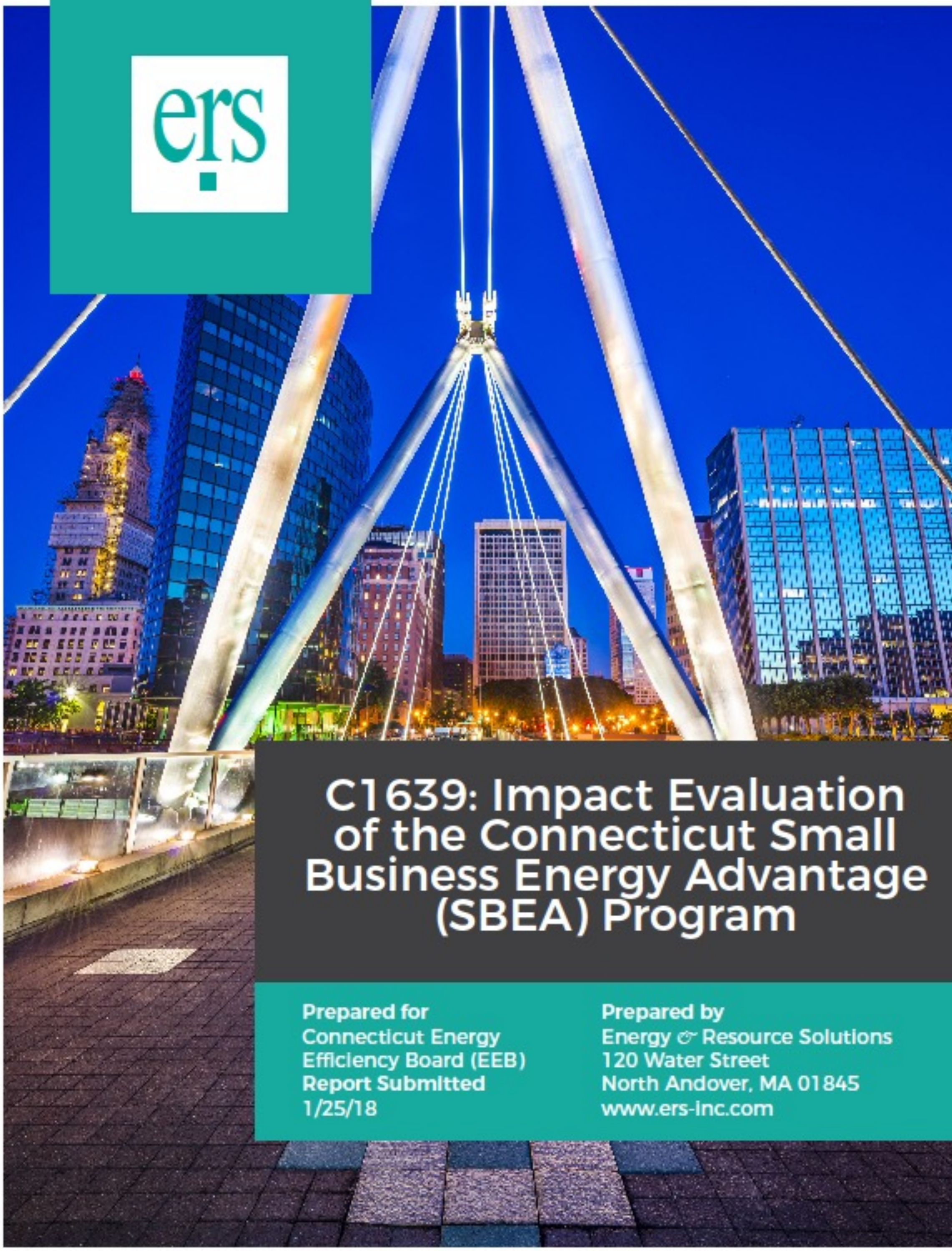

C1639: Impact Evaluation of the Connecticut Small Business Energy Advantage (SBEA) Program

Prepared for
Connecticut Energy Efficiency Board (EEB)
Report Submitted
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1 Executive Summary

This report presents the findings of an impact evaluation of the Connecticut Small Business Energy Advantage Program (SBEA, or "the program"), which offers a free energy assessment, monetary incentives, zero-interest financing, and other services to encourage small businesses in Connecticut to invest in energy-efficient upgrades. The SBEA program is one 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. The impact evaluation was performed in concert with an SBEA process evaluation that was conducted by ERS's subcontractor, Research into Action, and completed in 2017.[1]

The primary objectives of the SBEA impact evaluation, which examined the performance of projects completed during 2013, 2014, and 2015 program years,[2] were to:

1. Develop program-level electric and natural gas energy savings estimates targeted to achieve ±10% relative precision at the 90% level of confidence
2. Develop program-level electric demand savings coincident with summer and winter on-peak and seasonal peak periods, targeted to achieve ±10% relative precision at the 80% level of confidence

[1]"C1639: Process Evaluation of the Connecticut Small Business Energy Advantage (SBEA) Program," June 2017. https://www.energizect.com/sites/default/files/C1639_SBEA%20Process%20Evaluation%20Report__Final_6.30.17.pdf

[2]The evaluators received tracking data from each utility to develop a program-wide data set of record. For Eversource, the evaluators received tracking data for projects completed between 2013 and 2015; however, for UI, the evaluators were only able to obtain tracking data for projects completed between 2014 and 2015. Throughout this report, when the evaluation is characterized as covering 2013–15 projects, this difference by utility should be accounted for.

3. Provide recommendations to support future iterations of the Connecticut Program Savings Document (PSD) as appropriate with measure-level findings from the study

1.1 2013–15 Program Activity Summary

Between January 1, 2013 and December 31, 2015, 4,775 Connecticut small businesses participated in the SBEA program. The two program sponsors, Eversource and UI, combined for a total of 108,518,874 kWh and 37,075 MMBtu saved in the 2013–15 program years. Electricity contributed 91% of the total savings on a site Btu-equivalent basis, with lighting measures constituting the majority (90%) of electric savings. While nearly all of the sponsored projects featured a lighting upgrade (99.5%), the program also offers incentives for non-lighting efficiency upgrades, such as refrigeration, HVAC, motors and variable frequency drives (VFDs), and domestic hot water (DHW) measures. Breakdowns of the savings by measure category for electric projects have been provided in Table 1-1.

Table 1-1. 2013–15 SBEA Program Activity[1] (Electric Measures)

Measure Type	Eversource		UI		Statewide	
	kWh (N=4,014)	% of kWh	kWh (N=755)	% of Total	kWh (N=4,769)	% of Total
Lighting[2]	82,639,034	89%	14,332,731	90%	96,971,765	90%
Refrigeration	6,121,919	7%	886,514	6%	7,008,433	6%
Cooling	2,257,848	2%	100,294	1%	2,358,142	2%
Space heating	566,571	1%	492,891	3%	1,059,462	1%
Process	506,638	1%	0	0%	506,638	0%
Motor	263,816	0%	0	0%	263,816	0%
Custom	169,297	0%	53,148	0%	222,445	0%
Domestic hot water	87,589	0%	40,584	0%	128,173	0%
Total (kWh)		**92,612,712**		**15,906,162**		**108,518,874**
Total (%)		**85%**		**15%**		**100%**

[1] This data comprises 2014–15 UI program activity only.

[2] The lighting category consists of two categories in Eversource tracking data: lighting and high-performance lighting. The evaluators determined no significant differences in measure makeup or facility type between the two groups and therefore have consolidated them together into one measure category.

Natural gas savings (87%) were predominantly space heating-based, as detailed in Table 1-2.

Table 1-2. 2013–15 SBEA Program Activity[1] (Gas measures)

Measure Type	Eversource MMBtu (N=249)	Eversource % of Total	UI MMBtu (N=79)	UI % of Total	Statewide MMBtu (N=328)	Statewide % of Total
Space heating	25,157	86%	7,082	89%	32,238	87%
Process	2,263	8%	0	0%	2,263	6%
Domestic hot water	1,467	5%	114	1%	1,581	4%
Custom	271	1%	722	9%	993	3%
Total (MMBtu)		**29,157**		**7,918**		**37,075**
Total (%)		**79%**		**21%**		**100%**

[1]This data comprises 2014–15 UI program activity only.

1.2 Study Methods

ERS determined evaluation results through engineering assessment of 99 statistically sampled SBEA projects completed between 2013 and 2015. Although the program savings occur predominantly from lighting measures, the sample design segmented the population into other measure categories—non-lighting electric, space heating gas, space heating and DHW gas, and other gas— to develop representative conclusions for non-lighting measures as well. This study marks the first time that SBEA natural gas savings have been evaluated at the same engineering and statistical rigor as electric savings.

ERS engineers visited each of the 99 participating small businesses sampled for evaluation. On-site visits involved inspection and inventory of the incented equipment, interviews with key facility representatives, and deployment of data measurement and recording devices when possible and practical. In total, 346 loggers[3] were deployed. Field engineers conducted project-level assessments in accordance with the International Measurement and Verification Protocol (IPMVP[4]) for the majority of the savings, selecting the most appropriate options based on each project's relative savings per measure, the accessibility of equipment for safe inspection and metering, and the availability of other data sources, such as utility consumption data, that supplemented the original data collection.

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

[3]The 346 deployed loggers include: 272 lighting status or level loggers, 64 current transformers (CTs), and 10 ambient or surface temperature loggers.

[4]"IPMVP Concepts and Options for Determining Energy and Water Savings: Volume 1," March 2002, https://www.nrel.gov/docs/sy02osti/31505.pdf.

the ratio of project-level evaluated savings to reported savings. The 99 project-level RRs were combined in a statistical expansion analysis leading to the program-level RRs summarized in the next section. Aggregate analysis included review of the sources of savings discrepancies between the reported and evaluated results.

1.3 Results

The impact evaluation results are organized by savings type in the subsections that follow.

1.3.1 Electric Savings

Table 1-3 summarizes the evaluation results for the SBEA projects claiming electric savings during program years 2013, 2014, and 2015.

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

Metric	Total Reported Savings	Total Evaluated Savings	Evaluated Gross RR	Relative Precision
Annual energy savings (kWh)	108,518,874	111,360,123	1.03	8.0%
Summer on-peak demand savings (kW)[1]	14,842	17,616	1.19	10.1%
Summer seasonal demand savings (kW)[1]	14,842	16,847	1.14	10.5%
Winter on-peak demand savings (kW)[1]	15,222	15,491	1.02	9.1%
Winter seasonal demand savings (kW)	15,222	15,853	1.04	8.9%

[1]In the ISO New England Forward Capacity Market (FCM), Connecticut utilities submit energy efficiency demand resources using two definitions: on-peak and seasonal peak, as described in Section 3.3.4.

The evaluators determined an annual electric energy savings gross RR of 102.6%, at a relative precision of ±8.0% at the 90% confidence interval. Table 4-2 indicates that the program is saving higher levels of kWh than anticipated, by approximately 3%, as well as higher levels of summer and winter peak demand using both on-peak and seasonal definitions. All of the evaluated electric savings are generally at (or slightly better than) the precision targeted in the sample design. Figure 1-1 illustrates the key drivers behind the higher kWh RR, and their positive and negative impacts, organized into five distinct categories.[5]

[5]Discrepancy categories are defined in Section 3.3.5, and additional site-specific examples are provided in Appendix G.

