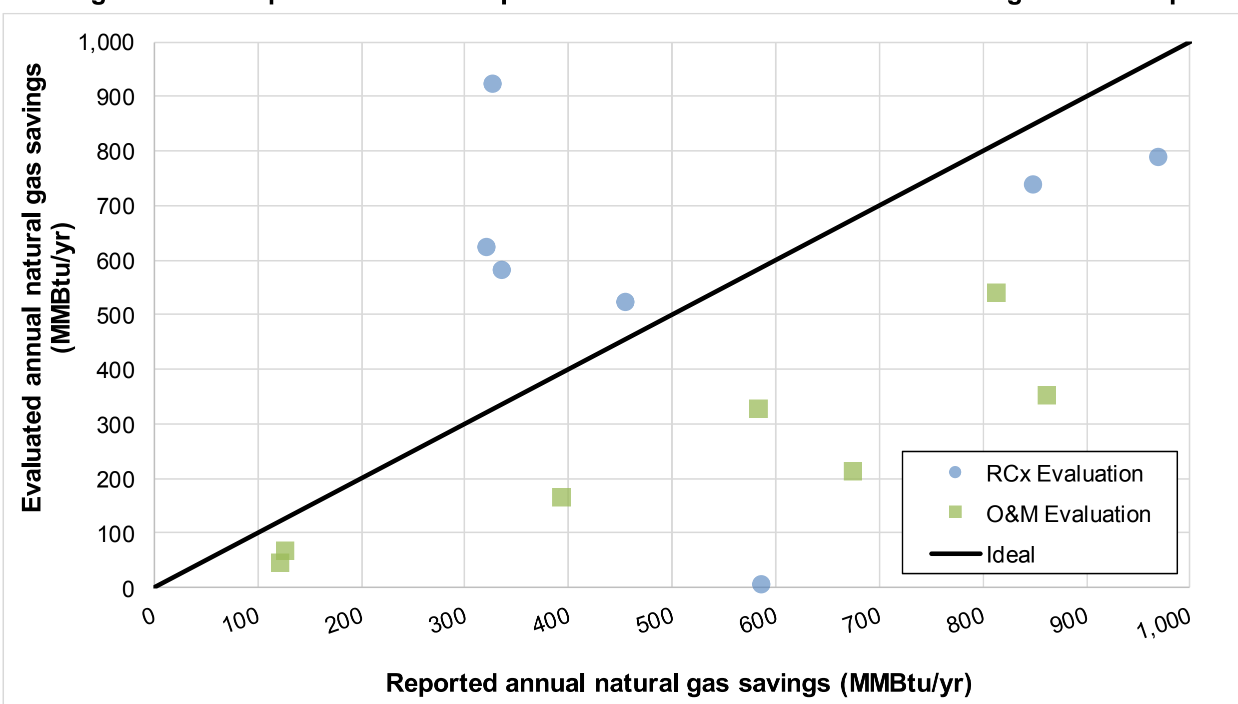


Figure 4-8. Comparison of BES Reported and Evaluated Natural Gas Savings – Close-Up



Figures 4-7 and 4-8 further illustrate how several of the O&M gas projects, many of which involved the repair or replacement of steam traps, featured lower evaluated savings than reported, resulting in an O&M gas RR of 70%. It should be noted that 18 of the 19 gas O&M projects involved steam trap repair or replacement measures. RCx gas projects, on the other hand, featured more mixed results, with about half of the small- and medium-sized projects scattered above the ideal line, and about half below, leading to an RCx gas RR of 90%.

4.2 Process Reengineering for Increased Manufacturing Efficiency (PRIME)

In order to contextualize this study's findings with prior evaluation results, Table 4-3 compares key evaluation criteria and findings for PRIME with the prior impact evaluation.

Table 4-3. Comparison of Key Criteria and Findings with Prior Impact Evaluation for PRIME

Parameter	Impact Evaluation Report Year	
Program Profile	**2007**	**2018**
Study period (program years)	2007	2015
Average reported annual savings (kWh)	1,280,994	2,187,794
Total number of sites	5	67
Average annual reported electricity savings/site (kWh)	256,199	32,654
Evaluation Approach		
Method(s)	Pilot program, census M&V	Sample M&V
Sampling method	N/A	SRE
Sample size (projects)	5	28
Results – RRs		
Electric energy	7%	54%

PRIME was previously evaluated in 2007[24] through a pilot assessment of the newly created program, examining only 5 projects in the evaluation. The current evaluation utilized an M&V approach among a sample of 28 projects completed in 2015, with results shown in Table 4-4.

Table 4-4. Comparison of BES Reported and Evaluated Savings: PRIME

Savings Metric	Total Reported Savings	Total Evaluated Savings	Evaluated Gross RR	Relative Precision
Annual energy savings (kWh)	2,187,794	1,180,245	0.54	29.4%

[24] "Process Reengineering for Increased Manufacturing Efficiency (PRIME) Program Evaluation", March 2007.
https://www.energizect.com/sites/default/files/CL&P%20PRIME%20Evaluation%20Report%20-%20FINAL%2003-26-07_0.pdf

The evaluators determined a gross kWh RR of 54%, at a relative precision of ±29.4% (±16% absolute precision) at the 90% confidence interval, for PRIME projects in the evaluation sample. The PRIME program does not report peak demand savings; however, as addressed in the next section, the evaluators identified peak demand savings for three PRIME projects in the evaluation sample.

4.2.1 Key Differences Influencing the PRIME Realization Rate

The evaluators investigated the key contributing factors leading to a 54% kWh RR for PRIME projects, as illustrated by Figure 4-9.

Figure 4-9. Key Drivers behind PRIME Electric Energy RR

	Negative Impact		Positive Impact		Overall	
Discrepancy Category	# Instances	Impact on RR	Impact on RR	# Instances	Impact on RR	# Instances
Differences in Production/Productivity	15	-77%	21%	7	-56%	22
Inaccurate breakdown of time/load-dependent kWh	8	-15%	47%	12	32%	20
Differences in utility billing data	9	-18%	7%	5	-10%	14
Revisions to process	1	-6%	0%	0	-6%	1
No evidence of production efficiency improvement	1	0%	0%	0	0%	1
Project not implemented	1	-5%	0%	0	-5%	1
Tracking savings discrepancy	1	-1%	0%	0	-1%	1
Total	**36**	**-121%**	**75%**	**24**	**-46%**	**60**

The most significant discrepancy categories are examined in more detail below:

- Differences in **production/productivity** between the evaluator's collected data and the applicant's assumptions most significantly impacted the PRIME kWh RR, leading to a 56% reduction in evaluated kWh savings. In general, the reported savings from PRIME projects are based on an assumption that production throughput will increase as a result of the project, but will not require as proportional an increase in required electric consumption (i.e., the normalized kWh-per-unit will decrease). However, the evaluators collected site-specific production data during the pre- and post-event periods to quantify the true change in production, if any. In 15 out of the 28 sampled PRIME projects, the evaluators determined lower-than-anticipated production change, leading to lower evaluated savings than anticipated. For 7 sampled PRIME projects, the evaluators determined that the production throughput decreased after the PRIME project was implemented, but the required energy use generally stayed the same, resulting in zero energy savings. We note that three of those projects occurred at the same facility, resulting in a 7% reduction in the overall PRIME electric realization rates. However, it is common for the PRIME program to sponsor multiple projects at the same facility, and the evaluators believe these findings are therefore appropriately representative.

- The next highest contributor to differences between the tracking and evaluated savings was due to an **inaccurate breakdown of time/load-dependent kWh** by the applicant in the reported savings calculation, though it resulted in an overall 32% increase to the evaluated kWh savings. As described in Section 3.3.1 and Appendix E, the PRIME algorithm categorizes facility electric consumption based on dependence on production hours and production load. The program PSD savings algorithm assumes the same blend of production-dependent and independent equipment for all PRIME projects. The evaluators calculated each factor site-specifically based on information gathered during the visit. Differences between the program-wide factor assumptions and the evaluator's site-specific factors led to greater evaluated savings overall. In 12 of the 28 sampled PRIME projects, the evaluators found a higher level of equipment time dependency, which is a key driver of savings in the algorithm presented in Section 3.3.1.
- Differences in **utility billing data** between the values used in the applicant analysis and those obtained by the evaluators resulted in a 10% reduction to the evaluated PRIME kWh savings. The evaluators requested utility bills spanning the pre- and post-event periods from both the utilities and customers themselves. During the site visits, the evaluators confirmed the account and meter number(s) impacted by the PRIME events. While the pre-project consumption theoretically should be identical between applicant and evaluator data sets, the evaluators often found significant discrepancies, resulting in lower evaluated savings for 9 projects. Additionally, the evaluators revised the PRIME algorithm's "percentage of sales impacted" value based on site-specific information; differences in that value are also included in this category, as the algorithm uses a product of that value and the total billed consumption.

4.2.2 Evaluator Findings on PRIME Algorithms Parameters

The CT PSD's lean manufacturing algorithm, as used by the PRIME program, is presented below.

$$
\begin{aligned}
&Annual\ kWh\ Savings \\
&\quad = Annual\ kWh \times PPA \\
&\quad \times \left[\left(\boldsymbol{Type\ A, B\ and\ Office} + \frac{N_a}{N_e}(\boldsymbol{Type\ C} + \boldsymbol{Type\ D})\right)\right. \\
&\quad \left. - \left(\boldsymbol{Type\ A, B\ and\ Office} + \boldsymbol{Type\ C} + \frac{N_a}{N_e}(\boldsymbol{Type\ D})(1 - SF)\right)\right]
\end{aligned}
$$

Where,

$Annual\ kWh$	= Annual electric usage, kWh
PPA	= Percentage of meter's total electricity consumption affected by PRIME event
$\boldsymbol{Type\ A, B, and\ Office}$	**= Percentage of facility loads independent of production hours and production throughput**
$\boldsymbol{Type\ C}$	**= Percentage of facility loads dependent on hours of production**
$\boldsymbol{Type\ D}$	**= Percentage of facility loads dependent on production throughput**
N_a	= Post-event production quantity
N_e	= Pre-event production quantity
SF	= Savings factor, detailed in Appendix E

The three load dependence factors, indicated in bold in the equation above, are constant values in the PSD algorithm and drive reported savings. The CT PSD incorporated results from the prior (2007) pilot evaluation that involved the assessment of five PRIME projects. The evaluators recalculated these factors separately for each sampled PRIME project using site-specific information in order to determine the evaluated savings by site. The weighted average of the evaluation values, aggregated among the sample of 28 projects and weighted by total annual dependent kWh, differed markedly from the CT PSD's recommended values, as shown in Table 4-5.

Table 4-5. Comparison of CT PSD's and Evaluator's Load Dependence Factors

kWh Load Type	Percentage of Facility Annual Electric Usage by Load Type	
	CT PSD Value	Evaluated Value
Constant (Type A & B & Office)	65%	41%
Time Dependent (Type C)	20%	41%
Time & Load Dependent (Type D)	15%	18%

4.3 Operations and Maintenance Services Program (O&M)

Table 4-6 compares key evaluation criteria and findings for O&M with the prior impact evaluation completed in 2013.[25]

Table 4-6. Comparison of Key Criteria and Findings with Prior Impact Evaluation for O&M

Parameter	Impact Evaluation Report Year	
Program Profile	**2013**	**2018**
Study period (program years)	2008-2010	2015
Average program reported annual savings (kWh)	4,119,770	2,004,007
Average annual number of electric sites	46	21
Average annual reported electricity savings per site (kWh)	88,916	95,429
Average program reported annual savings (MMBtu)	290	32,789
Average annual number of gas sites	1	19
Average annual reported gas savings per site (MMBtu)	290	1,726
Evaluation Approach		
Method(s)	Sample M&V	Electric - Sample M&V Gas - Census M&V
Sampling method	SRE	SRE
Sample size (projects)	47 (44 electric, 3 gas)	21 (12 electric, 19 gas)
Results – RRs		
Electric energy	73%	79%
Summer seasonal peak demand	84%	191%
Winter seasonal peak demand	101%	258%
Natural gas energy	87%	70%

While the number of O&M electric sites per year has decreased from the prior impact evaluation period, the O&M gas site count and savings per year have increased significantly due to the inclusion of steam trap repair/replacement projects. The program achieved higher RRs for electric energy and summer and winter peak demand, but a lower RR for natural gas energy, as compared to the prior impact evaluation that examined only three gas projects.