Figure 1-1. Key Drivers behind Overall Electric Energy Realization Rate

Discrepancy Category	Negative Impact		Positive Impact		Overall	
	# Instances	Impact on RR	Impact on RR	# Instances	Impact on RR	# Instances
Documentation	20	-1.2%	4.7%	28	3.5%	48
Technology	13	-0.4%	1.2%	30	0.7%	43
Quantity	7	-3.0%	0.0%	3	-3.0%	10
Operation	28	-9.2%	12.3%	26	3.1%	54
HVAC Interactivity	35	-2.9%	1.1%	16	-1.8%	51
Total	**103**	**-16.6%**	**19.2%**	**103**	**2.6%**	**206**

The evaluators determined that two differences primarily contributed to the higher RR. First, the evaluators found deviations between the reported savings and savings independently re-created using the PSD algorithm and tracked project characteristics such as quantity, wattage, and operating hours (categorized as "documentation"). Such documentation differences do not include inconsistencies regarding a measure's characteristics or operation; rather, documentation differences assess how appropriately the PSD was followed in the calculation of reported savings. The second major difference involved slightly higher operating hours determined through evaluator M&V compared to the program's assumptions (categorized as "operation").

ERS grouped the electric project population into two segments—lighting-only projects and projects that included at least one non-lighting measure—to ensure representation (and even oversampling) of non-lighting measures in the sample, as they had not been emphasized in prior evaluations. Table 1-4 compares the evaluation results for lighting and non-lighting measures.

Table 1-4. Comparison of SBEA Electric Results: Lighting vs. Non-lighting Measures

Measure Group	Metric	Total Reported Savings	Total Evaluated Savings	Evaluated Gross RR
Lighting measures	Annual energy savings (kWh)	96,971,765	105,820,670	1.09
	Summer on-peak demand savings (kW)[1]	13,672	17,078	1.25
	Summer seasonal demand savings (kW)[1]	13,672	16,213	1.19
	Winter on-peak demand savings (kW)[1]	14,490	15,297	1.06
	Winter seasonal demand savings (kW)[1]	14,490	15,703	1.08

Non-lighting measures	Annual energy savings (kWh)	11,547,109	8,351,639	0.72
	Summer on-peak demand savings (kW)[1]	1,170	984	0.84
	Summer seasonal demand savings (kW)[1]	1,170	998	0.85
	Winter on-peak demand savings (kW)[1]	732	538	0.73
	Winter seasonal demand savings (kW)[1]	732	532	0.73

[1]In the ISO New England Forward Capacity Market (FCM), Connecticut utilities submit energy efficiency demand resources using two definitions: on-peak and seasonal peak, as described in Section 3.3.4.

Lighting measure RRs greatly exceeded one, indicating that the SBEA's lighting fixture upgrades and controls installations are saving more electric energy and peak demand than anticipated. However, non-lighting measures resulted in RRs lower than 1. Savings from such measures are generally more difficult to predict than savings from lighting measures, as their performance often relies on facility-specific conditions. This unpredictability is reflected by the major contribution from the "operation" category in Figure 1-2's examination of the non-lighting electric energy RR.

Figure 1-2. Key Drivers behind the Non-Lighting Electric Energy RR

Discrepancy Category	Negative Impact		Positive Impact		Overall	
	# Instances	Impact on RR	Impact on RR	# Instances	Impact on RR	# Instances
Documentation	3	-0.1%	3.3%	9	3.1%	12
Technology	2	-0.1%	0.4%	2	0.3%	4
Quantity	5	-11.0%	0.0%	0	-11.0%	5
Operation	15	-26.5%	4.8%	6	-21.7%	21
HVAC Interactivity	0	0.0%	1.6%	8	1.6%	8
Total	**25**	**-37.7%**	**10.0%**	**25**	**-27.7%**	**50**

1.3.2 Natural Gas Savings

For the first time in the SBEA program's history, natural gas savings were evaluated at the same statistical and engineering rigor used for electric savings. Table 1-5 summarizes the evaluation results for the SBEA projects claiming natural gas savings during program years 2013, 2014, and 2015.

Table 1-5. Comparison of SBEA Reported and Evaluated Savings: Natural Gas Projects

Segment	Total Reported Savings (MMBtu)	Total Evaluated Savings (MMBtu)	Evaluated Gross RR	Relative Precision
Space heating-only projects	26,161	16,611	0.63	19.6%
Space heating and DHW projects	5,039	5,866	1.16	37.4%
Other projects	5,875	5,667	0.96	18.9%
Total	**37,075**	**28,404**	**0.77**	**17.4%**

The evaluators determined a gross RR of 76.6%, at a relative precision of ±17.4% at the 90% confidence interval, for annual natural gas savings. These findings indicate that the program is saving lower levels of natural gas than anticipated, by 23%, and the higher-than-anticipated relative precision value also illustrates higher variability in results than anticipated by the evaluators. Difficulty in predicting the operating conditions of the installed gas measures was the primary driver behind the lower RR, as illustrated by Figure 1-3.

Figure 1-3. Key Drivers behind the Overall Natural Gas RR

Discrepancy Category	Negative Impact		Positive Impact		Overall	
	# Instances	Impact on RR	Impact on RR	# Instances	Impact on RR	# Instances
Documentation	13	-7.7%	3.8%	11	-3.9%	24
Technology	4	-0.7%	0.5%	3	-0.2%	7
Quantity	6	-0.8%	0.1%	2	-0.7%	8
Operation	27	-29.5%	11.0%	14	-18.5%	41
HVAC Interactivity	1	-0.2%	0.0%	0	-0.2%	1
Total	**51**	**-38.8%**	**15.5%**	**30**	**-23.4%**	**81**

1.3.3 Additional Results

While the evaluation sample was designed to achieve statistically significant results on electric and natural gas savings overall, the evaluators further examined the results of the 99 sampled projects to ascertain other performance patterns within the SBEA program. Table 1-6 compares the evaluation results by utility.

Table 1-6. Comparison of SBEA Reported and Evaluated Savings by Utility

Savings Metric	Eversource (n=84)			UI (n=15)		
	Total Reported Savings	Total Evaluated Savings	Evaluated Gross RR	Total Reported Savings	Total Evaluated Savings	Evaluated Gross RR
Annual energy savings (kWh)	92,612,712	94,049,517	1.02	15,906,162	17,305,516	1.09
Summer on-peak demand savings (kW)	12,698	14,735	1.16	2,144	3,108	1.45
Summer seasonal demand savings (kW)	12,698	13,862	1.09	2,144	3,358	1.57
Winter on-peak demand savings (kW)	12,938	12,954	1.00	2,283	2,480	1.09
Winter seasonal demand savings (kW)	12,938	13,013	1.01	2,283	2,717	1.19
Natural gas savings (MMBtu)	29,157	24,554	0.84	7,918	4,202	0.53

Table 1-6 indicates that electric-saving projects sponsored by UI generally performed better than those sponsored by Eversource, particularly for summer peak demand savings. However, Eversource's natural gas-saving projects performed significantly better than UI's, by over 30 RR percentage points.

Additional evaluation results are examined in Section 4, Appendix C (supplementary results), Appendix D (review of program-wide contributors to the overall RRs), Appendix F (summary table of site-level RRs), and Appendix G (site reports).

1.4 Conclusions and Recommendations

To maximize the value of this study for the SBEA program moving forward, the evaluation team identified nine major conclusions and forward-looking recommendations to improve program effectiveness and savings estimation. These conclusions and recommendations are explored further in Section 5.

- **Conclusion 1** – The SBEA Program generates significant energy and peak demand savings, as is evident in Tables 1-3 and 1-5. The evaluators determined higher levels of total electric energy and peak demand savings than were reported by the program. However, the evaluators determined 23% lower natural gas savings and 28% lower non-lighting electric savings than reported.
- **Conclusion 2** – The Connecticut PSD provides reliable and cost-effective savings estimates for many measures offered by the SBEA, including lighting, refrigeration, packaged HVAC, boiler, and DHW measures. Overall, the RRs for projects with such measures generally did

not deviate significantly from 1. Non-lighting measures, which represented about 19% of the program's total energy savings,[6] proved more difficult to predict than lighting measures and resulted in RRs significantly lower than the lighting RRs. An objective of this impact evaluation was to compare the PSD's measure algorithms and assumptions with the evaluation findings and to subsequently provide recommendations to improve the PSD. However, given the evaluation results and key drivers of the RRs—in general, reductions in savings were most typically due to unanticipated, site-specific characteristics, such as overridden setpoints or hours of use – the evaluators do not recommend measure-level changes to the PSD at this time.

- **Conclusion 3** – ERS observed variation in the estimates of lighting fixture wattages among the SBEA contractors. Based on our review of project files supplied by program administrators, the contractors' derivation of fixture wattages was often unclear and sometimes varied from contractor to contractor.
  - **Recommendation 1** – The Connecticut PSD should be enhanced to include a Connecticut-specific fixture wattage table that encompasses all lighting technologies typically installed or removed through program activity. This fixture wattage standard would eliminate variation among SBEA contractor assumptions. Such a fixture wattage table is prevalent among many states' technical reference manuals, including Massachusetts', New York's, and Pennsylvania's. The lighting market is evolving rapidly with the emergence of cost-effective LED tubes, and the fixture wattage table should be revisited annually with each iteration of the PSD.
- **Conclusion 4** – In order to develop evaluation results most relevant to the program moving forward, ERS examined changes in the PSD from 2013 to the present and found that only three measures have undergone changes that affect the forward-looking RR (FRR) for natural gas, increasing the gas FRR by 1% compared to the evaluation RR. The evaluators found no changes for electric measures.
  - **Recommendation 2** – For electric projects, the evaluation results and RRs are directly applicable to SBEA participants moving forward. For natural gas projects, the program should apply a 78% RR, not a 77% RR, to projects moving forward.
- **Conclusion 5** – The evaluators found that non-lighting measures saved 28% and 23% less electric energy and natural gas, respectively, than anticipated by the program. Non-lighting measures such as energy management systems (EMSs) and vending machine

[6] Non-lighting measures represent 19% of *site* energy savings on a Btu basis.

controls were sometimes found by the evaluators not to be installed at all, or to be overridden or not functioning as intended. In some cases this was due to lack of customer training, awareness, or desire for the measure in the first place. For five sampled condensing boiler measures, the evaluators found higher return water temperatures that led to lower operating efficiencies, perhaps due to oversizing. Such savings discrepancies appear to be driven more by incomplete implementation than by overly optimistic savings estimates.

- **Recommendation 3** – To diversify and expand program offerings and to maximize savings, the SBEA should invest in contractor training to appropriately identify non-lighting measures, educate customers on their operation, and inform those customers of the benefits of high-efficiency equipment when maintained. Non-lighting measures should be a core objective for the program and its contractors. The most recent SBEA process evaluation,[7] completed in parallel with this impact study, provided a similar recommendation on recruiting and training contractors to be qualified to identify and sell non-lighting measures among small business tenants and building owners. Such training will proactively prepare the program for the future landscape of Connecticut small businesses, among which the natural penetration of LED lighting technology is expected to grow and offer fewer opportunities for lighting savings. Contractor training will also lead to higher savings per incentive dollar, particularly for HVAC measures that benefit from quality installation and right-sizing. In the case of condensing boilers, training both contractors and customers on the importance of low return water temperature is critical to achieving and maintaining expected savings.

- **Conclusion 6** – The evaluators experienced difficulties in obtaining sufficient and reliable utility billing data for conducting a program-wide analysis of natural gas savings. The evaluators could not obtain gas billing data for 41% of program participants over the evaluation time frame. This unfulfilled request led the evaluators to forgo a planned program-wide billing analysis approach for all program participants, not just those in the sample. After a second billing data request among 10 gas projects in the sample for which the data was particularly desired, the evaluators could not collect reliable sets of pre-

[7] "C1639: Process Evaluation of the Connecticut Small Business Energy Advantage (SBEA) Program," June 2017, page IV.
https://www.energizect.com/sites/default/files/C1639_SBEA%20Process%20Evaluation%20Report__Final_6.30.17.pdf

project and post-project utility billing data to undertake a site-specific billing analysis. As a result, among these 10 projects, the evaluators were forced to employ an alternative analysis approach, often at lower evaluation rigor.

- **Recommendation 4** – The program should better associate utility account numbers and archive utility billing data for participating SBEA customers, starting at least a year prior to the program application date. This archive will potentially allow for a program-wide billing analysis approach for evaluating natural gas savings, which could be worth exploring as a more economical approach than site-specific M&V. At the very least, more extensive billing data will bolster site-specific analysis, through pre-/post-retrofit comparison and/or calibration of engineering models with actual consumption data. When processing natural gas applications, the SBEA program and its contractors should more diligently establish protocols for assigning tenant-specific gas usage from master-metered or shared natural gas accounts.

- **Conclusion 7** – Similarly, for an estimated 30% of sampled projects, the evaluators had difficulties in obtaining sufficient project files from the utilities in a timely manner or at all. Multiple project file requests were submitted throughout the evaluation to attempt to fill these data gaps. This lack of project information, particularly basic installation information and savings calculations, resulted in complications in M&V planning, analysis, and reporting phases. Additionally, without detailed information on the reported savings derivation, the evaluators could not pinpoint the specific contributors to project-level RRs. These difficulties were experienced with each utility.

  - **Recommendation 5** – The utilities should adopt a more comprehensive method to digitally archive any relevant project files, such as pre- and post-installation inspection reports, particularly for non-lighting measures. These systems will provide more transparency and will allow the utilities to more quickly and cost effectively deliver project files in future evaluations. The savings calculations for all non-lighting projects should be reviewed by company technical staff and archived in a central place available to all for later review.

- **Conclusion 8** – The SBEA program's lighting installations often claimed HVAC interactive savings that differed from evaluator findings, claiming interactivity for only 63% of tracked lighting measures compared to the evaluator's 83%, thereby underclaiming interactive effects. But in some instances, the SBEA claimed HVAC interactive savings for lighting fixtures found by the evaluators in spaces not mechanically cooled, such as basements and mechanical rooms. Overall, these two effects led to a 3% reduction in kWh RR for lighting measures.

- **Recommendation 6** – The program's administrators and implementers should uniformly assess each lighting measure for potential HVAC interactivity and, through improved screening and inspection protocols, only claim interactive HVAC savings for fixtures installed in conditioned spaces. This recommendation is consistent with the prior impact evaluation's recommendation #5.

- **Conclusion 9** – The evaluators found three instances of unrealistically high savings percentages claimed by reported measures. For example, a sampled gas project with only one measure, an EMS, claimed savings that reflected a 54% reduction in pre-project gas consumption at the facility. In another example, a sampled electric project included an EMS measure that claimed reported savings representing approximately 120% of the facility's cooling kWh evident in monthly billing data.

  - **Recommendation 7** – For high-savings projects and/or those with complex measures such as EMSs, the SBEA program administrators and implementers should cross-reference at least the most recent year of monthly utility bill data to "sanity check" savings before reporting. If savings are above a certain percentage of annual usage they should be reviewed by program administrator's technical staff. The billing data archive recommendation complements this one.

2 Overview

This report describes the methodology and results for an impact evaluation of the Connecticut Small Business Energy Advantage Program (SBEA, or "the program"). A previous impact evaluation study of the program was performed on 2011 measure installations and was completed in 2014.[8] A process evaluation of the program occurred concurrently with this impact evaluation and was completed by Research into Action in 2017.[9]

Eversource Energy (Eversource) and United Illuminating (UI) administer the SBEA Program on their own behalf and that of Connecticut Natural Gas and Southern Connecticut Gas. The SBEA Program provides direct install of energy-efficient measures for small commercial and industrial (C&I) customers, defined by an average 12-month peak demand between 10 kW and 200 kW. The majority of the program's energy savings occur from electric measures (lighting in particular), and previous evaluation studies have therefore focused solely on lighting and non-lighting electric impacts. However, the SBEA Program also provides incentives for gas upgrades, such as DHW, high-efficiency boiler, insulation, and EMS measures. This evaluation therefore examines the performance of a variety of measures impacting both electric and natural gas usage at C&I facilities.

2.1 Purpose and Objectives of the Study

The primary objectives of the SBEA study are generally focused on determining program impacts, in addition to an effort to compare measure-level study findings to the current Program Savings Document (PSD) to identify opportunities in which the PSD might be refined. More specifically, the objectives include the following:

1. Develop program-level 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. Within the site-specific savings analyses, identify discrepancies in savings estimates between program tracking or reported savings estimates and final gross savings estimates, including the impact of documentation errors, technology

[8] "C9: Impact Evaluation of the Connecticut Small Business Energy Advantage (SBEA) Program," April 2014. https://www.energizect.com/sites/default/files/C9%20SBEA%20Impact%20Final%20Report%20-%20PY%202011%20May%202014%20%282%29.pdf

[9] "C1639: Process Evaluation of the Connecticut Small Business Energy Advantage (SBEA) Program," June 2017. https://www.energizect.com/sites/default/files/C1639_SBEA%20Process%20Evaluation%20Report__Final_6.30.17.pdf

adjustments, quantity adjustments, operational adjustments, and errors in interactive heating and cooling effects.

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 and quantify discrepancies between tracking demand savings estimates and final gross demand savings estimates, including the impact of documentation errors, technology adjustments, quantity adjustments, operational adjustments, and interactive heating and cooling effects.
3. Provide inputs to update the current PSD as appropriate with findings from the study, including metering results, installation results, and other parameters.

2.2 Program Population Summary

From January 1, 2013 through December 31, 2015, 4,775 Connecticut small businesses participated in the SBEA program. The two program sponsors, Eversource and United Illuminating (UI), combined for a total of 108,518,874 kWh and 37,075 MMBtu saved in the 2013–15 program years,[10] with lighting measures constituting the majority (90%) of the electric savings. The natural gas savings (87%) were predominantly space heating-based. To provide context on the types of measures assessed through this study, breakdowns of savings by measure for electric and gas projects have been provided in Tables 2-1 and 2-2, respectively.

Table 2-1. 2013–15 SBEA Program Activity[1] (Electric measures)

	Eversource		UI		Statewide	
Measure Type	kWh (N=4014)	% of kWh	kWh (N=755)	% of Total	kWh (N=4769)	% of Total
Lighting[2]	82,639,034	89%	14,332,731	90%	96,971,765	90%
Refrigeration	6,121,919	7%	886,514	6%	7,008,433	6%
Cooling	2,257,848	2%	100,294	1%	2,358,142	2%
Space heating	566,571	1%	492,891	3%	1,059,462	1%

[10] The evaluators received tracking data from each utility to develop a program-wide data set of record. For Eversource, the evaluators received tracking data for projects completed between 2013 and 2015; however, for UI, the evaluators were only able to obtain tracking data for projects completed between 2014 and 2015. Throughout this report, when the evaluation is characterized as covering 2013–15 projects, this difference by utility should be accounted for.

Measure Type	Eversource		UI		Statewide	
	kWh (N=4014)	% of kWh	kWh (N=755)	% of Total	kWh (N=4769)	% of Total
Process	506,638	1%	0	0%	506,638	0%
Motor	263,816	0%	0	0%	263,816	0%
Custom	169,297	0%	53,148	0%	222,445	0%
Domestic hot water	87,589	0%	40,584	0%	128,173	0%
Total (kWh)	**92,612,712**		**15,906,162**		**108,518,874**	
Total (%)	**85%**		**15%**		**100%**	

[1] This data comprises 2014–15 UI program activity only.

[2] The lighting category comprises two categories in Eversource tracking data: lighting and high-performance lighting. The evaluators determined no significant differences in measure makeup or facility type between the two groups and therefore have consolidated them into one measure category.

Table 2-2. 2013–15 SBEA Program Activity[1] (Gas measures)

Measure Type	Eversource		UI		Statewide	
	MMBtu (N=249)	% of Total	MMBtu (N=79)	% of Total	MMBtu (N=328)	% of Total
Space heating	25,157	86%	7,082	89%	32,238	87%
Process	2,263	8%	0	0%	2,263	6%
Domestic hot water	1,467	5%	114	1%	1,581	4%
Custom	271	1%	722	9%	993	3%
Total (MMBtu)	**29,157**		**7,918**		**37,075**	
Total (%)	**79%**		**21%**		**100%**	

[1]This data comprises 2014–15 UI program activity only.

Nearly every facility participating in the SBEA Program in 2013–15 received a lighting upgrade (99.5%); therefore, the evaluators assessed lighting performance for all projects in the electric sample. However, by segmenting the population into non-lighting measure groups, the evaluators ensured that the sample featured other prevalent measures, such as energy management systems (EMSs), high-efficiency boilers, and refrigeration fan motor controls, as further described in Section 3.1.

3 METHODOLOGY

This section provides the detailed methodology behind the selection of SBEA 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 RRs.

The major evaluation objectives are addressed in this study through site-level measurement and verification (M&V) and analysis among a statistically representative sample of participating small businesses. 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.[11] For some electric and gas projects for which M&V was unfeasible, the evaluators conducted a site-level billing analysis approach or verification of measure installation and operability with a Connecticut Program Savings Document (PSD) deemed savings calculation.

This engineering approach is appropriate for evaluating measures of the nature installed through the SBEA Program. Metered performance data of incented equipment led to the extrapolation of key operating profiles, such as time-of-use or consumption, resulting in the calculation of 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.[12] This approach allows for efficient sampling 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 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. ERS designed the sample on site-level kWh and MMBtu savings, targeting ±10% relative precision at the 90% confidence interval. Summer peak

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

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

demand savings were sampled targeting a two-tailed 80% confidence interval with ±10% relative precision, while winter peak demand savings were sampled targeting a one-tailed 80% confidence interval with ±10% relative precision. Table 3-1 summarizes the sample design.

Table 3-1. SBEA Impact Evaluation Sample Design Summary

Sample Design Parameter	Basis of Estimation or Approach
Population frame definition	SBEA participants with projects completed between 2013 and 2015
Sampling unit	Project
Population	4,775 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 variable	Project-level annual energy savings (kWh or MMBtu)
Lower-level stratification variables	Electric: presence of non-lighting measure(s) Gas: space-heating only, space-heating + DHW, other measures Project size (claimed savings magnitude)
Post-hoc stratification variables of interest	Utility company

For electric measure sampling, projects were classified into two segments: lighting-only projects and projects with at least one non-lighting measure. The former segment consists solely of lighting fixture upgrades and lighting controls installations, while the latter consists of projects with at least one non-lighting measure that saves electric energy, such as HVAC, refrigeration, and motor/VFD measures, but also typically featured lighting upgrades as well. As non-lighting electric measures were also an important part of the study, the evaluation team emphasized non-lighting electric measure sampling in the design through over-sampling relative to its contribution to savings alone. This study also marks the first time that SBEA natural gas measures have been assessed at the same statistical and engineering rigor as electric measures.

Table 3-2 presents the anticipated relative precision by segment for a total electric sample of 54 projects. Overall, 21 sampled lighting-only projects and 33 sampled projects with a non-lighting measure were expected to provide a 9.6% relative precision for energy and a 9.3% relative precision for summer peak demand savings when combined. Note that the evaluators referenced error ratios for energy and demand savings from the most recent SBEA impact evaluation (2014).