4.3.1 Electric O&M

Table 4-7 provides the impact evaluation results for O&M projects claiming electric savings during the 2015 program year.

[25] "Impact Evaluation of the Retrocommissioning, Operations and Maintenance and Business Sustainability Challenge Programs Impact Evaluation," January 2013. https://www.energizect.com/sites/default/files/RCx-OM-%20BSC%20Final%20Report%2001-21-13.pdf

Table 4-7. Comparison of Reported and Evaluated Savings: Electric RCx Projects

Savings Metric	Total Reported Savings	Total Evaluated Savings	Evaluated Gross RR	Relative Precision
Annual energy savings (kWh)	2,004,007	1,589,436	0.79	18.1%
Summer on-peak demand savings (kW)	74.1	141.8	1.91	28.7%
Summer seasonal demand savings (kW)	74.1	141.8	1.91	28.7%
Winter on-peak demand savings (kW)	45.6	117.7	2.58	21.1%
Winter seasonal demand savings (kW)	45.6	117.7	2.58	21.1%

The evaluators determined a gross kWh RR of 79%, at a relative precision of ±18.1% at the 90% confidence interval, for electric O&M projects in the evaluation sample. O&M projects save significantly more summer and winter peak demand than reported. Key drivers behind the O&M electric RRs are examined in the next section.

4.1.1.1 Key Differences Influencing the O&M Electric Realization Rate

The O&M projects in the electric sample consisted of lighting (5 projects), compressed air leak repair (4), PC power management (2), and idle load reduction (1). The small sample and technology diversity do not allow meaningful tabulation of discrepancies by measure category. The primary discrepancies between the reported and evaluated savings for O&M electric projects are examined below:

- **Lighting O&M** projects generally featured lower evaluated savings than anticipated. Differences in **HVAC interactive savings calculations** between the applicant and evaluator more significantly impacted the lighting kWh RR than adjustments to fixture power or hours of use. The program calculated the HVAC interactive savings using the CT PSD algorithms. However, the evaluation analysis incorporated the actual lighting metered data and typical weather data to determine full-load cooling hours for the spaces impacted by the fixture upgrade, leading to a 4% reduction in evaluated kWh savings for 4 out of the 5 lighting O&M projects in the sample.
- **Compressed air leak repair** projects featured higher evaluated savings than reported overall. The evaluators found that differences in **air compressor efficiency** (in kW/cfm), as assumed by the applicant and determined by the evaluators, was the highest contributor to an RR greater than 100% for compressed air leak repair projects. In one project example, the evaluators measured a kW/cfm value of 0.63 instead of the 0.16 kW/cfm assumed in the reported savings calculation. These higher kW/cfm represent less-efficient compressors in the evaluated case than the tracking estimate, leading to higher savings.

- **PC power management projects** featured lower evaluated savings than reported overall. For both projects in the evaluation sample, the evaluators found differences in **baseline assumptions** between the applicant and evaluator for PC idle load wattages to most significantly impact the kWh RR. The evaluators incorporated the actual metering data to determine the baseline (idle load) power consumption of laptops and desktops affected by the projects, leading to lower baseline power consumptions than what was used in the applicant analysis.

4.3.2 Natural Gas O&M

Table 4-8 provides the impact evaluation results for RCx projects claiming natural gas savings during program year 2015. The evaluation was based on a census attempt for all of the 19 projects with over 500 MMBtu/yr of savings.

Table 4-8. Comparison of Reported and Evaluated Savings: Natural Gas RCx Projects

Savings Metric	Total Reported Savings	Total Evaluated Savings	Evaluated Gross RR
Annual energy savings (MMBtu/year)	33,252	23,265	0.70

The evaluators determined a gross MMBtu RR of 70%, at a relative precision of ±10.0% at the 90% confidence interval, for natural gas O&M projects in the evaluation sample.

4.3.2.1 Key Differences Influencing the O&M Natural Gas Realization Rate

Since 18 of the 19 gas O&M projects sampled for evaluation involved steam trap repair/replacement measures, the evaluators focused the discrepancy analysis on that measure, as illustrated in Figure 4-10[26].

[26] The discrepancy analysis reflects the evaluated gross RRs, which were calculated based on ex-ante savings estimated using the PSD algorithms at the time of project implementation (2015). The steam trap measure algorithms have since been updated in the current (2018) CT PSD, and a forward-looking RR (FRR) of 0.94 is recommended in Section 4.6 for gas O&M projects.

Figure 4-10. Key Drivers behind O&M Steam Trap Measures RR

Discrepancy Category	Negative Impact		Positive Impact		Overall	
	# Instances	Impact on RR	Impact on RR	# Instances	Impact on RR	# Instances
Decommissioned equipment	3	-7%	0%	0	-7%	3
Difference in operating hours	4	-2%	1%	2	-1%	6
Difference in calculation methodology	14	-35%	7%	1	-27%	15
Difference in steam properties	0	0%	11%	3	11%	3
Difference in boiler efficiency	11	-4%	0%	0	-4%	11
Documentation differences	2	-7%	8%	2	2%	4
Total	**34**	**-54%**	**28%**	**8**	**-26%**	**42**

Selected discrepancy categories are examined in more detail below:

- Differences between the applicant's and evaluators' **calculation methodologies** most significantly impacted the RR for steam trap projects. As described in Section 3.3.2.1 and Appendix C, the evaluators used an alternative steam trap savings algorithm based on recent Massachusetts research[27] instead of the steam trap savings algorithm recommended in the CT PSD[28]. The MA algorithm has a similar structure and variables to the PSD algorithm but incorporates revised model coefficient values based on a recent study of actual steam trap performance in MA that was supported by pre/post gas billing analysis. The revised method and model coefficient values led to a 27% reduction in evaluated natural gas savings, compared with the PSD approach for the same project.
- Differences in **steam conditions** between those assumed in the applicant analysis and observed by the evaluators on-site was the next highest contributor, resulting in an overall 11% increase to the evaluated O&M natural gas savings. For 3 projects in the sample, the evaluators observed higher steam pressure at the traps than stated in the project application, leading to higher savings from trap repair/replacement.
- The evaluators encountered **decommissioned steam traps** during the site visits, which resulted in a 7% reduction to the evaluated O&M natural gas savings. For 3 out of the 18

[27] "Steam Trap Evaluation Phase 2 by ERS for Massachusetts (MA) Program Administrators and Energy Efficiency Advisory Council", March 18, 2017. This analysis derives algorithm variable values and savings based on billing analysis and engineering calculations of 24 office, health care, schools, municipal and industrial facilities. http://ma-eeac.org/wordpress/wp-content/uploads/Steam-Trap-Evaluation-Phase-II.pdf

[28] The PSD has since updated the algorithms for steam trap savings. The current version of the PSD (2018) recommends two mutually exclusive approaches to calculating steam trap savings—Napier and Grashof—each of which generally reflect the evaluator's savings factors based on recent Massachusetts research on actual steam trap performance through analysis of utility data. Therefore, evaluators calculated an O&M gas forward-looking RR (FRR) that reflects the current steam trap savings algorithm of 0.94 as further explained in Section 4.6.

evaluated steam trap projects, the evaluators found one or more claimed steam traps to be decommissioned, leading to lower evaluated savings than anticipated.

4.4 Retro-Commissioning Program (RCx)

In order to contextualize this study's findings with prior evaluation results, Table 4-9 compares key evaluation criteria and findings for RCx with the prior impact evaluation completed in 2013.[29]

Table 4-9. Comparison of Key Criteria and Findings with Prior Impact Evaluation for RCx

Parameter	Impact Evaluation Report Year	
Program Profile	**2013**	**2018**
Study period (program years)	2008-2010	2015
Average reported annual savings (kWh)	1,955,185	4,845,471
Average annual number of electric sites	6	16
Average annual reported electricity savings/site (kWh)	345,033	302,842
Average reported annual savings (MMBtu)	2,500	8,463
Average annual number of gas sites	1	10
Average annual reported gas savings/site (MMBtu)	1,875	846
Evaluation Approach		
Method(s)	Census M&V	Census M&V
Results – RRs		
Electric energy	74%	105%
Summer seasonal peak demand	113%	126%
Winter seasonal peak demand	90%	175%
Natural gas energy	60%	90%

The count of electric and natural gas sites per year has increased significantly from the prior RCx impact evaluation, subsequently increasing the number of evaluated sites using a similar census M&V approach. The current impact evaluation resulted in higher RRs for all savings metrics compared to the prior impact evaluation, as examined further in the next sections.

4.4.1 Electric RCx

Table 4-10 provides the impact evaluation results for RCx projects claiming electric savings during the 2015 program year.

[29] "Impact Evaluation of the Retrocommissioning, Operations and Maintenance and Business Sustainability Challenge Programs Impact Evaluation," January 2013. https://www.energizect.com/sites/default/files/RCx-OM-%20BSC%20Final%20Report%2001-21-13.pdf

Table 4-10. Comparison of Reported and Evaluated Savings: Electric RCx Projects

Savings Metric	Total Reported Savings	Total Evaluated Savings	Evaluated Gross RR	Relative Precision
Annual energy savings (kWh)	4,845,471	5,092,974	1.05	6.9%
Summer on-peak demand savings (kW)	505.8	636.2	1.26	17.4%
Summer seasonal demand savings (kW)	505.8	636.2	1.26	17.4%
Winter on-peak demand savings (kW)	251.6	440.4	1.75	4.6%
Winter seasonal demand savings (kW)	251.6	440.4	1.75	4.6%

The evaluators determined an annual RCx electric energy savings gross RR of 105%, at a relative precision of ±6.9% at the 90% confidence interval. Additionally, RCx was determined to save higher levels than reported of peak demand savings – 126% for summer peak and 175% for winter peak –at relative precisions of 17.4% and 4.6%, respectively, at the 80% confidence interval. The program achieved higher levels of kWh, summer peak demand, and winter peak demand savings than anticipated.

4.4.1.1 Key Differences Influencing the RCx Electric Realization Rate

The evaluators investigated the key contributing factors leading to a 105% kWh RR for electric RCx projects, as illustrated by Figure 4-11. Overall, the positive and negative factors cancelled out, producing an RR close to 100%.

Figure 4-11. Key Drivers behind RCx Electric Energy RR

Discrepancy Category	Negative Impact		Positive Impact		Overall	
	# Instances	Impact on RR	Impact on RR	# Instances	Impact on RR	# Instances
Difference in baseline assumptions	7	-6%	12%	2	6%	9
Difference in calculation methodology	4	-2%	0%	0	-2%	4
Difference in installed quantity	3	-16%	0%	0	-16%	3
Documentation differences	1	0%	0%	0	0%	1
Measure not implemented	1	0%	0%	0	0%	1
Difference in equipment operation	10	-5%	24%	6	18%	16
Total	**26**	**-31%**	**36%**	**8**	**5%**	**34**

Selected discrepancy categories are examined in more detail below:

- Differences in **equipment operation** estimated by the applicant and measured by the evaluators most significantly contributed to the 105% RR, leading to an 18% increase in evaluated kWh savings. Since RCx measures often involve optimizing fan/pump speed through VFDs, this discrepancy category encompasses differences in equipment load profiles as well as setbacks, and differences in equipment operating hours. The evaluators observed this difference in 9 out of the 12 sampled RCx electric projects. The reported savings were based on the applicant's predicted equipment operating profiles based on outside weather conditions and/or building occupancy. The evaluators obtained site-specific equipment loading data, through metering and/or collection of trended data, to update the savings calculation.