Table 3-2. Anticipated Precision for Electric Sample

Savings Type	Metric	Lighting-Only Projects	Projects with Non-Lighting Measure(s)	Total
Energy	Total savings (kWh)	67,028,859	41,490,014	108,518,874
	Error ratio	0.387	0.387	0.387
	Confidence level	90%	90%	90%
	Planned sample size	21	33	54
	Anticipated relative precision	14.0%	10.9%	9.6%
Summer peak demand savings	Total savings (kW)	9,455	5,387	14,842
	Error ratio	0.467	0.467	0.467
	Confidence level	80%	80%	80%
	Planned sample size	21	33	54
	Anticipated relative precision	13.4%	10.2%	9.3%
Winter peak demand savings	Total savings (kW)	10,114	5,107	15,222
	Error ratio	0.874	0.874	0.874
	Confidence level	80%	80%	80%
	Planned sample size	21	33	54
	Anticipated relative precision	16.2%	12.6%	10.3%

SRE involves sorting the population of projects by magnitude of savings to establish stratum thresholds that result in similar savings per sampled stratum. In the case of the electric sample, four strata were defined within each of the two segments. Stratum 1, or the census stratum, contained the highest-saving projects in the segment. Strata 2 and 3 represent the medium savers from which a sample of projects are drawn. Stratum 4, the small savers, were excluded from the evaluation sample due to relatively low savings contribution (2.7% in the case of electric savings).

The final stratified electric energy sample design is provided in Table 3-3. The third column indicates the maximum energy savings represented within each stratum, while the fourth column indicates how many projects from the population are included within each stratum of each segment. The rightmost column is calculated as the ratio of the population project count (fourth column) to the sample project count (sixth column), defining the case weights used in the expansion analysis of sample results to program-wide results as described in Section 3.4.

Table 3-3. Sample Design for Electric Savings

Project Segment	Stratum	Maximum Savings (kWh)	Total Project Count	Total Savings (kWh)	Sample Size	Case Weight
Lighting-only projects	1	505,410	1	505,410	1	1.0
	2	321,303	435	32,358,899	10	43.5
	3	37,834	2,325	32,175,348	10	232.5
	4	3,997	868	1,992,274	0	N/A
Projects with non-lighting measure(s)	1	536,897	3	1,463,896	3	1.0
	2	385,825	200	19,575,562	15	13.3
	3	50,944	767	19,491,607	15	51.1
	4	8,959	170	958,949	0	N/A
Total			**4,769**	**108,521,946**	**54**	

For gas measure sampling, projects were classified into three segments: space heating, space heating + DHW, and “others.” The space heating projects consisted of upgrades to high-efficiency boilers or furnaces, while the space heating + DHW projects also typically included hot water measures, such as the installation of low-flow devices. Examples of “other” measures include kitchen hood exhaust fans and building envelope improvements. Table 3-4 illustrates the anticipated relative precision by segment for a total gas sample of 45 projects. Overall, 28 sampled space heating projects, 7 sampled space heating + DHW projects, and 10 sampled “other” projects were expected to provide a 9.9% relative precision for natural gas savings. The evaluators assumed an industry-standard error ratio of 0.6 for all gas projects, which were not included in the scope of previous SBEA impact evaluations in Connecticut.

Table 3-4. Anticipated Precision for Natural Gas Sample

Savings Type	Metric	Space Heating Only	Space Heating + DHW	Others	Total
Natural gas energy	Total savings (MMBtu)	26,161	5,039	5,875	37,075
	Error ratio	0.6	0.6	0.6	0.6
	Confidence level	90%	90%	90%	90%
	Planned sample size	28	7	10	45
	Anticipated relative precision	12.4%	27.5%	16.2%	9.9%

Three strata were defined within each gas segment. The final stratified natural gas sample design is provided in Table 3-5.

Table 3-5. Sample Design for Natural Gas Savings

Project Segment	Stratum	Maximum Savings (MMBtu)	Total Project Count	Total Savings (MMBtu)	Sample Size	Case Weight
Space heating only	1	4,564	2	5,931	2	1.0
	2	1,005	83	20,190	26	3.2
	3	50	48	897	0	N/A
Space heating + DHW	1	917	2	1,547	2	1.0
	2	498	29	3,363	5	5.8
	3	13	17	129	0	N/A
Others	1	2,263	1	2,263	1	1.0
	2	548	32	3,112	9	3.6
	3	15	114	488	0	N/A
Total			**328**	**37,919**	**45**	

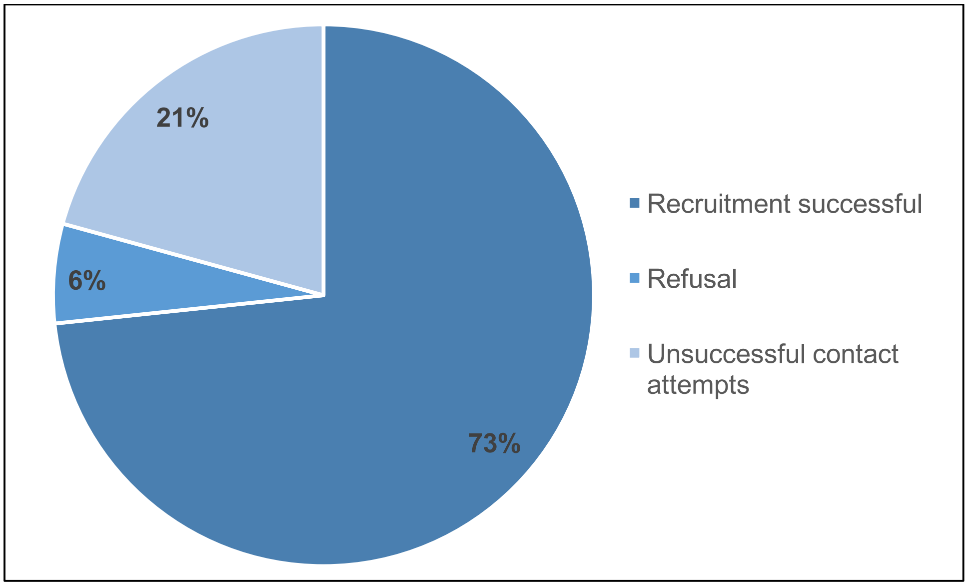
3.2 Data Collection

This section describes the methods used by the evaluation team to collect sufficient site-level data for calculation of evaluated impacts, from arranging site visits with sampled customers, to collecting relevant project information, to deploying performance measurement equipment.

3.2.1 Recruitment

ERS 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 measurement devices when possible and practical. Figure 3-1 illustrates the disposition of recruitment calls made for the study's 99 site visits. 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 a 73% response rate, an improvement from the prior SBEA impact evaluation completed in 2014.

Figure 3-1. Impact Evaluation Recruitment Disposition



The response rate is critical in impact evaluation studies, as it can indicate potential bias associated with the representativeness of sample results for the program population. However, due to the relatively high response rate and low refusal rate, we believe that the recruitment dispositions achieved in this study do not result in significant bias on program-wide impact evaluation results.

3.2.2 On-Site Data Collection

ERS field engineers conducted site visits at all sampled electric- and gas-saving projects. Site visits included physical inspection and inventory associated with incented equipment, interviews with relevant facility personnel, surveys of general facility operating conditions, characterization of pre-project facility operations and equipment, and requests of relevant documentation, such as equipment specifications, facility schedules, or production data. Of particular interest to the evaluators were the following facility characteristics that might influence the extrapolation of project savings over a full year:

- **Annual operating conditions –** The facility's relative operating levels throughout a full year (e.g., typical shifts per day, business hours), compared to the evaluation data collection period, is critical in ensuring fair assessment of annual project savings.
- **Changes in occupancy or employment –** A fluctuation in the number of employees or occupants at the facility might influence the fair comparison of pre- and post-project utility consumption.

- ❑ **Other projects –** Field engineers also collected information about other projects at the facility that might impact billed electric or gas usage.

3.2.3 Performance Measurement

When possible and practical, ERS field engineers deployed data measurement devices on facility equipment impacted by the sampled SBEA projects. ERS's typical metering approach by measure category is illustrated in Table 3-6 and further described in Appendix A.

Table 3-6. Most Prevalent M&V Methods by Measure Category

Measure Category	IPMVP Option A	IPMVP Option B	IPMVP Option C	Verification
Interior lighting	✓			
Exterior lighting		✓		
Packaged cooling		✓		
Energy management system (EMS)			✓	✓
Refrigeration		✓		✓
Motor/VFD		✓		
Space heating: boilers		✓	✓	✓
Space heating: furnaces			✓	✓
DHW fixtures				✓

ERS deployed 346 loggers among the 99 sampled projects: 272 lighting status or level loggers[13], 64 current transformers (CTs) with data loggers, and 10 ambient or surface temperature loggers.

3.3 Site-Level Analysis

ERS's analysis methods for various measure categories are described in the following sections.

3.3.1 Lighting

The evaluation of lighting measures, for the most part, included inventory of installed fixture types and quantities and installation of run-time loggers to measure hours of operation in accordance with IPMVP Option A. Upon retrieving the loggers, ERS engineers processed the

[13] 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.

interval run-time data into hourly operating profiles for representative usage groups[14] among the installed lighting fixtures.[15] 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, as illustrated in the example profile provided in Figure 3-2.

Figure 3-2. Example Lighting Percentage-On Profile Based on Facility Schedule (Office)

Day of Week, Hour of Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Sunday	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	4%	4%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Monday	1%	0%	0%	0%	0%	0%	0%	12%	71%	72%	75%	75%	71%	66%	59%	59%	48%	25%	0%	0%	0%	0%	0%	6%
Tuesday	0%	0%	0%	0%	0%	0%	0%	6%	68%	88%	91%	88%	88%	85%	82%	76%	66%	29%	5%	9%	13%	13%	11%	0%
Wednesday	0%	0%	0%	0%	0%	0%	0%	5%	61%	84%	100%	100%	94%	87%	83%	91%	91%	26%	0%	0%	0%	0%	0%	0%
Thursday	0%	0%	0%	0%	0%	0%	0%	14%	78%	98%	98%	98%	98%	98%	96%	93%	80%	26%	14%	16%	14%	0%	0%	1%
Friday	0%	1%	0%	0%	0%	0%	0%	6%	84%	98%	74%	98%	98%	90%	75%	74%	80%	37%	3%	0%	0%	0%	0%	1%
Saturday	0%	0%	0%	0%	0%	0%	0%	0%	2%	0%	0%	0%	9%	3%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

For each metered usage group, ERS engineers extrapolated operation by hour and by day of week over a full year using an hourly ("8,760") analysis. For calculating evaluated demand savings, the annual hourly analysis allowed examination of lighting fixture operation at summer and winter on-peak and summer and winter seasonal peak periods. Additionally, the 8,760-hour analysis associated typical meteorological year (TMY) outside air temperatures (OATs) with hourly fixture operation, allowing for the calculation of interactive HVAC impacts discussed later in this section.

Hourly fixture operating profiles over a full year were next distilled into key values used in the calculation of evaluated savings: annual full-load[16] hours of operation, summer peak coincidence factors, winter peak coincidence factor, annual full-load cooling hours, annual full-load heating hours, and pre-project annual full-load hours of operation (for lighting controls measures). These values were next associated with the fixture information inventoried by ERS engineers during on-site visits, as described in the next paragraph.

[14] 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, sales areas, hallways, storage areas, bathrooms, and mechanical rooms.

[15] Technicians installed a lighting run-time logger on each uniquely scheduled circuit affected by the measure(s), up to a total of 10 circuits. If the measure affected more than 10 circuits, the analyst followed a random within-site circuit selection procedure to ensure that a representative sample was metered by the loggers.

[16] Full-load hours refers to the equivalent number of annual hours an examined lighting fixture would have operated at 100% output. For example, if evaluators determined that a lighting fixture operates at 50% output over a full year (8,760 hours), its equivalent annual full-load hours would be 4,380.

ERS engineers independently inspected and inventoried the installed lighting fixtures during logger deployment and retrieval visits. The following fixture parameters were emphasized during on-site visits: pre- and post-project fixture quantities; pre-/post- fixture types, including lamp characteristics, lamp quantity per fixture, and ballast characteristics; pre-/post- lighting control type; and fixture locations by usage group. Field engineers also administered a survey with the facility's manager, owner, or other knowledgeable representative, to identify characteristics that affect facility energy use for lighting operation, such as the following:

- Seasonal changes in facility use
- Typical business holidays
- HVAC system characteristics: type, size, vintage, fuel type
- Cooling operating patterns: time of year or typical OAT when activated/deactivated
- Heating operating patterns: time of year or typical OAT when activated/deactivated

Site-level fixture inventories were reviewed by an ERS senior engineer before being aggregated into a program-wide master analysis spreadsheet. For all projects in the electric sample, the master lighting analysis file paired each line item in the program's tracking database with evaluator inventory information as well as the appropriate lighting operating profile for that usage group. In this manner, pre- and post-project fixture wattages[17] and quantities were 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,[18] and summer and winter peak coincidence factors were incorporated to provide summer and winter peak demand savings, respectively.

A portion of the electric energy to lighting fixtures is dissipated in the form of heat; as a result, lighting fixture retrofits in conditioned spaces result in indirect impacts to a facility's cooling or heating energy consumption. Therefore, the master lighting analysis spreadsheet calculated

[17]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 vendor assumptions and the NY TRM's Appendix C, the evaluators adopted the same fixture wattages as estimated by vendors. http://www3.dps.ny.gov/W/PSCWeb.nsf/96f0fec0b45a3c6485257688006a701a/72c23decff52920a85257f1100671bdd/$FILE/ATTESQKL.pdf/TRM%20-%20Version%204.0-April%202016.pdf.

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

interactive HVAC impacts within spaces verified by ERS field engineers to be mechanically cooled and/or heated. The spreadsheet allowed the evaluators to input site-specific information on HVAC system type(s), efficiencies,[19] and operating characteristics. The 8,760 extrapolation totals the number of full-load hours in the year that lighting operation coincided with cooling or heating system operation. These cooling and heating hours values (and summer and winter peak coincidence factors) were applied to the PSD's HVAC interactive savings algorithm (PSD page 71) to determine the evaluated interactive impacts per lighting line item. The evaluators made an additional revision to the PSD's interactive savings algorithm with the assumption that 80% of the lighting fixtures' dissipated heat requires removal (during cooling periods) or defrays the facility's space heating load (during heating periods).

The SBEA evaluation sample included a number of projects that involved the installation of automatic lighting controls, most prominently motion-based occupancy sensors. For these measures, savings occur from reduced operation of the controlled lighting fixtures. Therefore, the pre-project operating profile differs from the post-project operating profile for such fixtures. The evaluators were able to determine the latter through on-site M&V, but the former required one of three derivation techniques, in order of preference:

- **Proxy profile –** The evaluators referenced a metered operating profile for a manually controlled fixture corresponding to a similar usage group. For example, if half of a participating office facility's enclosed offices received occupancy sensors while the other half did not, the other half's metered lighting operation was assumed to reflect the pre-project profile for the fixtures with occupancy sensors.
- **Higher-use baseline –** The evaluators analyzed the post-project profile's typical start and end times, as well as the maximum hourly lighting operation observed over any hour in a typical day, to estimate the pre-project, manually controlled operation. With this technique, the baseline profile features the maximum hourly operation applied to all hours between typical start and end times.
- **On-site interview –** The evaluators collected information from the facility representative on pre-project fixture operation. For example, if a warehouse previously activated and deactivated fixtures at the start and end of a shift, respectively, the evaluators assumed that the pre-project fixture operation reflected this schedule.

[19] In some cases, the evaluators were not able to access the HVAC equipment for inspection and inventory of nameplate specifications (rooftop units, for example). In these instances, the evaluators relied on standard efficiency assumptions by system type in the calculation of interactive impacts.

3.3.2 M&V for Non-Lighting Electric and Gas Measures

Certain non-lighting electric and gas measures were most conducive to an M&V approach in accordance with IPMVP Option B. Table 3-7 outlines ERS's ideal M&V approach for two prevalent non-lighting measure categories in the SBEA sample. For some projects, due to various on-site circumstances,[20] unfavorable weather conditions,[21] or relatively low measure savings compared to the lighting upgrades, the evaluators implemented a more limited approach that often relied on verification that the same measure described in the tracking database was installed and operational. For further information on non-lighting evaluation techniques, see Appendix A for M&V approaches for other measures and Appendix G for the individual M&V reports.

Table 3-7. Evaluation Approach for Prevalent Non-Lighting Electric Measures

Measure Category	Prevalent Measures	M&V and Analysis Approach
Refrigeration	Electronically commutated motors (ECMs) for evaporator fans Advanced evaporator fan controls Automatic door heater controls	Disassemble the impacted refrigeration case. Attempt to isolate the affected electrical circuit(s) (typically fan motors and/or door heater). Deploy a low-amperage current transformer (CT) on the appropriate electrical circuit(s) if identifiable and safely accessible. In some cases, the impacted circuit(s) could not be isolated due to inaccessibility or unclear wiring diagrams. For metered cases, analyze amperage data to determine typical operating schedule. Assess potential dependencies on weather or schedule. Calculate coincidence factors and annual full-load hours from extrapolated profile. Revise PSD algorithm with verified system characteristics and measured hours and coincidence factors. For measures that could not be fully metered, update the PSD algorithm with project-specific information gathered during the site visit.
Motors/VFDs	VFD on supply or exhaust fans VFD on air compressor	Deploy a CT in the electrical panel serving the affected motor. Spot-measure the voltage, amperage, power factor, and wattage at time of deployment. After 4–6 weeks, retrieve CT(s) and repeat spot measurements. Analyze amperage data, assessing correlations with hourly OAT data and/or facility schedule. Calculate the motor load of impacted motors using manufacturer efficiency specifications and load factor estimates. Determine the baseline power requirement (preexisting or code-compliant unit(s) of comparable size) for delivering the same motor load. Calculate savings as the difference between the baseline energy usage and installed energy usage, extrapolated over a full year based on independent variable(s). For measures that could not be fully metered, update the PSD algorithm with project-specific information gathered during the site visit.

[20]Such circumstances include inaccessibility of equipment or electrical panels, safety concerns, time constraints, or insufficient cooperation from facility staff.

[21]The project's data collection mostly occurred in the fall and winter of 2016. Therefore, some HVAC measures could not be metered over a fully representative range of cooling season temperatures.

For all of the measures in the sample, ERS engineers collected information on pre-project equipment operability and age. Generally, for measures that involved an upgrade of operable equipment that had not approached or exceeded its effective useful life (EUL)—defined as *early replacements*—or added controls to existing equipment also within its useful life such as an EMS, the baseline reflected the preexisting equipment. For measures that involved replacing failed equipment or equipment exceeding its EUL—defined as *replace-on-burnout* or *normal replacement*, respectively—the baseline reflected the code-compliant equipment of similar type and size.[22]

3.3.3 Site-Specific Billing Analysis

When appropriate (see Section 3.2.3), the evaluators employed an analysis of pre- and post-project utility consumption to assess project savings. Typically, a simple comparison of the two sets of bills was not appropriate, as the independent variables governing consumption during the pre- and post-project periods (e.g., weather conditions) were often unequal. Therefore, the evaluators utilized a normalized billing analysis approach for calculation of project savings; further discussion of ERS's site-specific billing analysis approach is provided in Appendix A and in Appendix G for individual projects.

While planning this study, the evaluation team's scope included a program-wide analysis of billed natural gas consumption to determine the SBEA's evaluated gas savings. However, the evaluators faced difficulties in obtaining comprehensive, reliable gas consumption data over a representative duration of pre- and post-project periods for all gas projects in the population. The gas utilities were simply not able to supply comprehensive billing data for a sufficient number of projects to conduct a program-wide billing pre-/post- analysis as planned. Furthermore, for some sites where billing data was available, the evaluators determined that the project's claimed savings fraction was not consistently large enough to confidently apply program-level billing analysis. For these reasons, the evaluators instead employed a project-level data collection and analysis approach among the sample of gas projects.

3.3.4 Peak Demand Savings

In the ISO New England Forward Capacity Market (FCM), a participating utility may submit energy-efficiency demand resources as one of three different types: on-peak, seasonal peak, and critical peak. The first two peak definitions, on-peak and seasonal peak, are of importance to the SBEA Program, as Eversource and UI submit SBEA impacts to the FCM as a seasonal peak

[22]The ASHRAE 90.1 Energy Standard for Buildings was referenced in the reported savings calculations and in various iterations of the Connecticut PSD. Therefore, the evaluators adopted ASHRAE 90.1 as the primary code baseline reference in this study.

demand resource, but are interested in comparing that with the on-peak demand savings value. Therefore, an objective of the SBEA impact evaluation is to determine and compare both on-peak and seasonal peak demand impacts, which are defined[23] as follows:

- "**Demand Resource On-Peak Hours** are hours ending 1400 through 1700, Monday through Friday on non-Demand Response holidays during the months of June, July, and August and hours ending 1800 through 1900, Monday through Friday on non-Demand Response holidays during the months of December and January."
- "**Demand Resource Seasonal Peak Hours** are those hours in which the actual, real-time hourly load, as measured using real-time telemetry… for Monday through Friday on non-Demand Response holidays, during the months of June, July, August, December, and January, as determined by the ISO, is equal to or greater than 90% of the most recent 50/50 system peak load forecast, as determined by the ISO, for the applicable summer or winter season."

The evaluators calculated on-peak and seasonal demand savings, as well as associated coincidence factors, for all electric measures in the sample. The calculation of seasonal peak demand savings is considerably more complex than on-peak, as it involves analysis of prior grid loading and its correlation with weather conditions; this analysis is further described in Appendix B.

In the case of lighting measures, for which the evaluators calculated hourly operating profiles over a full year, the on-peak and seasonal demand savings typically differed. Additionally, for other non-lighting measures assessed through M&V that demonstrated variability with schedule or weather conditions (e.g., high-efficiency rooftop units), the evaluators typically determined different seasonal peak demand savings than on-peak. But for other electric measures that did not demonstrate variability with schedule or weather conditions (e.g., refrigeration fan motors, which often feature a relatively constant profile), the evaluators determined seasonal peak demand savings identical to on-peak. A more detailed breakdown of on-peak versus seasonal demand savings by electric measure type is provided in Appendix B.

3.3.5 Discrepancy Analysis

The primary objective of this study involves not only calculating the gross savings estimates at the required statistical precision, but also identifying why those estimates differ from program-

[23] "ISO New England Inc. Transmission, Markets, and Services Tariff: General Terms and Conditions," November 2017. https://www.iso-ne.com/static-assets/documents/regulatory/tariff/sect_1/sect_i.pdf

reported savings estimates. For all projects in the sample, the evaluators completed a discrepancy analysis, a quantification and classification of savings differences among five key categories, for which descriptions and evaluator analysis techniques are summarized in Table 3-8.

Table 3-8. Explanation of Discrepancy Categories and Analysis Approaches

Discrepancy Category	Research Questions	Analysis Technique
Documentation	Do the reported savings comply with the CT PSD algorithm for that measure (if applicable) if they are used in the reported savings calculation? Does the reported savings value match the savings value determined in the applicant analysis file?	Per the measure-level information in the tracking database and/or applicant analysis file (e.g., quantity, wattage), re-create the PSD-compliant savings and subtract the reported savings.
Quantity	Was the measure installed? Does the reported quantity of installed equipment match the evaluators' inventory?	Assume that all other tracked measure parameters *except* quantity (e.g., wattage and operating hours) are correct. Compare savings calculated from the evaluators' inventoried quantity with reported savings. In cases where the measure was not installed, the quantity discrepancy complements the documentation adjustment, if any, to represent the full difference between the evaluated and reported savings.
Technology	Does the reported wattage or size of installed equipment match the evaluators' inventory? Does the verified equipment match the type of equipment reflected in the reported savings?	Assume that all other tracked measure parameters *except* wattage or size (e.g., quantity, operating hours) are correct. Compare savings calculated from evaluators' inventory of wattage/size with the reported savings.
Interactivity	Are interactive HVAC savings appropriately calculated for the measure, per recommendations set forth in the CT PSD?	Assess whether interactive savings are appropriate (e.g., measure installed in a conditioned space). If appropriate, calculate CT PSD-compliant interactive savings using tracked measure characteristics. Compare that value with the evaluator's independently calculated interactive effects based on on-site verification and metered operation.
Operation	Does the measure operate for the hours or loading level assumed in the applicant analysis? Does the measure operate at the efficiency assumed in the applicant analysis?	Quantify the total difference between reported savings (reflecting tracked hours of use) and evaluated savings (reflecting evaluated hours of use). Subtract the differences from the cumulative effects of the above four categories.