- Differences in **installed equipment quantity** between the applicant paperwork and evaluator inspection was the next highest contributor to the kWh RR, leading to a 16% reduction to the evaluated kWh savings. This category includes equipment that could not be found during the evaluators' site visits or were decommissioned or removed. In three instances, the evaluators found different quantities of installed equipment than the value reflected in the applicant's paperwork.
- The evaluators found **differences in baseline** assumed by the applicant and characterized by the evaluators, resulting in a 6% increase in evaluated kWh savings. Generally, for RCx projects, the baseline reflects the pre-project operating conditions. In nine instances, the evaluators found different pre-project operations than that reflected in the reported savings calculation.

4.4.2 Natural Gas RCx

Table 4-11 provides the impact evaluation results for RCx projects claiming natural gas savings during the 2015 program year.

Table 4-11. Comparison of Reported and Evaluated Savings: Natural Gas RCx Projects

Savings Metric	Total Reported Savings	Total Evaluated Savings	Evaluated Gross RR
Annual energy savings (MMBtu/year)	8,463	7,579	0.90

The evaluators determined an RCx gas RR of 90% at a relative precision of ±0%, since each RCx project claiming natural gas savings in 2015 was evaluated.

4.4.2.1 Key Differences Influencing the RCx Natural Gas Realization Rate

The evaluators investigated the key contributing factors leading to a 90% RR for natural gas RCx projects, as illustrated by Figure 4-12.

Figure 4-12. Key Drivers behind RCx Natural Gas RR

Discrepancy Category	Negative Impact		Positive Impact		Overall	
	# Instances	Impact on RR	Impact on RR	# Instances	Impact on RR	# Instances
Difference in baseline assumptions	4	-5%	2%	7	-3%	11
Difference in calculation methodology	1	-5%	3%	1	-2%	2
Difference in installed quantity	1	0%	0%	0	0%	1
Difference in equipment operation	7	-17%	8%	6	-9%	13
Documentation differences	0	0%	3%	7	3%	7
Total	**13**	**-27%**	**16%**	**21**	**-10%**	**34**

Selected discrepancy categories are examined in more detail below:

- Differences in **equipment operation**, as estimated by the applicant and measured by the evaluators, most significantly impacted the RCx gas RR, leading to a 9% reduction in evaluated natural gas savings. Similar to the electric RCx difference in the prior section, the evaluators observed this discrepancy in 7 out of the 10 RCx natural gas projects.
- The evaluators encountered errors in applicant savings calculations or discrepancies between the applicant-calculated savings and reported savings in 7 out of the 10 RCx gas projects, categorized as **documentation differences** in Figure 4-12. Overall, this led to a 3% increase in the evaluated natural gas savings. In one example, the evaluators found that a sub-measure originally included in the applicant analysis was removed from the reported savings. The measure was confirmed by the evaluators to be installed and operable and counted toward the evaluated savings.
- The evaluators found **differences in baseline** assumed by the applicant and characterized by the evaluators, resulting in a 3% reduction in evaluated natural gas savings. Generally, for RCx projects, the baseline reflects the pre-project operating conditions. In eleven instances, the evaluators found different pre-project operations than that reflected in the reported savings calculation.

4.5 Additional Results

This section summarizes the evaluation results segmented by utility, as well as the statistical metrics that might inform future impact evaluations of the BES programs.

4.5.1 Results by Utility

The evaluation sample design was optimized to achieve statistically significant results on electric and natural gas savings overall. Analysts conducted post hoc stratification by utility company on the results of the 81 sampled projects. Eversource and UI separately issue implementation contracts for the various programs offered by BES. Eversource accounted for approximately 85% of the BES programs' energy savings in Connecticut over the evaluation time frame, and Eversource projects sampled for evaluation outnumbered the sampled UI projects by nearly four-to-one. Tables 4-12, 4-13, and 4-14 compare energy savings realization rates segmented by utility for PRIME, O&M, and RCx, respectively. Because of the small size of the UI sample, and because of the relatively low populations of projects for RCx and O&M programs overall, none of the segmented results below can be considered statistically significant, and small differences in RR should not be considered meaningful. The utility-specific results are provided for illustrative purposes only and should not be used for computing utility-level evaluated results.

Table 4-12. Comparison of PRIME Reported Savings and RRs by Utility

	Eversource (n=25)		UI (n=3)[1]		Overall
Savings Metric	Total Reported Savings	Evaluated Gross RR	Total Reported Savings	Evaluated Gross RR	Evaluated Gross RR
Annual energy savings (kWh)	1,950,093	0.58	237,701	0.22	0.54

[1] The evaluators acknowledge that the UI representation within the PRIME sample is noticeably low. However, of the population of 67 PRIME projects completed in 2015, UI only sponsored 9 projects. The UI representation in the evaluation sample is somewhat proportional to the PRIME population overall, but the utility-specific results cannot be considered statistically significant and are provided for illustrative purposes only.

Table 4-13. Comparison of O&M Reported Savings and RRs by Utility[1]

	Eversource (n=24)		UI (n=7)		Overall
Savings Metric	Total Reported Savings	Evaluated Gross RR	Total Reported Savings	Evaluated Gross RR	Evaluated Gross RR
Annual energy savings (kWh)	1,776,296	0.63	227,711	1.71	0.79
Natural gas savings (MMBtu)	26,366	0.61	6,886	1.07	0.70

[1] Peak demand savings were rare among O&M measures, except for lighting, which accounted for the majority of reported peak demand savings in PY2015. As utilities have acknowledged that lighting measures have been phased out of the O&M program, evaluators have not included evaluation peak demand results in this table.

Table 4-14. Comparison of RCx Reported Savings and RRs by Utility

Savings Metric	Eversource (n=18)		UI (n=4)		Overall
	Total Reported Savings	Evaluated Gross RR	Total Reported Savings	Evaluated Gross RR	Evaluated Gross RR
Annual energy savings (kWh)	4,200,843	1.08	644,628	0.82	1.05
Summer on-peak demand savings (kW)	501.80	1.21	3.95	6.70	1.26
Summer seasonal demand savings (kW)	501.80	1.21	3.95	6.70	1.26
Winter on-peak demand savings (kW)	237.52	1.48	14.11	6.67	1.75
Winter seasonal demand savings (kW)	237.52	1.48	14.11	6.67	1.75
Natural gas savings (MMBtu)	8,463	0.90	0.00	N/A	0.90

4.5.2 Statistical Results

Section 3.1 summarized the evaluators' assumptions in the sample design, including the error ratio, which represents a prediction of the variability of results. Using the evaluated results, the evaluators were able to compare error ratio predictions with actual findings, as summarized in Table 4-15.

Table 4-15. Comparison of Predicted and Actual Error Ratios

Savings Type	Predicted Error Ratio	Actual Error Ratio - PRIME	Actual Error Ratio - RCx	Actual Error Ratio – O&M
Electric energy	0.50	1.35	0.34	0.57
Summer peak demand	0.60	N/A	0.85	0.58
Winter peak demand	0.60	N/A	0.61	0.64
Natural gas	0.50	N/A	0.60	0.86

The evaluators generally found higher error ratios than predicted for BES projects. Since PRIME was previously evaluated as a pilot program, and due to the 7 zero-saver PRIME projects determined by the evaluators, the actual error ratio for PRIME was significantly higher than the assumed value of 0.5. RCx electric energy is the lone savings metric that produced a slightly better error ratio than predicted. Barring any significant changes in program design, offerings, or participation, the actual error ratios in Table 4-16 can be used to more realistically inform the sample designs of future BES impact evaluations.

4.6 Forward-Looking Realization Rates

The evaluators examined differences between the current (2018) version of the Connecticut PSD and the versions active at the time of application for BES projects completed in 2015. The BES suite of programs contains several measures that are not addressed in the Connecticut PSD due to their site-specific nature, as they are not conducive to a deemed savings approach. Such measures in the evaluation sample included all RCx measures as well as three O&M measures: compressed air leak repair, idle load reduction, and PC power management.

Prevalent measures in the BES evaluation sample that are addressed in the PSD include PRIME lean manufacturing events, O&M lighting, and O&M steam traps. The evaluators identified differences in algorithms only for the O&M steam trap measure. A measure-by-measure summary is provided in Table 4-16, indicating no changes to the PSD since 2015 for all measures except O&M steam traps.

Table 4-16. PSD Algorithms for BES Measures

Program	Measure	PSD Changes Since 2015?	Notes
PRIME	Lean manufacturing	No	No changes since 2015 PSD.
RCx	RCx improvements	N/A	Measure not addressed in PSD.
O&M	Steam trap replacement	Yes	PSD was revised in 2018 to more closely reflect the evaluator's savings approach that incorporates steam loss adjustment factors for failed and leaking traps and a condensate return factor based on MA evaluation findings. The 2018 PSD recommends two mutually exclusive methodology options (Napier and Grashof) to calculate savings from steam trap repair or replacement. The O&M gas FRR has been calculated based on the evaluator's forthcoming recommendation that only the Grashof method is used moving forward.
	Compressed air leak repair	N/A	Measure not addressed in PSD.
	Pipe insulation	No	No changes since 2015 PSD.
	Lighting	No	Reported savings were not calculated using a lighting power density (LPD) approach, and exterior savings were calculated in accordance with the current PSD. No FRR adjustment needed.
	PC power management	N/A	Measure not addressed in PSD.
	Idle load reduction	N/A	Measure not addressed in PSD.

For all electric projects, the forward-looking realization rates (FRRs) are identical to the evaluation RRs for all BES programs, since there were no algorithm changes since 2015 for any electric measures addressed by the PSD.

For natural gas, since the O&M steam trap algorithm was revised in the 2018 version of the PSD, the evaluators factored out the gas RR discrepancy due to differences in calculation methodology (see Figure 4-10), as it will no longer impact the reported savings using the algorithms currently reflected in the 2018 PSD. The project-level results were then re-aggregated using the same case weights to produce a program-level FRR for O&M gas projects. The results of the FRR analysis are compared to the evaluation RRs in Table 4-17.

Table 4-17. Comparison of Evaluation RRs with Forward-Looking RRs

Savings Type	Program	Evaluated Gross RR	Forward-Looking RR	Note
Electric	PRIME	0.54	0.54	No PSD changes between 2015 and 2018.
	O&M	0.79	0.79	No PSD changes between 2015 and 2018.
	RCx	1.05	1.05	No PSD changes between 2015 and 2018.
	Total	**0.88**	**0.88**	
Gas	O&M	0.70	0.94	Only steam trap measures have changed.
	RCx	0.90	0.90	No PSD changes between 2015 and 2018.
	Total	**0.74**	**0.93**	

4.7 Non-Energy Impacts

One of the research objectives for this study was to estimate the non-energy impacts (NEIs) of the BES program through site-specific assessment among the sample of evaluated projects. Currently, no NEIs are tracked for commercial and industrial programs. The goal of the NEI quantification is to monetize the NEIs that customers described and then express them in terms of NEI dollars per kWh or natural gas MMBtu saved. This study's NEI results can be expressed at the program level if desired, applied to benefit-cost analysis, or used for planning purposes similar to the residential NEI values recommended in Appendix 6 of the 2017 Connecticut PSD.

The evaluators developed comprehensive NEI survey templates (see Appendix F) and conducted on-site NEI surveys for every project in the sample to estimate the program's impacts on metrics other than electricity and natural gas.

During each site visit, the evaluators identified the most appropriate facility representative(s) to answer questions about non-energy impacts resulting from the implemented BES project. When non-zero NEIs were identified in the survey, the evaluators probed further to most quantitatively estimate the NEIs.

Table 4-18 lists the NEI categories that were investigated in this study, along with the count of sampled projects with non-zero NEIs by program. Participants identified a total of 100 incidences of NEIs among the 70 surveyed projects, indicating that, on average, participants identified 1.43 NEIs per project.

Table 4-18. NEIs by Category and BES Program

NEI Category	Count of Projects with NEIs			
	PRIME	O&M	RCx	Total
Fuel oil consumption/propane consumption/wood as an energy resource	0	1	2	**3**
Fresh potable water supplies	0	1	3	**4**
Wastewater generation and treatment	3	0	1	**4**
Solid, non-waste water liquid or gaseous hazardous waste generation and treatment	6	3	0	**9**
Labor requirements or labor associated costs	17	3	0	**20**
Equipment operations and maintenance	7	10	8	**25**
Materials or other supply needs	4	2	3	**9**
Productivity	13	4	3	**20**
Product spoilage	0	2	0	**2**
Transportation costs	1	0	0	**1**
Rent or insurance associated costs	0	1	0	**1**
Other benefits (emission reductions, health benefits)	1	1	0	**2**
Total	**52**	**28**	**20**	**100**

Table 4-19 below, illustrates the percentage of sampled projects with NEIs for each category and program, as well as the quantified impacts per source MMBtu savings claim as determined from customer responses. While some NEI categories were conducive to quantifying NEIs, others required engineering judgment to convert the customer's qualitative survey responses to more quantitative data using other proxy variables (e.g., as a function of project savings magnitude, number of employees, etc.). The impacts presented in Table 4-19 are not reported with statistical significance. While the NEI estimates have higher levels of both engineering and statistical uncertainty than energy impact estimates, the evaluators find them non-zero and credible and believe they are worthy of consideration when valuing the BES programs' overall impact and cost-effectiveness. The RCx material cost impacts are less than zero in Table 4-19 since one of the projects in the sample incurred significant material costs after the project implementation.

Table 4-19. NEIs Associated with BES Projects

NEI Category	Total Count of Projects with NEIs	Units for Impacts (per source MMBtu of Program Energy Savings)[1]	PRIME		O&M		RCx	
			% of Sampled Projects with NEIs	Impacts for Projects with the NEI	% of Sampled Projects with NEIs	Impacts for Projects with the NEI	% of Sampled Projects with NEIs	Impacts for Projects with the NEI
Fuel oil, propane, wood	3	MMBtu	0%	N/A	3%	N.D.	13%	0.0640
Fresh potable water supplies	4	Gallons	0%	N/A	3%	278	20%	641
Wastewater generation & treatment	4	N/A	11%	N.D.	0%	N/A	7%	N.D.
Solid, non-waste water liquid or gaseous hazardous waste generation and treatment	9	Lb. or mg	21%	0.408 lbs waste reduction	10%	0.099 mg Mercury disposal reduction (lighting)	0%	N/A
Labor requirements or labor associated costs	20	$	61%	$253	10%	$4.31	0%	N/A
Equipment operations and maintenance	25	$	25%	N.D.	32%	N.D.	53%	$1.00
Materials or other supply needs	9	$	14%	N.D.	6%	$22.84	20%	($8.70)
Productivity	20	% increase per project[2]	46%	10%	13%	N.D.	20%	1%
Product spoilage	2	$	0%	N/A	6%	$5.47	0%	N/A
Transportation costs	1	N/A	4%	N.D.	0%	N/A	0%	N/A
Rent or insurance associated costs	1	N/A	0%	N/A	3%	N.D.	0%	N/A
Other benefits (emission reductions, health benefits)	2	N/A	4%	N.D.	3%	N.D.	0%	N/A

[1] When a measure that generates NEIs saves both electricity and natural gas, analysts need a way to associate the NEI dollars equitably between gas and electricity. In the team's experience, simply using site Btus (e.g., 1 kWh = 3.413 kBtu) as the common denominator disproportionately skews the allocations in favor of natural gas. Use of "source MMBtus" as the common denominator corrects the imbalance. By accounting for electric generation efficiency (e.g., 1 kWh =3.413 kBtu / ≈34% generation efficiency = 0.010 source MMBtus) the allocation aligns more closely to both emissions and customer bill value.

[2] Impacts are represented as the facility-wide productivity increase, estimated based on a combination of data collected by evaluators from the engineering review and NEI survey: number of employees affected by the project, productivity increase for employees affected by the project, overall number of employees in the facility, and data collected from PRIME evaluation on percentage sales affected by the project.

N/A = Not applicable

N.D. = No data from survey to quantify impacts

For most of the categories listed above (all but two) with quantifiable data from the survey, the analysts converted the NEI (unregulated fuel energy saved, water gallons saved, labor hours saved, etc.) into a dollar value. Cost impacts from reduction of waste generation and increase in productivity were not quantified due to the challenges involved in converting survey documented data to cost estimates. The latter is a significant omission. The PRIME program is conceived around productivity improvement. This study's data simply did not provide sufficient context to translate the expressed percentage gains into added customer profits. The NEI engineering judgments and economic assumptions used for the translation can be found in Appendix F.

Table 4-20 presents the average cost impacts from NEI categories for the BES suite of programs for all projects, not just those with NEIs.

Table 4-20. Dollar Impacts from NEI for BES Suite of Programs by NEI Category

NEI Category	NEI Dollar Impacts ($/source MMBtu Savings)		
	PRIME	O&M	RCx
Fuel oil, propane, wood	N/A	N.D.	$0.15
Fresh potable water supplies	N/A	$0.06	$0.82
Labor requirements or labor associated costs	$153	$0.42	N/A
Equipment operations and maintenance	N.D.	N.D.	$0.53
Materials or other supply needs	N.D.	$1.47	($1.74)[1]
Product spoilage	N/A	$0.44	N/A
TOTAL	**$153**	**$2.39**	**($0.23)**

[1]The RCx material cost impacts are less than zero, as one of the projects in the sample incurred significant material costs as a result of the project implementation.

N/A = Not applicable

N.D. = No data from survey to quantify impacts

The RCx cost impacts are less than zero, as one of the projects in the sample incurred significant material costs that offset cost benefits from other RCx NEI categories. Table 4-21 expresses the total results by program energy savings source. Analysts converted the NEI dollar impacts to percentage of avoided costs using assumptions for typical electric and natural gas rate structures, for large commercial and industrial customers in Connecticut, which can be found in Appendix F.

Table 4-21. Dollar Impacts from NEI for BES Suite of Programs by Program Energy Source

Program Source of Energy Savings	NEI Units	NEI Dollar Impacts		
		PRIME	O&M	RCx
Electricity	$ Per MWh reported savings	$15.49	$0.24	($0.02)
	Percent of avoided costs (%)	9.78%	0.15%	(0.01%)
Natural gas	$ Per MMBtu reported gas savings	$0.00	$2.39	($0.23)
	Percent of avoided costs (%)	0.00%	32.17%[1]	(3.14%)

[1]The natural gas O&M percentage of avoided costs are higher than typical values since one of the steam trap repair/replacement projects in the sample resulted in significant material storage costs reduction.

5 CONCLUSIONS AND RECOMMENDATIONS

This section highlights the study's major findings and concludes with nine recommendations to improve the BES programs moving forward. ERS analyzed the achieved electric and natural gas savings of the suite of BES programs among a sample of 81 projects completed in 2015. As detailed in Section 4, the PRIME, O&M, and RCx programs generate significant savings, achieving 88% of the reported electric energy savings and 74% of the reported natural gas savings. The primary drivers of the lower-than-anticipated evaluated energy savings include changes in site-specific operation or production levels, differences in calculation methodology, removal or failure of previously repaired equipment, and differences in pre-project (baseline) operating conditions.

The O&M and RCx programs achieved significantly higher summer and winter peak demand savings than reported. For 7 projects in the sample, the evaluators determined additional peak demand savings that were not reported by the programs, indicating opportunities for the BES to more comprehensively report peak demand impacts moving forward. From the evaluation team's assessment of projects completed in 2015, it is not clear if the programs place an emphasis on estimating demand savings for all installations.

Overall, the evaluators found that the program's savings claims were reasonable, relying on the Connecticut PSD when possible (e.g., steam traps and lean manufacturing) or involving site-specific analysis when warranted (e.g., RCx projects). Many of the key contributors to the RRs, as examined in Sections 4.2, 4.3, and 4.4, involved facility- or equipment-specific operation that could not be precisely predicted by vendors a year or more in advance. Nonetheless, an objective of any evaluation in Connecticut is to examine the PSD's recommendations compared with the evaluation results, and to recommend updates if appropriate. As described in recommendation #7 below, the evaluators have calculated alternative parameter values that we recommend the programs adopt.

Another objective of this study was the assessment of non-energy impacts (NEIs) among the BES projects sampled for evaluation. Through site-specific interviews and analyses, the evaluators identified some prevalent NEIs among the evaluated projects, including increased productivity, reduced labor costs, decrease in hazardous waste, and raw materials savings. In Section 4.7, the evaluators normalized the NEIs by reported source MMBtu savings so that the BES programs may incorporate this data into future cost-effectiveness tracking.

The evaluation team also identified opportunities to improve program operations and savings estimation in the future, in hopes of narrowing the variation in RRs. The recommendations are as follows:

1. The BES PAs should apply the evaluation RRs to PRIME and RCx projects moving forward, barring any significant changes in program design, measure offerings, or customers. Additionally, the PAs should apply the evaluation RR to electric O&M projects moving forward; however, the PAs should prospectively apply the forward-looking RR (FRR) of 0.94 to gas O&M projects. The evaluators assessed changes in the PSD from the 2015 version to present (2018) and found that, of the measures addressed by the PSD and featured in this evaluation, only the steam trap measure has undergone changes that result in an FRR considerably higher than the evaluation RR. The evaluators found no such changes for electric measures, as summarized in Section 4.6.

   The current version of the PSD (2018) recommends two mutually exclusive approaches to calculating steam trap savings—Napier and Grashof. Without knowing which of these approaches will be utilized by the program to estimate steam trap savings, an explicit FRR cannot be calculated. Evaluators' FRR recommendation of 0.94 for gas O&M projects is therefore based on an assumption that the PAs will follow this report's Recommendation #9 and use only the PSD's Grashof algorithm to calculate steam trap savings moving forward. If Recommendation #9 is not adopted, an alternative FRR must be calculated.

2. Each BES program should implement pre- and post-project inspections and possible metering to more comprehensively document the baseline conditions and most up-to-date facility operations. For PRIME projects, the standard practice involves a 90-day review of facility operations compared to savings assumptions at the time of project implementation. This 90-day true-up is highly valuable to refine the savings claim and subsequent incentive amount based on actual performance. Based on the project documentation provided by program staff, the evaluators could not confirm if the 90-day review occurred for 32% of the sampled PRIME projects. The kWh RR for these projects were 43% lower than projects with 90-day review documentation available to the evaluators. While pre- and post-project inspections are standard practice for RCx and O&M programs, the evaluators were unable to obtain the relevant inspection documentation for 42% of the sampled RCx and O&M projects. The kWh and natural gas RRs for these projects were 36% and 9% lower, respectively, than projects with relevant inspection documentation confirmed by the evaluators. In order to reduce uncertainty in savings claims, the RCx and O&M programs should more frequently include pre- and

post-project metering, particularly for the largest or most complex projects, in the calculation of reported savings and subsequent incentive amounts.

3. The evaluators believe the BES programs are best suited as a cost-effective gateway to build relationships with Connecticut commercial and industrial customers that may lead to additional capital improvement projects down the road. However, among the sampled RCx projects, the evaluators identified 10 instances of equipment replacements or add-ons, such as variable frequency drives implemented as part of the O&M program. Among the sampled O&M projects, 5 involved the upgrade to more efficient lighting systems, which were incentivized at the same level as other standard, more prescriptive interior lighting projects indicating additional administrative costs for processing O&M applications than was necessary. The evaluators recommend that the Connecticut Energy Efficiency Board and utilities more carefully reassess if such equipment replacement or add-on measures should be classified as operations and maintenance or retro-commissioning improvements. Streamlining the BES suite of programs to include only low- or no-cost improvements to existing equipment or operations that will result in cost-effectiveness metrics that more accurately reflect the programs' objectives. The BES PAs should collaborate more closely with other Connecticut commercial and industrial programs, such as Energy Opportunities, that can offer capital improvement measures at facilities participating in BES programs.