3.4 Expansion Analysis

With all project-level results calculated using the methods in Sections 3.2 and 3.3, the evaluators next calculated program-level evaluation results through a 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 3-3 and 3-5)
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 results, overall and by segment, using the recommendations set forth in the California Evaluation Framework. 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 SBEA program. First, Table 4-1 compares key evaluation criteria with prior SBEA impact evaluations to contextualize this study's findings.

Table 4-1. Comparison of Key Criteria and Findings with Prior SBEA Impact Evaluations

Parameter	Impact Evaluation Report Year		
	2009[1]	2014[2]	2017
Program Profile			
Study period (program years)	2007	2011	2013–15
Average reported annual savings (MWh)	37,114	35,205	40,552
Average annual number of electric sites	1,752	1,696	1,760
Average annual reported electricity savings/site (kWh)	21,184	20,758	23,047
Percent of electric energy savings to lighting	93%	86%	90%
Average reported annual savings (MMBtu)	N.E.[3]	N.E.[3]	12,962
Average annual number of gas sites	N.E.[3]	N.E.[3]	128
Average annual reported gas savings/site (MMBtu)	N.E.[3]	N.E.[3]	102
Evaluation Approach			
Scope	Lighting	Lighting + Non-lighting electric	Lighting + Non-lighting electric + Natural gas
Method(s)	Sample M&V	Sample M&V + Program-level bill analysis (not used)	Sample M&V
Sampling method	SRE	SRE	SRE
Sample size (projects)	126 electric	60 electric	99 (54 electric, 45 gas)
Recruiting completion rate (including non-respondents)	78%	68%	73%
Number of loggers deployed	300+ lighting	370 lighting 18 current or power	272 lighting 64 current or power 10 temperature

Results – RRs			
Electric energy	120% lighting *(99% excluding HVAC adjustment)*	96% overall 99% lighting 79% non-lighting	103% overall 109% lighting 72% non-lighting
Summer on-peak demand	107% lighting *(77% excluding HVAC adjustment)*	89%	119%
Summer seasonal peak demand		90%	114%
Winter on-peak demand	67%	109%	102%
Winter seasonal peak demand		94%	104%
Natural gas energy	N/A[4]	N/A	77%
Statistical Results – Confidence / Relative Precision			
Electric energy	80%/11%	90%/8%	90%/8%
Summer on-peak demand	80%/9%	80%/19%	80%/10%
Summer seasonal peak demand		80%/20%	80%/11%
Winter on-peak demand		80%/16%	80%/9%
Winter seasonal peak demand		80%/18%	80%/9%
Natural gas energy	N/A	N/A	90%/17%

[1]"Connecticut SBEA Impact Evaluation Report Program Year 2007," https://www.energizect.com/sites/default/files/ct_sbea_2007_impact_evaluation_report_updatednov091.pdf

[2]"Impact Evaluation of the Connecticut SBEA Program," https://www.energizect.com/your-town/sbea-impact-evaluation-c9-may-2014-2

[3] N.E. = Not evaluated

[4]N/A = Not applicable

Table 4-1 compares the last three impact evaluations of the SBEA program, which has been relatively consistent over the 8-year period. Both annual reported electric savings and savings per site have increased since the prior evaluation period, by 15% and 11%, respectively. The evaluation scope and complexity gradually have expanded to reflect the program's increased adoption of non-lighting and natural gas measures. Overall, the profiles, approaches, and results reflect a relatively stable program and consistently defensible evaluation results.

4.1 Electric Results

Table 4-2 provides the impact evaluation results for the SBEA projects claiming electric savings during program years 2013, 2014, and 2015. Appendix F summarizes the site-level RRs contributing to the program's electric results examined throughout this section.

Table 4-2. Comparison of SBEA Reported and Evaluated Savings: Electric Projects

Savings Metric	Total Reported Savings	Total Evaluated Savings	Evaluated Gross RR	Relative Precision
Annual energy savings (kWh)	108,518,874	111,360,123	1.03	8.0%
Summer on-peak demand savings (kW)	14,842	17,616	1.19	10.1%
Summer seasonal demand savings (kW)	14,842	16,847	1.14	10.5%
Winter on-peak demand savings (kW)	15,222	15,491	1.02	9.1%
Winter seasonal demand savings (kW)	15,222	15,853	1.04	8.9%

The evaluators determined an annual electric energy savings gross RR of 102.6%, at a relative precision of ±8.0% at the 90% confidence interval. Table 4-2 indicates that the program is saving more kWh than anticipated, by approximately 3%, most notably due to higher-than-anticipated equipment operating hours measured by the evaluators. Other contributing factors to the kWh RR are discussed in Section 4.1.2. Evaluated results for kWh are markedly more precise than the ±9.6% relative precision targeted in the sample design.

Table 4-2 also shows that the program has led to higher summer and winter peak demand savings than anticipated, primarily due to multiple instances of positive evaluated peak savings reported as zero in the tracking data. Other contributing factors to the kW RRs are discussed in Appendix D. Winter peak results are more precise at the 80% confidence interval (±9.1% on-peak, ±8.9% seasonal) than targeted in the sample design (±10.3%). However, the summer peak demand results are slightly less precise at the 80% confidence interval (±10.1% on-peak, ±10.5% seasonal) than targeted in the sample design (±9.3%).

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

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

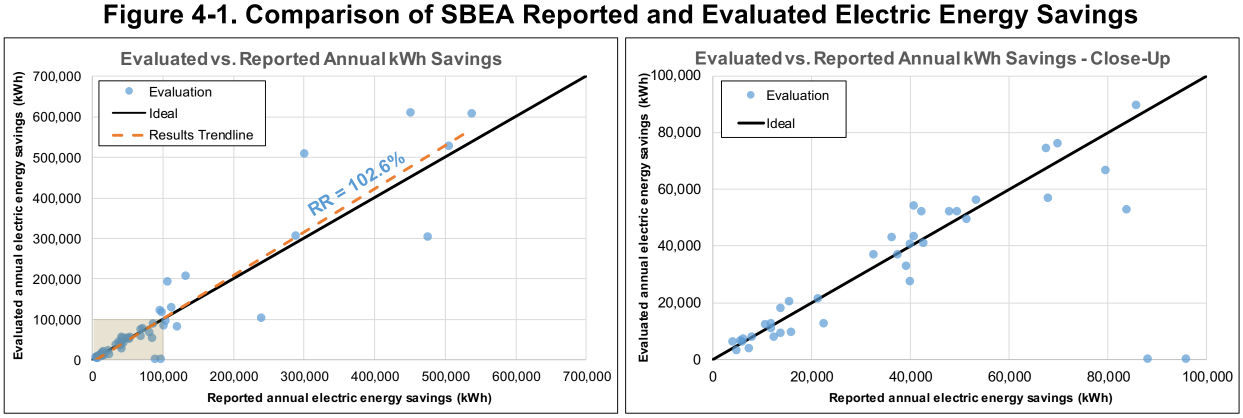


Figure 4-1 illustrates how several of the largest-saving electric projects in the sample featured higher evaluated savings than reported, resulting in points above the ideal line and contributing to an overall electric energy RR of 103%. The close-up figure indicates that the majority of the smaller-saving electric projects did not deviate significantly from the ideal line, except for two medium-saver projects with RRs near zero.

Figures 4-2 and 4-3 illustrate similar comparisons for summer and winter seasonal peak demand, respectively.

Figure 4-2. Comparison of SBEA Reported and Evaluated Summer Seasonal Peak Demand Savings

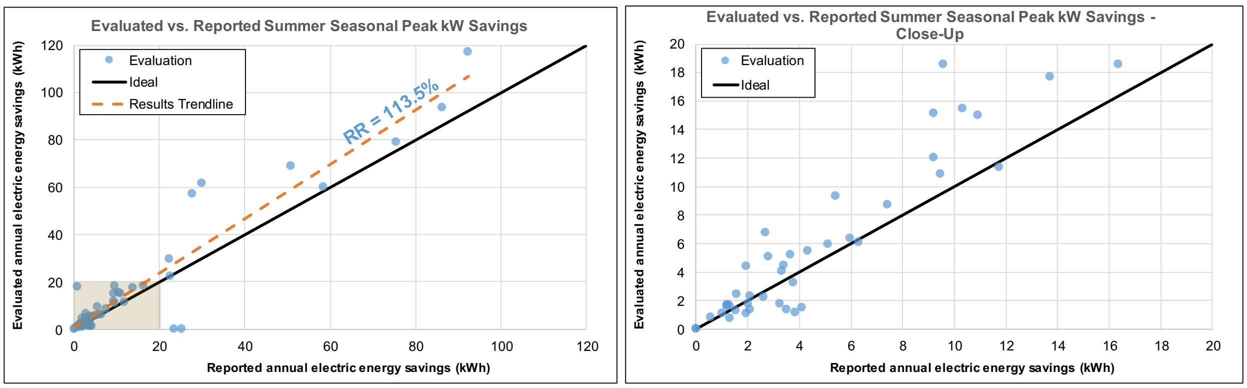
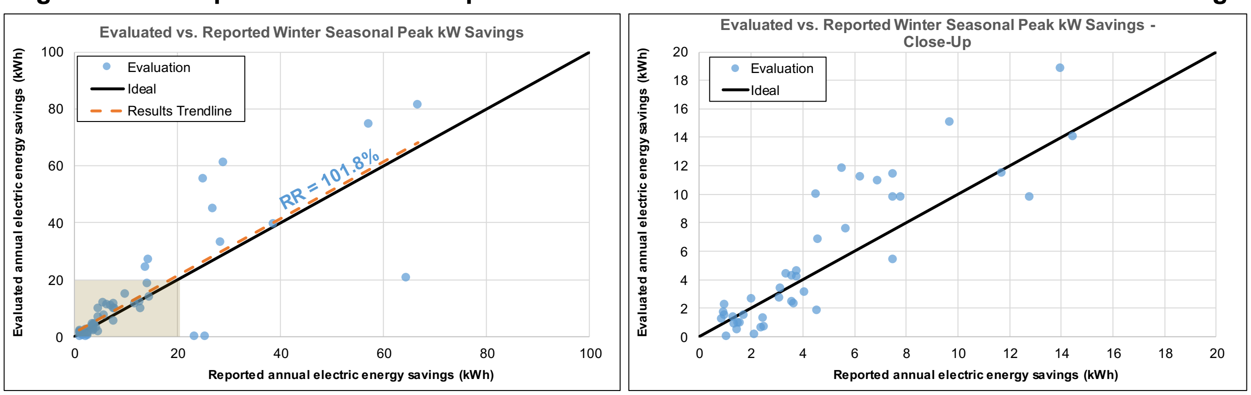


Figure 4-3. Comparison of SBEA Reported and Evaluated Winter Seasonal Peak Demand Savings



Figures 4-2 and 4-3 illustrate that most of the large-saving 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 114% and 102%, respectively.