4. The BES programs' vendors should more comprehensively train the participating facilities' staff to maintain the implemented operational improvements. For example, the evaluators found that the poorest-performing RCx projects involved facility staff that were unaware of the controls improvements and the process of restoring them if overridden. The PRIME program sponsors 5-day lean manufacturing events but should follow-up with similar supplementary training at the 90-day review to ensure that facility staff become experts on optimizing the operation of the equipment they use every day. The evaluators recommend that the PRIME, O&M, and RCx project closeout process is supplemented to include "handoff" paperwork and best-practices documentation before incentive payout, in order to maximize the savings persistence of the incented improvements.

5. BES programs should more frequently consider peak demand impacts. While O&M and RCx electric projects typically claim positive peak demand savings, some do not. The PRIME program should consider peak demand impacts in site-specific savings estimation. None claimed such impact, but the evaluators found that 3 of the 28 sampled PRIME

electric projects caused a total of 38.9 kW savings. The evaluators found the following patterns that suggest demand savings from PRIME projects are possible: 1) The facility's typical work day does not fully cover the peak summer weekday hours that typically occur in summer weekday afternoons., and expanded production without the program intervention would result in increased peak usage; 2) The impacted equipment operates at a lower load; and 3) The event resulted in the removal or shutdown of electric equipment that previously operated during the on-peak hours. It must however be noted that if the BES programs begin to consider peak demand impacts for all electric projects, the prospective realization rates presented in this report for peak demand savings may no longer be applicable.

6. The BES PAs should more carefully organize and archive relevant project files such as pre- and post-installation inspection reports, pre-project trended or metered data, and vendor analysis spreadsheets. For 27% of the sampled projects, the evaluators encountered difficulties in obtaining these relevant files, requiring three data request submittals that spanned 5 months and delayed evaluation activities for an estimated 6 months. Files are often not stored in a central depository but on individual computers. Evaluators recommend that the utilities adopt a more comprehensive method to digitally archive relevant project files. These systems will provide more transparency and will allow the utilities to more quickly and cost-effectively deliver project files in future evaluations.

7. For the PRIME program, the evaluators recommend that the lean manufacturing savings algorithm is updated with evaluation results on load dependence factors. As described in Section 4.2.2, the evaluators recommend that the existing load dependence factors for constant loads (65% as recommended in the current PSD), time-dependent loads (20%), and time- and production-dependent loads (15%) are updated to reflect evaluated values of 41%, 41%, and 18%, respectively. The existing factors in the PSD are based on a pilot evaluation from 2007 that involved the assessment of 5 projects, whereas the evaluated results reflect weighted averages among the sample of 28 projects completed in 2015. The evaluators recommend that the algorithm's other parameters, as outlined in Section 4.2.2 and Appendix E, continue to be estimated site-specifically, including pre-event annual electric energy consumption, percentage of total consumption affected by the PRIME event, and production increase. These factor revisions should result in more realistic savings claims for PRIME projects.

8. The PRIME program, like other BES programs, offers an attractive, low-cost gateway for industrial customers to become more familiar with efficiency offerings in Connecticut,

thereby potentially driving up the overall cost-effectiveness of the C&I portfolio. Eversource has indicated that 8 of 12 PRIME participants in 2015 went on to complete additional energy efficiency projects through other C&I programs. The evaluators recommend that the utilities continually revisit the PRIME benefits and costs, examining in particular if PRIME participants are more likely to engage other C&I programs as a result of their experience with PRIME, to ensure that the program is contributing towards overall C&I portfolio cost-effectiveness.

9. The current version of the PSD (2018) recommends two mutually exclusive approaches to calculating steam trap savings—Napier and Grashof—each of which generally reflect the evaluator's savings approach based on recent Massachusetts research on actual steam trap performance through analysis of utility data.[30] Evaluators believe that the condensate return factor of 0.45 currently recommended in the PSD's Napier algorithm is appropriate for low-pressure steam systems (5 psig or below), as it accounts for the overstatement in flow in the Grashof-based equation. However, for steam system pressures over 5 psig, evaluators believe that the Grashof method is most appropriate, as the 0.45 condensate return factor will result in overestimated savings using the Napier approach. Therefore, to simplify steam trap savings calculation moving forward, the evaluators recommend that the PAs use only the PSD's Grashof algorithm.

[30] "Steam Trap Evaluation Phase 2 by ERS for Massachusetts (MA) Program Administrators and Energy Efficiency Advisory Council," March 18, 2017. This analysis derives algorithm variable values and savings based on billing analysis and engineering calculations of 24 office, health care, school, municipal, and industrial facilities. http://ma-eeac.org/wordpress/wp-content/uploads/Steam-Trap-Evaluation-Phase-II.pdf.

Appendix A: Discrepancy Categories and Definitions

This appendix supplements Sections 3 and 4 by defining the various discrepancy categories considered in the analysis of realization rates (RRs) for PRIME, O&M, and RCx projects in the BES sample. For all projects in the BES sample, the evaluators completed a discrepancy analysis, including a quantification and classification of savings differences among key categories by program and/or measure type.

A.1 Discrepancy Categories for PRIME

Table A-1 defines the discrepancy categories considered in the analysis of PRIME projects.

Table A-1. Explanation of Discrepancy Categories for PRIME Projects

Discrepancy Category	Explanation
Differences in production/productivity	Reflects any change in savings due to the applicant's assumption on pre- to post-event production throughput change, compared with the evaluators' collected data on production throughput before and after the PRIME event.
Inaccurate breakdown of time/load-dependent kWh	Reflects any changes in savings due to inaccuracy in the CT PSD's recommended load factors for constant (Type A & B & Office), time dependent (Type C), and time & load dependent (Type D) equipment. The CT PSD algorithm recommends the same blend of load dependence factors for all PRIME projects, whereas the evaluators calculated each load dependence factor site-specifically based on information gathered during the site visit.
Differences in utility billing data	Reflects any change in savings due to differences between the following factors used in the applicant and evaluation analyses: • Pre-event utility billing data • Estimated percentage of sales impacted by the PRIME project Evaluators collected pre- and post-event utility billing data from utilities as well as customers and surveyed facility staff to estimate the true percentage of sales impacted.
Revisions to process	Reflects any change in savings due to equipment or operational changes at the facility and/or the impacted production line(s) that affected the savings achieved by the PRIME event.
No evidence of production efficiency improvement	Reflects any change in savings due to lack of evidence from the evaluator's site visit and/or project documentation that the implementation of the project improved the production energy efficiency of the facility.

Discrepancy Category	Explanation
Project not implemented	Reflects any change in savings due to the PRIME event's lean manufacturing techniques being no longer implemented or overridden at the facility.
Tracking savings discrepancy	Reflects any change in savings due to a clerical mismatch between the reported savings value and the savings value reflected in the most up-to-date version of the applicant's analysis spreadsheet. Differences in savings between the initial and 90-day reported savings estimates are also included in this category.

A.2 Discrepancy Categories for O&M Steam Traps

Table A-2 defines the discrepancy categories considered for O&M gas projects with steam trap measures.

Table A-2. Explanation of Discrepancy Categories for O&M Steam Traps Projects

Discrepancy Category	Explanation
Decommissioned equipment	Reflects any change in savings due to decommissioned steam traps observed during the evaluation site visit.
Difference in operating hours	Reflects any changes in savings due to differences in steam trap operation between the applicant's assumption and the evaluator's site-verified estimate of annual operating hours.
Difference in calculation methodology	Reflects any change in savings due to differences in savings algorithm and assumptions between the applicant and evaluator. Specifically, this category includes savings differences between the CT PSD-recommended method (Napier's equation, no condensate return factor) and the evaluator's recommendation (Grashof's equation with condensate return factor) based on recent Massachusetts evaluation research.
Difference in steam conditions	Reflects any change in savings due to differences in steam pressure/temperature between the evaluator's on-site inspection and the applicant's claim.
Difference in boiler efficiency	Reflects any change in savings due to differences in operating efficiency of the parent boiler(s) between the evaluator's on-site inspection and the applicant's claim.
Documentation differences	Reflects any change in savings due to a clerical mismatch between the reported savings value and the savings value reflected in the most up-to-date version of the applicant's analysis spreadsheet. Additionally, includes any savings differences that could not be determined from the most granular version of the applicant analysis available.

A.3 Discrepancy Categories for RCx

Table A-3 defines the discrepancy categories considered for RCx electric and gas projects.

Table A-3. Explanation of Discrepancy Categories for RCx Projects

Discrepancy Category	Explanation
Difference in baseline assumptions	Reflects any change in savings due to differences in preexisting conditions (early replacement or add-on measure) or code baseline assumptions (normal replacement) between the applicant and evaluator.
Difference in calculation methodology	Reflects any changes in savings due to differences in savings algorithm and/or assumptions between the applicant and evaluator. Generally, the evaluator reviewed the applicant's analysis approach for reasonableness and followed the same analysis approach with updated parameters. However, this category reflects differences when the evaluator did not follow the same approach.
Difference in installed quantity	Reflects any change in savings due to differences in post-project equipment quantity between the applicant's proposed count and the evaluator's on-site inventory.
Documentation differences	Reflects any change in savings due to a clerical mismatch between the reported savings value and the savings value reflected in the most up-to-date version of the applicant's analysis spreadsheet. Additionally, includes any savings differences that could not be determined from the most granular version of the applicant analysis available.
Difference in equipment load profiles	Reflects any change in savings due to differences in equipment operation between the evaluator's analysis of post-project trended/metered data and the applicant's proposed assumptions on post-project operation.
Measure not implemented	Reflects any change in savings due to the evaluator's on-site confirmation that the measure was never installed or programmed, or was otherwise overridden or removed at the time of the evaluation site visit.

This appendix supplements the on-site data collection methodologies for steam traps described in Section 3.3.2.

B.1 Steam Trap Inventory Form

Table B-1 illustrates an example steam trap inventory form used by field engineers during the site visit.

Table B-1. Steam Trap Inventory Form Example

Tag #	Application	Type	Annual Trap Hours of Operation (hrs/yr)	Steam Pressure at Trap (psig)	Orifice Size (in)	Steam Trap Initial Status	Steam Trap Status during Site Visit	Is trap venting directly to the atmosphere?
126170	Air Handling Unit	Float & Thermostatic	1,700	5	5/16	Leaking	Fully Operational	No
127004	Drip Leg	Inverted Bucket	8,760	10	3/16	Plugged	Fully Operational	No
126159	Drip Leg	Float & Thermostatic	8,760	5	7/32	Leaking	Fully Operational	No
126054	Drip Leg	CAPS	8,760	80	1/8	Blowing by	Leaking	No
126055	Flash Tank	Float & Thermostatic	8,760	35	7/16	Leaking	Fully Operational	No
126058	Drip Leg	CAPS	8,760	80	1/8	Leaking	Fully Operational	No
126059	Drip Leg	CAPS	8,760	60	1/8	Blowing by	Fully Operational	No
126082	Drip Leg	Inverted Bucket	8,760	60	5/32	Plugged	Fully Operational	No
126083	Flash Tank	Float & Thermostatic	8,760	10	7/32	Plugged	Blowing by	No
126085	Drip Leg	Inverted Bucket	8,760	60	5/32	Plugged	Fully Operational	No
126007	Drip Leg	Float & Thermostatic	8,760	15	5/8	Leaking	Fully Operational	No
126015	Drip Leg	Inverted Bucket	8,760	40	5/32	Plugged	Fully Operational	No

Appendix C: Steam Trap Saving Algorithms

This appendix supplements Section 3.3.2 and Section 4.3.2 by comparing 2015 CT PSD-recommended and evaluator-recommended algorithms for steam trap repair/replacement measures, as illustrated in Table C-1. The reported natural gas savings for steam trap measures were estimated using the algorithms provided in the 2015 CT PSD. The current version (2018) of the PSD now recommends two algorithms for steam traps that more closely reflect the evaluator algorithms below.

Table C-1. Comparison of CT PSD (2015) and Evaluation Savings Algorithms

CT PSD (2015)	Evaluation per Recent MA Research[31]
Methodology: Modified Napier	Methodology: Grashof
$ACCF = \frac{lb/hr_{steam,modified\ Napier} \times h_{fg} \times EFLH \times L_{f,CT\ PSD}}{Eff \times 102{,}900}$	$ACCF = \frac{lb/hr_{steam,Grashof} \times h_{fg} \times EFLH \times L_{f,MA\ Eval} \times CR}{Eff \times 102{,}900}$
where,	where,
ACCF = Annual natural gas savings, in ccf	*ABTU* = Annual natural gas savings, in Btu
$lb/hr_{steam,modified\ Napier}$ = Steam flow rate in the orifice per Modified Napier method, in lb/hr	**$lb/hr_{steam,Grashof}$ = Steam flow rate in the orifice per Grashof method, in lb/hr**
h_{fg} = Specific enthalpy of evaporation, in Btu/lb	h_{fg} = Specific enthalpy of evaporation, in Btu/lb
EFLH = Site-specific hours (varies for each trap)	*EFLH* = Site-specific hours (varies for each trap)
$L_{f,CT\ PSD}$ = Steam loss adjustment factor, %	**$L_{f,MA\ Eval}$ = Steam loss adjustment factor, %**
Eff = Heating system efficiency, %	***CR* = Condensate return factor, %**
102,900 = Conversion factor, in Btu/ccf	*Eff* = Heating system efficiency, %
	102,900 = Conversion factor, in Btu/ccf

[31] "Steam Trap Evaluation Phase 2 by ERS for Massachusetts (MA) Program Administrators and Energy Efficiency Advisory Council," March 18, 2017. This analysis derives algorithm variable values and savings based on billing analysis and engineering calculations of 24 office, health care, schools, municipal, and industrial facilities. http://ma-eeac.org/wordpress/wp-content/uploads/Steam-Trap-Evaluation-Phase-II.pdf

Please note that the terms in bold represent the key differing factors between the two algorithms; these terms are further examined in this appendix. The parameters h_{fg}, *EFLH* and *Eff* included in both algorithms presented above map uniformly between the two algorithms.

1. Steam Flow Rate in the Orifice, in lb/hr

A comparison of the steam flow rates estimated from the Modified Napier and Grashof methodologies is presented in Table C-2.

Table C-2. Comparison of Steam Flow Rates per Modified Napier and Grashof Methods

CT PSD (2015)	Evaluation
Methodology: Modified Napier	Methodology: Grashof
$lb/hr_{steam,modified\ Napier} = lb/hr_{steam,Napier} \times Modified\ Discount$ $= \frac{A \times P_a}{70} \times 3{,}600 \times 0.6$ where, A = Area of the orifice, in square inches Pa = Absolute pressure, in psia 70 = Empirical constant per Napier equation 3,600 = Conversion factor, in hrs/sec Modified Discount = Factor to account for trap hole not being a perfect orifice, 0.6 Simplifying the equation further, $lb/hr_{steam,modified\ Napier} = 24.24 \times D^2 \times P_a$ where, D = Diameter of the orifice, in inches	$lb/hr_{steam,Grashof} = 60 \times A \times P_a^{0.97} \times C_d$ $= \frac{A \times P_a^{0.97}}{60} \times 3{,}600 \times 0.7$ where, A = Area of the orifice, in square inches Pa = Absolute pressure, in psia 60 = Empirical constant per Grashof equation 3,600 = Conversion factor, in hrs/sec Cd = Discharge co-efficient, a factor to account for trap hole not being a perfect orifice, 0.7 Simplifying the equation further, $lb/hr_{steam,Grashof} = 32.99 \times D^2 \times P_a^{0.97}$ where, D = Diameter of the orifice, in inches

The Grashof and Napier equations are both generally recognized as valid methods for estimating steam flow. The two approaches provide similar results, generally within 7% of the same steam flow at typical plant operating pressures. Both were developed from empirical laboratory data measurements. Adding the discount factor of 0.6 to Napier and the discharge coefficient of 0.7 to Grashof causes the flow estimates to diverge more. The consequence of the differences shown in Table C-2 is that the Grashof-based equation, as used in the evaluation analysis, results in an increase of the steam flow rates and natural gas savings by 15%–25%, compared with the Napier equation recommended in the 2015 CT PSD, depending on the operating steam pressure.

2. Condensate Return Factor, CR

The condensate return factor accounts for energy returned to and recovered by the heating system from a condensate line. Theoretically, if there is no condensate return system, the CR value is 1.0, but for all other systems, the CR value ranges from 0.3 to 1.0. Evaluators adopted a CR value of 0.36 based on billing analysis of 24 facilities in the aforementioned MA research.[32] The 2015 CT PSD did not recommend a CR value in its steam trap savings algorithms. Having no CR factor (or a CR of 1.0) implies that all of the thermal energy from leaking traps is lost to atmosphere. The CR factor more realistically discounts the energy loss and subsequent savings by accounting for energy recovery from condensate lines. Of the 18 steam trap projects that were evaluated in this study, 17 had condensate being returned to the heating system.

3. Steam Loss Adjustment Factors, L_f

Table C-3 compares the steam loss adjustment factors recommended by the 2015 CT PSD and those developed by the evaluators.

Table C-3. Comparison of Steam Loss Adjustment Factors

CT PSD (2015)	Evaluation
L_f, failed traps = 50%	L_f, failed traps = 55%
L_f, leaking traps = 12.5%	L_f, leaking traps = 26%

The steam loss adjustment factors, which represent the reduction in steam loss from the repaired traps, were developed in the MA study through iterative regression analysis based on actual pre/post-project billing data. For failed traps, the loss adjustment factors are similar, but for leaking traps, the evaluators recommend a loss adjustment factor more than double that recommended in the 2015 CT PSD. Consequently, with regard to the loss adjustment factors, the natural gas savings increase with the MA method compared with the CT method.

[32] In total, 24 sites were sampled from an initial population of 192 candidate facilities which included a mix of office, health care, schools, municipal, and industrial facilities. The research also found that low pressure steam distribution systems (5–10 psig) were more prevalent than high pressure distribution systems, and most of the sampled facilities employed condensate return systems.

Appendix D: PRIME Data Collection Template

This appendix supplements the on-site data collection template for PRIME projects provided in Section 3.3.1. Engineers developed comprehensive data collection templates for all PRIME projects in the sample to characterize key equipment affected by the project, as shown below.

Site ID:______________

6. GENERAL INFORMATION

Site visit date	
Company	
Contact name/title	
Contact number	

7. FACILITY BASICS

Company product/service	
Affected facility square footage	
Facility operating hours per day	
Typical operation days per week	
Seasonal variation in production or shifts? If so, describe.	
Number of PRIME projects at facility in eval. sample	
Utility billing data available for affected accounts?	
Meter number(s) of affected utility accounts	

8. PROJECT BASICS

Date of project implementation	
Date of project verification (typically ~3 months later)	
Description of project (in their own words)	
Description of process line(s) affected	
Location(s) of affected production lines	

General overview of equipment affected by project	
Estimated % of line's production affected by project	
Estimated % of total process line kW affected	
Other projects occurred at facility that affected kWh over pre/post period?	
Other factors that could affect meter(s) kWh over pre/post period (e.g., market, demand, turnover)?	
Non-energy benefits from project? (see survey)	

9. PRE/POST COMPARISON OF ENERGY, DEMAND, AND PRODUCTION - ENERGY BREAKDOWN METHOD

Parameter	Pre-project	Post-project
Total annual kWh of affected process line(s)		
Total peak (summer) kW of affected process line(s)		
Total annual production (e.g., units, tons, revenue) of line(s)		
Alternative: shifts per week, average daily op. hrs		
For reduced changeover time: # changeovers per day		
Estimated time per changeover (minutes)		
For reduced downtime: estimated downtime (hrs/week)		
For reduced setup time: estimated setup time (hrs/week)		
For reduced cycle time: estimated cycle time (min/unit)		
For rework/scrap reduction: estimated scrap/rework %		

Customer Questions

Are all of the productivity improvements still in place? If no, why?
Have any of these productivity techniques been applied to other parts of the company's operation? Why or why not?
Were you familiar with how the electric savings were estimated for this project? If yes, explain.
Are the affected process line(s) tracked by an EMS or SCADA system with trending capability?
Can monthly electric bills for the affected system(s) be made available?
Is it possible to measure the electric usage of the existing process line(s), either through long-term measurement or spot-measurement?

Option #2 - Detailed Equipment Inventory

Affected Equipment Component	Rated horsepower	Estimated Annual % Time Loaded	Estimated Annual % Time Idle	Estimated Annual % Time Off	Loaded - Est. Load Factor	Idle - Est. Load Factor	Submetered? If yes, request data.	*Time/Load Dependency Classification** Office Equipment	**A** - Production/Hours Independent	**B** - Production Dependent	**C** - Hours Dependent	**D** - Production/Hours Dependent

Other Notes:

* Equipment can be grouped into five categories – one for office equipment and four representing manufacturing equipment, referred to as Types A through D. The five types of equipment are:

Office equipment

Type A - Manufacturing equipment with energy use independent of production hours and production quantity

Type B - Manufacturing equipment with energy use dependent on production quantity

Type C - Manufacturing equipment with energy use dependent on production hours

Type D - Manufacturing equipment with energy use dependent on production hours and quantity

Option #3 - Broad Bill Disaggregation

	Portion of bill				*% of Load in Time/Load Dependency Classifications Below*					
Equipment Category	% of total kWh - nonseasonal	% of total kWh - summer	% of total kWh - winter	% of category's usage affected by project	Office Equipment	**A** - Production/Hours Independent	**B** - Production Dependent	**C** - Hours Dependent	**D** - Production/Hours Dependent	Notes
Lighting										
Cooling - comfort										
Cooling - process										
Ventilation										
Heating - comfort										
Heating - process										
Compressed air										
Process - affected										
Process - unaffected										
Refrigeration										
Office equipment/IT										
Other plug loads										
Miscellaneous										

Other Notes:

10. REFERENCE: LEAN IMPROVEMENT TYPES & DATA COLLECTION STRATEGIES

Improvement Type	Description	Strategy
Inventory reduction, space reduction	Reduce lead time (duration between raw materials purchase and product shipment). Inventory reduction does not typically lead to savings unless a reduction in inventory space requirements.	Collect operation data on key systems reduced or turned off as a result of the inventory/space reduction: lights, fans, conditioning, etc.
Changeover time reduction	Changeover is the process of preparing equipment to manufacture a different part than previously produced. During changeover, non-production equipment uses power, and production equipment may idle.	Collect data on affected production and nonproduction systems' usage pre- vs. post project. Verify that the project still results in reduced changeover time.
Downtime reduction	Downtime occurs when equipment fails, personnel are absent, materials are unavailable, or other factors result in stoppages. Non-production equipment is likely to operate during these periods.	Collect data on affected production and nonproduction systems' usage pre- vs. post project. Verify that the project still results in reduced downtime.
Setup time reduction	Similar to changeover, but may occur only once per week. Setup may occur during or before normal production hours and may or may not affect production. When it occurs during prod., impacts are similar to changeover. Outside of production, it might only reduce facility op. hours.	Collect info on setup time-does it occur during or outside of production? If during, see changeover above. If outside, collect data on reduced non-production equipment operation.
Cycle time reduction	Cycle time is the duration from when one unit of production enters the process until the next unit enters the process. Reducing cycle time can reduce runtime of non-production equipment, reduce idle time of production equipment, and possibly increase efficiency of production equip.	Collect info on pre- vs. post cycle times for all affected components of the production line. Verify that cycle time is still being reduced.
Increased throughput	For un-cyclical production (e.g. food or chemicals) increasing production may result in energy savings from bringing process systems to closer to design loads. But negative impacts can occur if components get overloaded.	Collect data on pre- vs. post equipment loads and efficiencies before and after the increase in throughput. Collect data on typical process runtimes and production levels.
Rework/ scrap reduction	Rework (requires reprocessing) and scrap (discarded) decrease sellable product and therefore lower the system's energy efficiency. Rework/scrap reduction might not result in any pre/post difference of units or energy, but its savings calc. must be approached differently.	Consider all production units-- sellable, rework, scrap-- in the savings calculation. The baseline then becomes the energy required to meet the sellable quantity of the post case.
Part travel reduction	Part travel reduction can reduce lead time or cycle time, but if the travel involves energized equipment (e.g. conveyors, forklifts, vacuum tubes) can also have direct energy impacts. Human travel time does not directly result in energy impacts but may lead to higher production per kWh.	Determine if energized equipment affected by reduce travel-- if so, collect detailed data on pre/post. Otherwise determine if part travel reduction led to lower lead time or cycle time.
Direct equipment efficiency improvement	Traditional energy efficiency improvements of operating equipment, due to better maintenance, training, or standards. This is rare.	Collect detailed data on pre/post operating efficiency of affected systems. This will require interviews with process experts.