4.1.1 Lighting vs. Non-Lighting Measures

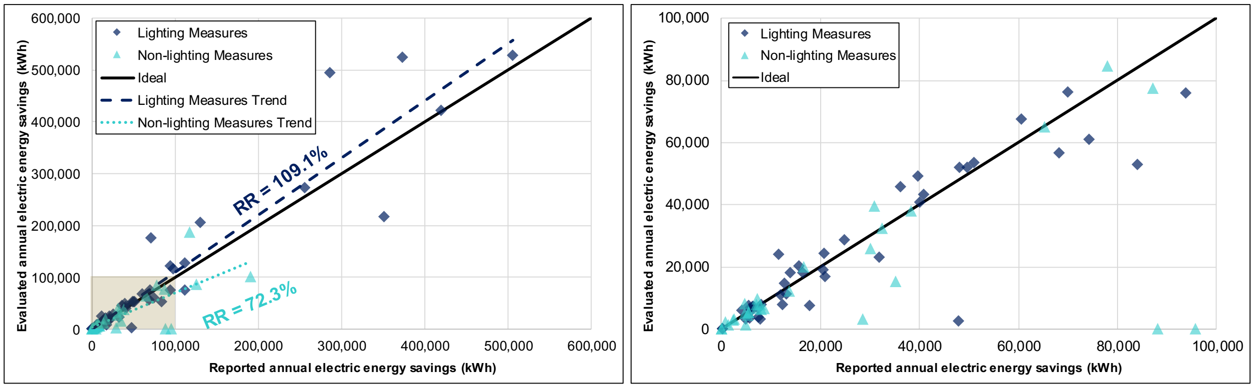
Lighting measures accounted for 90% of SBEA electric energy savings over the evaluation time frame; therefore, lighting measures—both fixture upgrades and automatic lighting controls installations—were a focus of this study. When designing the sample, ERS grouped the electric project population into two segments—lighting-only projects and projects that included at least one non-lighting measure—to ensure representation (and even oversampling) of non-lighting measures in the sample. Segment-level results can be found in Appendix C, but as lighting measures were assessed by the evaluators in all sampled electric projects, the RRs do not vary greatly between the two segments.

Isolating and comparing lighting and non-lighting evaluation results reveals that the program had more difficulty with predicting non-lighting savings. Table 4-3 and Figure 4-4 compare the reported and evaluated electric savings for lighting and non-lighting measure groups. The right-hand figure is a close-up of the left-hand figure's shaded area.

Table 4-3. Comparison of RRs between Lighting and Non-Lighting Measure Groups

Measure Group	Savings Metric	Total Reported Savings	Total Evaluated Savings	Evaluated Gross RR
Lighting measures	Annual energy savings (kWh)	96,971,765	105,820,670	1.09
	Summer on-peak demand savings (kW)	13,672	17,078	1.25
	Summer seasonal demand savings (kW)	13,672	16,213	1.19
	Winter on-peak demand savings (kW)	14,490	15,297	1.06
	Winter seasonal demand savings (kW)	14,490	15,703	1.08
Non-lighting measures	Annual energy savings (kWh)	11,547,109	8,351,639	0.72
	Summer on-peak demand savings (kW)	1,170	984	0.84
	Summer seasonal demand savings (kW)	1,170	998	0.85
	Winter on-peak demand savings (kW)	732	538	0.73
	Winter seasonal demand savings (kW)	732	532	0.73

Figure 4-4. Comparison of Site-Level Electric Energy Results: Lighting vs. Non-Lighting Measures



Lighting measure RRs exceeded one, to a greater degree than the overall electric RRs, indicating that the SBEA is saving more electric energy and peak demand from lighting measures than anticipated. However, non-lighting measure RRs were significantly lower than lighting RRs—34% lower in the case of electric energy. Non-lighting measures prevalent in the evaluation sample included refrigeration equipment or controls (21 projects), vending machine controls (7), motors/variable frequency drives (5), and energy management systems (5). Savings from such measures are generally more difficult to predict than lighting measures, as their performance is often more influenced by facility-specific conditions. As detailed in the next section, differences in quantity and operating hours were the key contributors to the 72% RR for electric energy. Due to the approximate nine-to-one ratio of lighting savings to non-lighting in the evaluation population, overall electric RRs ended up higher than one, despite the markedly lower non-lighting RRs.

4.1.2 Key Differences Influencing the Electric Realization Rates

To best inform evaluation conclusions and program recommendations, the evaluators next investigated the key reasons that evaluated electric savings differed from tracking savings. All contributing factors were grouped into the five categories defined in Section 3.3.5. While only electric energy is examined in the tables following, summer and winter seasonal peak demand discrepancies are examined in Appendix D.

The overall electric energy RR did not deviate significantly from one (103%), but, as illustrated in Figure 4-5, various factors somewhat cancelled each other out to produce slightly higher evaluated kWh savings overall. Section 3.3.5 describes the discrepancy categories.

Figure 4-5. Key Drivers behind Overall Electric Energy RR

Discrepancy Category	Negative Impact		Positive Impact		Overall	
	# Instances	Impact on RR	Impact on RR	# Instances	Impact on RR	# Instances
Documentation	20	-1.2%	4.7%	28	3.5%	48
Technology	13	-0.4%	1.2%	30	0.7%	43
Quantity	7	-3.0%	0.0%	3	-3.0%	10
Operation	28	-9.2%	12.3%	26	3.1%	54
HVAC Interactivity	35	-2.9%	1.1%	16	-1.8%	51
Total	**103**	**-16.6%**	**19.2%**	**103**	**2.6%**	**206**

To explain the contributing factors further, the evaluators delved deeper into the electric sample's segmentation. Lighting measures comprise 90% of the population's kWh savings and were isolated in the results of Table 4-3; the key drivers behind the lighting kWh RR (109%) are illustrated in Figure 4-6.

Figure 4-6. Key Drivers behind Lighting-Only Electric Energy RR

Discrepancy Category	Negative Impact		Positive Impact		Overall	
	# Instances	Impact on RR	Impact on RR	# Instances	Impact on RR	# Instances
Documentation	19	-1.4%	5.0%	29	3.6%	48
Technology	12	-0.5%	1.3%	30	0.8%	42
Quantity	4	-1.2%	0.0%	3	-1.2%	7
Operation	26	-6.9%	15.3%	28	8.5%	54
HVAC Interactivity	38	-3.6%	1.1%	13	-2.5%	51
Total	**99**	**-13.6%**	**22.8%**	**103**	**9.1%**	**202**

Selected discrepancy categories are examined further with site-specific anecdotes:

- Differences in **operation** were the highest contributor to the 109% lighting kWh RR, overall and on positive and negative sides. This finding is not unusual for a direct-install program referencing estimated lighting operating hours. Examples of high-impact spaces with higher lighting operating hours measured by the evaluators include: lobbies/hallways (42% higher weighted average operating hours than claimed), exterior (20% higher), and warehouse (5% higher).
- Differences due to **documentation** was the next highest contributor. For 295 out of 1,846 (16%) sampled lighting measures, the evaluators found that the tracked savings did not reflect the PSD algorithm paired with the tracked measure characteristics such as quantity, wattage, operating hours, and coincidence factor. Such deviations from the PSD's formula or recommendations could not be further pinpointed and were classified in the documentation category.

- The evaluators determined lower levels of **HVAC interactive** savings than reported by the program. Using the PSD's HVAC interactivity formula with inputs of facility square footage and HVAC coefficient of performance, the evaluators calculated a weighted average cooling kWh interactivity factor of 4.6%, compared to the 11.8% value backed out from tracking data. The evaluation analysis incorporated actual lighting metered data and typical weather data to determine full-load cooling hours for the upgraded fixtures; the derivation of reported HVAC interactive savings was not clear from the tracking data.

Though non-lighting measures comprise only 10% of total program kWh savings, the makeup of their RR (72%) provides an interesting comparative breakdown, as illustrated in Figure 4-7.

Figure 4-7. Key Drivers behind Non-Lighting Electric Energy RR

Discrepancy Category	Negative Impact		Positive Impact		Overall	
	# Instances	Impact on RR	Impact on RR	# Instances	Impact on RR	# Instances
Documentation	3	-0.1%	3.3%	9	3.1%	12
Technology	2	-0.1%	0.4%	2	0.3%	4
Quantity	5	-11.0%	0.0%	0	-11.0%	5
Operation	15	-26.5%	4.8%	6	-21.7%	21
HVAC Interactivity	0	0.0%	1.6%	8	1.6%	8
Total	**25**	**-37.7%**	**10.0%**	**25**	**-27.7%**	**50**

Selected categories are examined further with site-specific anecdotes:

- Differences in **operation** contributed most to the non-lighting kWh RR. Non-lighting measures included several controls measures that were either found by the evaluators to be no longer installed or observed to operate differently than expected. Examples include vending machine controls projects with zero evaluated savings due to overridden controls (two projects) or vending machines no longer present (three), as well as three EMS projects not operating as intended in the project documents, one of which led to zero electric savings. Savings from EMS measures, in particular, are difficult to predict prescriptively, but the evaluators found instances of unusually high tracking savings claims. For example, one sampled EMS project claimed approximately 120% of the facility's total cooling load evident in monthly utility bills; such discrepancies were typically classified as operational.
- Some non-lighting measures were found to no longer be installed, as reflected by five instances of the **quantity** discrepancy: three vending machine controls projects for which the controls or the vending machines themselves were no longer installed; an EMS originally intended to control 30 rooftop units (RTUs) but found to only control 3 RTUs, as others had been replaced and were now controlled by a different system; and an HVAC

upgrade for which only two of three installed units were currently serving conditioned spaces.

Further examination of differences in summer and winter peak kW RRs, for lighting and non-lighting and overall, can be found in Appendix D. Key findings on peak demand savings discrepancies include:

- The evaluators found 41 instances of improper documentation that led to more summer peak savings than anticipated by the program. Specifically, of the 1,846 lighting measures assessed in this study, the evaluators found 234 instances of fixture upgrades that led to actual summer peak savings but claimed zero summer peak savings in the tracking data.
- Seven instances of incorrect tracking increased the seasonal winter peak RR by 3%. The evaluators found instances of refrigeration measures listed in the tracking database, verified as installed and operable, but not claiming any reported winter peak kW savings.
- HVAC interactive savings were not appropriately claimed for some lighting and refrigeration measures. For lighting, the evaluators calculated a higher summer peak kW interactivity factor, on average, than that recommended in the PSD. For refrigeration, the evaluators found that interactive impacts were not properly accounted for within tracking savings for six sampled projects, resulting in an underestimation of the refrigeration measures' true savings

4.2 Natural Gas Results

For the first time in the SBEA program's history, natural gas savings were evaluated at the same statistical and engineering rigor used for electric savings. Table 4-4 provides the impact evaluation results, by sampling segment and overall, for the SBEA projects claiming natural gas savings during program years 2013, 2014, and 2015.

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

Segment	Total Reported Savings (MMBtu)	Total Evaluated Savings (MMBtu)	Evaluated Gross RR	Relative Precision
Space heating only projects	26,161	16,611	0.63	19.6%
Space heating + DHW projects	5,039	5,866	1.16	37.4%
Other projects	5,875	5,667	0.96	18.9%
Total	**37,075**	**28,404**	**0.77**	**17.4%**

The evaluators determined a gross RR of 76.6%, at a relative precision of ±17.4% at the 90% confidence interval, for annual natural gas savings. Table 4-4 indicates that the program is saving less natural gas than anticipated, by 23%, and the higher-than-anticipated relative precision value also illustrates higher variability than expected in the sample design[24] described in Section 3.1.

Figure 4-8 further illustrates this unanticipated variability by comparing the reported and evaluated annual MMBtu savings among the sample of SBEA projects studied. Again, the ideal project performance is represented by a solid black line on the charts, and the right-hand figure illustrates a close-up of the shaded portion of the left-hand figure.