Appendix E: PRIME Algorithms and Definition of Terms

This appendix supplements the energy savings algorithms provided in Section 3.3.1 for PRIME projects.

E.1 PRIME Energy Savings Algorithms

The PRIME program provides training and consulting to implement lean manufacturing techniques at participating industrial facilities. To determine the energy impacts of these lean techniques, the evaluators identified and classified the types and characteristics of equipment impacted by the lean measures. Based on a prior pilot program evaluation of PRIME in 2007, equipment at participating manufacturing facilities can be grouped into five categories as listed below and illustrated in Table E-1:

A. Manufacturing equipment with energy use independent of production hours and production throughput

B. Manufacturing equipment with energy use dependent on production throughput but independent of production hours

C. Manufacturing equipment with energy use dependent on production hours but independent of production throughput

D. Manufacturing equipment with energy use dependent on production hours and throughput

E. Office equipment

Table E-1. PRIME Equipment Classification Categories

		Production Throughput	
		Dependent	Independent
Production Hours	Dependent	Type D	Type C
	Independent	Type B	Type A + Office

The program's savings algorithm allocates all impacted equipment energy consumption among the five categories based on the 2007 pilot impact evaluation. The CT PSD's lean manufacturing algorithm, as used by the PRIME program, is presented below.

$$\begin{aligned} Annual\ kWh\ Savings \\ &= Annual\ kWh \times PPA \\ &\times \left[\left(Type\ A, B\ and\ Office + \frac{N_a}{N_e}(Type\ C + Type\ D) \right) \right. \\ &\left. - \left(Type\ A, B\ and\ Office + Type\ C + \frac{N_a}{N_e}(Type\ D)(1 - SF) \right) \right] \end{aligned}$$

where,

$Annual\ kWh$	= Annual electric usage, kWh
PPA	= Percentage of meter's total electricity consumption affected by PRIME event
$Type\ A, B, and\ Office$	= Percentage of facility loads independent of production hours and production throughput (65%)
$Type\ C$	= Percentage of facility loads dependent on hours of production (15%)
$Type\ D$	= Percentage of facility loads dependent on production throughput (20%)
N_a	= Post-event production quantity
N_e	= Pre-event production quantity
SF	= Savings factor

The savings factor, *SF*, is defined from the 2007 PRIME pilot evaluation as follows:

$$SF = 0.1168 \times \left[\frac{N_a - N_e}{N_e}\right]^3 - 0.3402 \times \left[\frac{N_a - N_e}{N_e}\right]^2 + 0.4732 \times \left[\frac{N_a - N_e}{N_e}\right] + 0.0011$$

The three load dependence factors are constant values in the PSD algorithm and drive reported savings as shown in Table E-2.

Table E-2. PRIME Equipment Load Dependence Factors in CT PSD

		Production Throughput	
		Dependent	Independent
Production Hours	Dependent	15%	20%
	Independent	65%	

Appendix F: NEI Methods and Assumptions

This appendix supplements Section 4.7 with NEI survey templates used by field engineers as well as the key engineering judgments and parameter assumptions used for the translation of self-reported NEIs to dollar impacts.

F.1 NEI Survey Template

The evaluators developed the following comprehensive NEI survey template and conducted on-site NEI surveys for every project in the sample to estimate the BES's impacts on metrics other than electricity and natural gas.

Non-Energy Impacts Survey Questionnaire

Interviewee Name:	
Organization:	
Phone:	
Email:	
Survey Date:	

I have identified you as the contact for the *{PROJECT NAME}* sponsored by *{Eversource/UI}*'s *{RCx/O&M/PRIME}* program. I would like to confirm before proceeding that you are the best person at your company to answer questions about potential non-energy impacts, which includes non-electric or non-gas related impacts from this project.

[If NO] Can you suggest a more appropriate employee to interview about this project?

[Obtain contact information of the person]

Survey Introduction: I would like to ask you a few questions about the potential effects resulting from this project other than impacts on {electricity/natural gas} consumption. Depending on your answers, an assessment of the project's non-energy impacts could be conducted as part of our study.

As you think about the answers, we encourage you to consider both direct and indirect consequences from the project. One case of indirect benefits is where improvements to a refrigeration system reduce the amount of ammonia needed below a threshold where certain insurance is no longer needed. Also, consider that the effects could be positive, providing more savings of some sort or negative, such as an increase in cost, i.e. more labor or increase in use of electricity for a gas savings project, etc.

As a preliminary survey of potential non-energy impacts, which of the following do you think have been impacted by the implementation of this project? You may select all that apply.

P1. Fuel oil consumption/propane consumption/wood as an energy resource *(see page 2)* ☐Yes ☐No
P2. Fresh potable water supplies *(see page 3)* ☐Yes ☐No
P3. Wastewater generation and treatment *(see page 4)* ☐Yes ☐No
P4. Solid, non-waste water, liquid, or gaseous hazardous waste generation and treatment *(see page 4)* ☐Yes ☐No
P5. Labor requirements or labor associated costs *(see page 5)* ☐Yes ☐No
P6. Equipment operations and maintenance (O&M) *(see page 7)* ☐Yes ☐No
P7. Materials or other supply needs *(see page 7)* ☐Yes ☐No
P8. Productivity *(see page 8)* ☐Yes ☐No
P9. Product spoilage *(see page 9)* ☐Yes ☐No
P10. Transportation costs *(see page 9)* ☐Yes ☐No
P11. Rent or insurance associated costs *(see page 10)* ☐Yes ☐No
P12. Costs associated with any other non-energy characteristic I have not mentioned *(p.11)* ☐Yes ☐No

[For all topics with YES response] Are you the most appropriate person to interview for these topic areas?
[If NO] Can I get the contact information for other staff that might be knowledgeable in these areas?

[If P1 YES] Ask questions in section N1, *[If P2 YES]* Ask questions in section N2 etc.

N1. Did this project increase or decrease one or more of the following types of <u>energy</u> uses?

N1A. Fuel oil used for space heating, process, water heating, or other non-space heating uses
☐Increase ☐Decrease ☐No Change

N1B. Propane consumption of the facility ☐Increase ☐Decrease ☐No Change

N1C. Wood as an energy resource ☐Increase ☐Decrease ☐No Change

[If N1A Increase/Decrease] N1Aa. Can you briefly describe how the {project/measure} impacted **<u>fuel oil</u>** usage?

N1Ab. Can you provide a ball park estimate of the {increase/decrease} in gallons of fuel oil consumed annually?

[If N1Ab NO] N1Ac. Can you estimate the percent change in the fuel oil consumption due to the project?

[If NIAc YES] Can you estimate the total annual fuel oil consumption prior to the project?

[If N1Ac NO] N1Ad. What range best describes the {increase/decrease} in fuel oil consumption?

0-10% 10-20% 20-30% 30-40% 40-50% >50% DK

[If N1B Increase/Decrease] N1Ba. Can you briefly describe how the project/measure impacted **<u>propane</u>** usage?

N1Bb. Can you provide a ball park estimate of the {increase/decrease} in gallons of propane consumed annually?

[If N1Bb NO] N1Bc. Can you estimate the percent change in the propane consumption due to the project?

[If N1Bc YES] Can you estimate the total annual propane consumption prior to the project?

[If N1Bc NO] N1Bd. What range best describes the {increase/decrease} in propane consumption?

0-10% 10-20% 20-30% 30-40% 40-50% >50% DK

[If N1C Increase/Decrease] N1Ca. Can you briefly describe how the project/measure impacted **wood** usage?

N1Cb. Can you provide a ball park estimate of the {increase/decrease} in tons of wood consumed annually?

[If N1Cb NO] N1Cc. Can you estimate the percent change in the wood consumption due to the project?

[If N1Cc YES] Can you estimate the total annual wood consumption prior to the project?

[If N1Cc NO] N1Cd. What range best describes the {increase/decrease} in wood consumption?

0-10% 10-20% 20-30% 30-40% 40-50% >50% DK

N2. Did this project increase or decrease the use of fresh potable water supplies?
☐ Increase ☐ Decrease ☐ No Change

[Provide if needed] Here are some examples of how water use could be impacted:
- Water used in the HVAC or HVAC control systems
- Water used for process cooling
- Water used for processing or for materials handling
- Water used as a feedstock or as a supply material
- Water used for as a mechanical movement or transport
- Any other water use

[If N2 Increase/Decrease] N2a. Can you briefly describe how the project/measure impacted fresh water consumption?

N2b. Can you provide a ball park estimate of the {increase/decrease} in gallons of fresh water consumed annually?

[*If N2b NO*] N2c. Can you estimate a percentage {increase/decrease} of pre-project fresh water consumption?

[If N2c YES] Can you estimate the total annual fresh water consumption at the time of this project?

[*If N2c NO*] N2d. What range best describes the {increase /decrease} in fresh water consumption?

0-10% 10-20% 20-30% 30-40% 40-50% >50% DK

N3. Did this project increase or decrease the generation and treatment of <u>wastewater</u>?

☐ Increase ☐ Decrease ☐ No Change

[Provide if needed] Wastewater costs can be impacted in a number of ways including:

- Changes in the amount of waste water generated associated with an increase or decrease in the use of fresh water, or independent of it
- Changes in the chemical or supply cost to treat wastewater
- Change in the cost to monitor wastewater levels or content
- Changes in the equipment needed to treat wastewater
- Other changes associated with wastewater generation or treatment

[If N3 Increase/Decrease] N3a. Can you briefly describe how the {project/measure} impacted the wastewater generation and treatment?

N3b. Can you provide a ball park estimate of the {increase/decrease} in gallons of wastewater generated annually?

[If N3b NO] N3c. Can you estimate a percentage {increase/decrease} of pre-project wastewater generation?

[If N3c YES] Can you estimate the total annual wastewater generation at the time of this project?

[If N3c NO] N3d. What range best describes the {increase/decrease} in wastewater generation?

0-10% 10-20% 20-30% 30-40% 40-50% >50% DK

N4. Did this project increase or decrease the rate or type of <u>solid, non-waste water liquid or gaseous hazardous waste</u> generation and treatment?

☐ Increase ☐ Decrease ☐ No Change

[Provide if needed] Solid, liquid and gaseous waste levels and their associated economic impacts can occur in a number of ways, including:

- Lower levels of emissions that have to be treated or detoxified
- Lower levels of hazardous materials that have to be managed
- Less toxic emissions that are cheaper to handle or manage
- Reduce security associated with emissions storage or handling
- Lower solid waste transport and tipping fees
- Ability to acquire NOx or other credits of economic value

- Other changes that have waste-related costs or revenues

[If N4 Increase/Decrease] N4a. Can you briefly describe how the {project/measure} impacted waste generation and treatment?

N4b. Can you provide a ball park estimate of the {increase/decrease} in the amount of waste generation and treatment?

[If N4b NO] N4c. Can you estimate a percentage {increase/decrease} of pre-project waste generation?

[If N4c YES] Can you estimate the total annual waste generation at the time of this project?

[If N4c NO] N4d. What range best describes the {increase/decrease} in waste generation?

0-10% 10-20% 20-30% 30-40% 40-50% >50% DK

N5. Did this project increase or decrease the costs associated with <u>labor requirements or labor associated costs</u>? This includes costs related to employee salaries, hourly pay, labor hours, and benefits.

[If N5 YES] Can you briefly describe how the project/measure impacted the labor requirements or associated costs?

N5a. Did the project result in an increase or a decrease in the number of <u>worker-hours</u> needed for a specific job?

[If N5a NO, Skip to N5b]

[If N5a YES] N5aa.Can you provide a ball park estimate of the increase or decrease in the number of worker-hours required for a specific job?

[If N5aa NO] N5ab. Can you estimate a percentage increase or decrease in the number of worker-hours required for a specific job?

[If N5ab YES] Can you estimate the number of employees for this job at the time of this project?

[If N5ab NO] N5ac. What range best describes the increase or decrease in number of worker-hours required for a specific job?

0-10% 10-20% 20-30% 30-40% 40-50% >50% DK

N5b. Did the employee benefits or benefit requirements as a result of the change in labor or labor hours increase or decrease?

[If N5b NO, Skip to N5c]

[If N5b YES] N5ba.Can you provide a ball park estimate of the increase or decrease in the employee benefits, in dollar value?

[If N5ba NO] N5bb. Can you estimate a percentage increase or decrease of pre-project employee benefits?

[If N5bb YES] N5bc. Can you estimate the total dollar value for employee benefits at the time of this project?

[If N5bb NO] N5bd. What range best describes the increase or decrease in employee benefits?

0-10% 10-20% 20-30% 30-40% 40-50% >50% DK

N5c. Did the project create any other changes that had an influence on labor costs?

[If N5c NO, Skip to N6]

[If N5c YES] N5ca. Can you briefly describe the other impacts to labor costs as a result of the project?

N5cb.Can you provide a ball park estimate of the increase or decrease in the labor costs due to this change, in dollar value?

[If N5cb NO] N5cc. Can you estimate a percentage increase or decrease of pre-project labor costs due to this change?

[If N5cc YES] N5cd. Can you estimate the total associated labor costs in dollar value at the time of this project?

[If N5cc NO] N5de. What range best describes the increase or decrease in labor costs due to this change?

0-10% 10-20% 20-30% 30-40% 40-50% >50% DK

N6. Did the project increase or decrease the costs associated with <u>equipment operations and maintenance (O&M)</u>, including in-house staff as well as service contracts? O&M cost changes can occur in a number of ways:

- Equipment that t runs less can last longer or has fewer outages/breakdowns
- Equipment that has fewer maintenance requirements
- Equipment that is faster or cheaper to maintain
- Equipment that needs fewer supplies to maintain or service
- Other changes that have an influence on O&M costs

[If N6 YES] N6a. Can you briefly describe how the project/measure impacted equipment O&M costs?

N6b. Can you provide a ball park estimate of the increase or decrease in equipment O&M costs, in dollars?

[If N6b NO] N6c. Can you estimate a percentage increase or decrease of pre-project O&M costs?

[If N6c YES] Can you estimate the total annual equipment O&M costs at the time of this project?

[If N6c NO] N6d. What range best describes the increase or decrease in equipment O&M costs?

0-10% 10-20% 20-30% 30-40% 40-50% >50% DK

[*If DK*] N6e. Can you come up with any other way of quantifying the value of the change in equipment or process reliability as a result of the project?

N7. Did this project increase or decrease the costs associated with <u>materials</u> or other supply needs? Material or supply cost changes can occur in a number of ways, such as:

- Changes in the type of materials or supplies needed
- Changes in the amount of materials or supplies needed
- Changes in the level of inventory needed on hand
- Other changes that have an influence on material costs

[If N7 YES] N7a. Can you briefly describe how the project/measure impacted material or supply costs?

N7b. Can you provide a ball park estimate of the increase or decrease in the materials or supply costs, in dollars?

*[If N7b NO] N7*c. Can you estimate a percentage increase or decrease of pre-project materials or supply costs?

[If N7c YES] Can you estimate this process's total annual materials or supply costs at the time of this project?

[If N7c NO] N7d. What range best describes the increase or decrease in materials or supply costs for the affected process?

0-10% 10-20% 20-30% 30-40% 40-50% >50% DK

The next set of questions is about employee productivity, comfort, and absenteeism.

N8. Did this project increase or decrease <u>productivity</u>?

☐ Increase ☐ Decrease ☐ No Change

[Provide if needed] Energy efficiency projects can change productivity in a number of ways, including:
:

- Process changes that improve productivity
- Morale changes that improve conditions and increase productivity
- Environmental changes such as better cooling that increase customer satisfaction causing longer periods of employment, thereby increasing productivity
- Other changes that have an influence on productivity

N8aa. Can you estimate how much the project/measure impacted productivity?

N8ab. How many employees work at this facility?

N8ac. How many employees did this measure impact?

N8ad. Do you use a metric to track employee productivity? If so, what metric do you use?

N8B. Do you track <u>work order requests</u> corresponding to the systems affected by this project?

[If N8B YES] N8Ba. Did the number of work orders increase or decrease due to the project?

[If N8Ba YES, Record change in work order requests.]

N8C. In your opinion, how has <u>employee or occupant comfort</u> changed due to this project?

Reduced Considerably Reduced Same Improved Improved Considerably Don't Know

[If change] N8Ca. Can you quantify that change in employee or occupant comfort in any way? Such as, for example, an increase or decrease in the number of calls to maintenance staff due to occupant or employee discomfort?

[If N8Ca YES, Record response]

N8D. Did worker absenteeism change due to this project?

[Provide if needed] From the US Bureau of Labor Statistics: Absences are defined as instances when persons who usually work full time worked less than full time for one of the following reasons:
-own illness, injury, or medical problems;
-child care problems;
-other family or personal obligations;
-civic or military duty;
-and maternity or paternity leave.
-Absenteeism *excludes* situations in which work was missed due to vacation or personal days, holiday, labor dispute, and other reasons.

[If N8D NO, Skip to Next NEI Group]

[If N8D YES] N8Da. Can you estimate a percentage increase or decrease of pre-project worker absenteeism?

[If N8Da NO] N8Db. What range best describes the increase or decrease in worker absenteeism?

0-10% 10-20% 20-30% 30-40% 40-50% >50% DK

N9. Did this project increase or decrease the rate or amount of product spoilage?
☐ Increase ☐ Decrease ☐ No Change

[Provide if needed] Spoilage can be affected in a number of ways, such as:
- More consistent temperatures in temperature controlled areas
- Fewer or shorter periods of time when spoilage can occur
- Better processes that reduce spoilage rates
- Increased quality control ability that reduce spoilage
- Other ways in which spoilage is reduced

[If N9 Increase/Decrease] N9a. Can you briefly describe how the {project/measure} impacted product spoilage?

N9b. Can you estimate a percentage {increase or decrease} of pre-project amount of product spoilage?

[If N9b YES] Can you estimate the annual costs incurred due to product spoilage at the time of this project?

[If N9b NO] N9c. What range best describes the {increase or decrease} in amount of product spoilage?

0-10% 10-20% 20-30% 30-40% 40-50% >50% DK

N10. Did this project increase or decrease <u>transportation costs</u>?

☐ Increase ☐ Decrease ☐ No Change

[Provide if needed] Transportation costs can be impacted in a wide variety of ways including:

- Transportation related equipment or vehicles
- Diesel fuel, gasoline, ethanol or other motor fuel
- Electricity used for transportation or product movement such as in fork-lifts
- Propane used as a transportation fuel such as in forklifts or on-site mini-trucks
- Compressed natural gas used for transportation
- Other transportation fuels consumed by this customer

[If N10 Increase/Decrease] N10a. Can you briefly describe how the project/measure impacted transportation costs?

N10b. Can you provide a ball park estimate of the project's resulting {increase or decrease} in the transportation costs, in dollars?

[If N10b NO] N10c. Can you estimate a percentage {increase or decrease} of pre-project transportation costs?

[If N10c YES] Can you estimate the total associated annual transportation costs at the time of this project?

[If N10c NO] N10d. What range best describes the project's resulting {increase or decrease} in transportation costs?

0-10% 10-20% 20-30% 30-40% 40-50% >50% DK

N11. Did this project increase or decrease the costs associated with <u>rent or insurance associated costs</u>?

☐ Increase ☐ Decrease ☐ No Change

[Provide if needed] Rental costs can be affected in a number of ways, such as:

- Energy improvements can lead to increased rent collected as a result of the energy efficient changes made via the program
- Property that is energy efficient is more easily rented, decreasing the vacancy period
- Other changes that have an influence on rental costs and revenues or insurance premiums
- Changes in value of property assets due to efficiency improvements

[If N11 Increase/Decrease] N11a. Can you briefly describe how the {project/measure} impacted the rent or insurance associated costs?

N11b. Can you provide a ball park estimate of the {increase or decrease} in the rent or insurance associated costs, in dollars?

[If N11b NO] N11c. Can you estimate a percentage {increase or decrease} of pre-project rent or insurance associated costs?

[If N11c YES] N11d. Can you estimate the total annual rent or insurance costs at the time of this project?

[If N11c NO] N11e. What range best describes the {increase or decrease} in rent or insurance associated costs?

0-10% 10-20% 20-30% 30-40% 40-50% >50% DK

N12. Did this project increase or decrease the costs associated with <u>any other non-energy characteristic</u> we have not discussed yet, including greenhouse gas emissions? If so, what would that be?

[Provide if needed] Greenhouse gas emissions include carbon dioxide, as well as methane, HFCs, CFCs, nitrous oxide, etc.

[If N12 YES] N12a. Can you briefly describe how the project/measure impacted the costs you mentioned?

N12b. Can you provide a ball park estimate of the increase or decrease in the cost, in dollars?

[If N12b NO] N12c. Can you estimate a percentage increase or decrease of pre-project costs?

[If N12c YES] N12d. Can you estimate the total annual costs you mentioned at the time of this project?

[If N12c NO] N12e. What range best describes the increase or decrease in cost?

0-10% 10-20% 20-30% 30-40% 40-50% >50% DK

Thank you very much for your assistance with this survey. We appreciate your support of our research into Connecticut's Business Energy Suite Programs.

Is there anything else you would like to add or discuss?

F.2 NEI Parameter Assumptions

The evaluators referenced the following parameter assumptions when quantifying customer survey responses to NEIs and dollar impacts.

Table F-1. Calculation Assumptions for Quantifying NEIs

Term	Values	References and Notes
No. 2 Fuel Oil Heating Value	140,000 Btu/gallon	U.S. Energy Information Association (EIA)
Ccf to MMBtu conversion for Natural Gas	0.1029 MMBtu/Ccf	Energy conversion factor from 2017 Connecticut Program Savings Document (PSD) https://www.energizect.com/sites/default/files/2017%20CT%20Program%20Savings%20Document_Final.pdf
Labor cost estimate	$35/hour	Average of production employees and supervisor labor costs from Bureau of Labor Statistics (BLS) https://www.bls.gov/oes/current/oes_ct.htm
Number of employee working days per year	260	Assuming 5 working days per week for 52 weeks
Mercury content in T8 fluorescent lamp	3.5 mg per lamp	Mercury Quantity in Lamps for General Lighting Applications http://assets2.sylvania.com/media/bin/asset-2709308/asset-2709308
No. 2 Fuel oil cost per gallon	$2.5/gallon	Average prices from Connecticut Regional Retail Heating Oil Prices http://www.ct.gov/deep/lib/deep/energy/shopp_survey/ct_heating_oil_regional_retail_prices.pdf
Large C&I Average Electric Rates in Connecticut	$0.1585/kWh	Average prices for commercial and industrial customers from U.S. Energy Information Association (EIA) https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_6_a
Large C&I Average Natural Gas Rates in Connecticut	$7.55/MMBtu	Average prices for commercial and industrial customers from U.S. Energy Information Association (EIA) https://www.eia.gov/dnav/ng/ng_pri_sum_dcu_SCT_m.htm
Water cost per 1,000 gallons	$6.403/1,000 gallons	Average price for Commercial and Industrial customers from Connecticut Water Fact Sheet https://www.ctwater.com/media/1321/cwc7-15-16.pdf