Figure 4-8. Comparison of SBEA Reported and Evaluated Natural Gas Savings

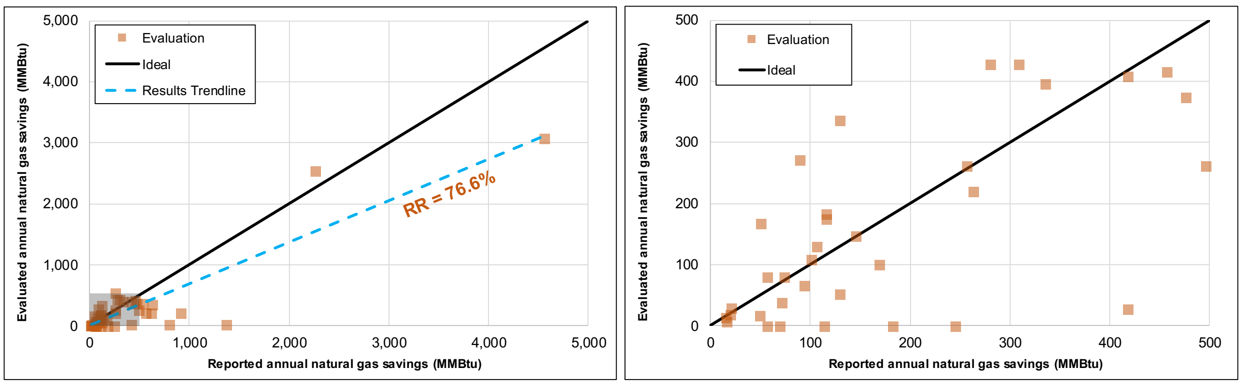


Figure 4-8 illustrates how the natural gas savings were dominated by two extremely large savers, one of which performed near ideal, with the other performing similarly to the overall RR. Zooming in on the left-hand scatter, the right-hand plot reveals a high variability in the performance of small- and medium-saver projects. Five out of 45 projects were found to produce zero savings, and more than half of the small/medium projects deviated considerably (by more than 45% of reported savings) from the ideal line. Appendix F provides a summary and a brief explanation of project-level RRs for all sites in the sample.

4.2.1 Key Differences Influencing the Natural Gas Realization Rate

The evaluators investigated the key contributing factors leading to a 77% RR for natural gas savings, as illustrated by Figure 4-9.

[24]Without prior SBEA gas evaluation results, evaluators could not reference a program-specific error ratio to inform the sample design, and an industry-standard error ratio of 0.60 was therefore assumed. The results of Table 4-4 reflect an actual error ratio of 0.75.

Figure 4-9. Key Drivers behind Overall Natural Gas RR

Discrepancy Category	Negative Impact		Positive Impact		Overall	
	# Instances	Impact on RR	Impact on RR	# Instances	Impact on RR	# Instances
Documentation	13	-7.7%	3.8%	11	-3.9%	24
Technology	4	-0.7%	0.5%	3	-0.2%	7
Quantity	6	-0.8%	0.1%	2	-0.7%	8
Operation	27	-29.5%	11.0%	14	-18.5%	41
HVAC Interactivity	1	-0.2%	0.0%	0	-0.2%	1
Total	**51**	**-38.8%**	**15.5%**	**30**	**-23.4%**	**81**

Selected categories are examined further with site-specific anecdotes:

- Similar to non-lighting electric measures, gas measures were influenced by facility-specific **operation** typically unknown during project implementation but confirmed by the evaluators, often through M&V. The highest-impact differences in operation among the evaluation sample each involved energy management system (EMS) measures. The evaluators often found differences between the systems' actual control strategies and those documented in project files. In two cases, the evaluators found unusually high savings claims (e.g., 30%–50% of pre-project billed natural gas consumption) that were disproven through evaluator analysis of equipment performance data and/or utility bills.
- Differences in **documentation** also resulted in a 4% reduction to the RR, with contributors on both positive and negative sides. Most examples involved mismatches between savings values in project documents, tracking savings values, and/or the deemed savings recommended by the PSD.
- Finally, although differences in **quantity** led to less than a 1% reduction in RR, one site-specific example illustrates the challenges of identifying appropriate non-lighting measures for small businesses. A participating country club received a suite of lighting measures in addition to 146 faucet aerators throughout the facility. During the on-site visit, the evaluators found that all 146 aerators were removed and replaced with a less-efficient alternative shortly after the project, as the rebated aerators generated several complaints from club members. A larger customer not in a direct install program model may have been able to test such fixtures before wholesale installation.

Appendix D examines the natural gas discrepancies by sample segment.

4.3 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 SBEA program.

4.3.1 Results by Utility

While the evaluation sample was designed to achieve statistically significant results on electric and natural gas savings overall, the evaluators further segmented the results of the 99 sampled projects to ascertain other performance patterns. Eversource and UI separately issue SBEA implementation contracts, but there is significant overlap between their approved contractor pools, and both utilities follow the same program guidelines. Therefore, it is worthwhile to compare the evaluation results by utility, as illustrated in Table 4-5. As Eversource accounted for approximately 80% of energy savings in Connecticut over the evaluation time frame, sampled Eversource projects outnumbered sampled UI projects by nearly a six-to-one ratio. Because of the small size of the UI sample, none of the differences can be considered statistically meaningful, although the differences in natural gas savings are suggestive. After comparing the gas results between the two utilities, the evaluators concluded that the difference in natural gas savings is likely explained by the measure mix. For example, the UI gas sample contained a greater share of difficult-to-predict EMS measures than the Eversource sample, but a lower share of space heating measures.

Table 4-5. Comparison of SBEA Reported and Evaluated Savings by Utility[1]

	2013–15 Eversource (n=84)			2014–15 UI (n=15)		
Savings Metric	Total Reported Savings	Total Evaluated Savings	Evaluated Gross RR	Total Reported Savings	Total Evaluated Savings	Evaluated Gross RR
Annual energy savings (kWh)	92,612,712	94,049,517	1.02	15,906,162	17,305,516	1.09
Summer on-peak demand savings (kW)	12,698	14,735	1.16	2,144	3,108	1.45
Summer seasonal demand savings (kW)	12,698	13,862	1.09	2,144	3,358	1.57
Winter on-peak demand savings (kW)	12,938	12,954	1.00	2,283	2,480	1.09
Winter seasonal demand savings (kW)	12,938	13,013	1.01	2,283	2,717	1.19
Natural gas savings (MMBtu)	29,157	24,554	0.84	7,918	4,202	0.53

[1]This data comprises 2013–15 Eversource activity and 2014–15 UI program activity.

Table 4-5 indicates that electric-saving projects sponsored by UI generally performed better than those sponsored by Eversource, particularly for summer peak demand savings. However, Eversource's natural gas-saving projects performed significantly better than UI's, by over 30 RR percentage points.

4.3.2 Statistical Results

Section 3.1 summarized the evaluators' assumptions in the sample design, including the error ratio, which represented a prediction of the variability of results. For electric savings, the error ratios referenced results from the prior (2014) SBEA impact evaluation; for gas, the evaluators assumed an error ratio of 0.6, as the SBEA had never evaluated gas measures previously. With this study's results, the evaluators can compare error ratio predictions with actual findings, as summarized in Table 4-6.

Table 4-6. Comparison of Predicted and Actual Error Ratios

Savings Type	Predicted Error Ratio	Actual Error Ratio
Electric energy	0.387	0.351
Lighting-only projects		0.210
Projects with non-lighting measure(s)		0.449
Summer on-peak demand	0.467	0.846
Lighting-only projects		1.082
Projects with non-lighting measure(s)		0.534
Summer seasonal peak demand	0.467	0.907
Lighting-only projects		1.197
Projects with non-lighting measure(s)		0.480
Winter on-peak demand	0.874	0.652
Lighting-only projects		0.569
Projects with non-lighting measure(s)		0.740
Winter seasonal peak demand	0.874	0.627
Lighting-only projects		0.563
Projects with non-lighting measure(s)		0.694
Natural gas	0.600	0.752
Space heating-only projects		0.784
Space heating + DHW projects		0.671
Other projects		0.472

The evaluators generally found higher error ratios than predicted for the measures and elements that had been subject to less or no prior evaluation. The key electric energy error ratio was slightly better than predicted. The actual error ratios in Table 4-6 can be used to inform future SBEA impact evaluation sample designs.

4.4 Forward-Looking Realization Rates

The evaluators examined differences between the current (2017) version of the Connecticut PSD and the versions active at the time of most 2013–2015 project applications. For some measures included in the SBEA evaluation sample, the evaluators identified differences in algorithms and assumptions among the PSD versions. The objective of this exercise was to determine the evaluation results most relevant for programs moving forward, through the calculation of forward-looking realization rates (FRRs).

When differences in PSDs between the 2013 and 2017 iterations were encountered, the evaluators adjusted the project-level reported savings to reflect the current PSD algorithm and assumptions. The project-level results were then re-aggregated using the same case weights to produce program-level FRRs. The results of the FRR analysis are compared to the evaluation RRs in Table 4-7.

Table 4-7. Comparison of Evaluation RRs with Forward-Looking RRs

Savings Metric	Evaluated Gross RR	Forward-Looking RR
Electric energy	1.03	1.03
Summer on-peak demand	1.19	1.19
Summer seasonal demand	1.14	1.14
Winter on-peak demand	1.02	1.02
Winter seasonal demand	1.04	1.04
Natural gas energy	0.77	0.78

As is evident in Table 4-7, only the natural gas FRR differed from the evaluated gross RR, and by only one percentage point. The evaluators determined that PSD recommendations changed for six measures between 2013 and 2017: unitary A/Cs and heat pumps, boilers and furnaces, DHW heaters, steam traps, HVAC VFDs, and vending machine controls. However, upon investigating the reported savings calculations among all projects containing those measures, the evaluators found that the reported savings algorithm and assumptions matched the 2017 PSD for all sampled projects with unitary A/C, heat pump, DHW heater, HVAC VFD, and vending machine measures. Only projects with boiler, furnace, or steam trap measures—all gas measures—required adjustment in the FRR calculation. Therefore, for electric savings, including both lighting and non-lighting measures, the FRRs are identical to the evaluated gross RRs.

Appendix E contains additional measure-by-measure details on the FRR calculation.

4.5 Comparison of Evaluation Results with PSD Recommendations

The Connecticut PSD recommends algorithms, parameters, and/or deemed savings for nearly all measures offered by the SBEA program. The PSD's recommendations are updated annually to reflect new measures, findings, and studies, and our FRR analysis indicates that the SBEA program adopts new PSD recommendations in a timely manner. While revision of the PSD was not in the scope of this study, ERS compared the evaluation results for two measures—lighting and boilers—with PSD recommendations to identify opportunities for further research or pooling with other data for possible updates in future iterations of the PSD.

4.5.1 Lighting

The primary contributor to the lighting RRs was differences in hours of operation and peak coincidence factor (CF) between evaluator measurements and PSD assumptions. Table 4-8 examines these differences among five prevalent building types in the evaluation sample.

Table 4-8. Comparison of Evaluated Lighting Operation with PSD Assumptions

Facility Type (Sampled Project Count)	2017 Connecticut PSD			Evaluation Results (Weighted by kW)		
	Annual Operating Hours	Summer Peak CF	Winter Peak CF	Annual Operating Hours	Summer Peak CF	Winter Peak CF
Restaurant (n=9)	4,182	0.78	0.64	4,471	0.51	0.72
Office (n=7)	3,748	0.70	0.54	1,826	0.53	0.22
Manufacturing (n=5)	2,857	0.67	0.43	4,567	0.84	0.68
Medical (n=4)	3,748	0.74	0.62	4,557	0.75	0.70
Other[1] (n=16)	N/A	0.48	0.43	5,483	0.65	0.68

[1]Prevalent "other" building types in the sample included country clubs, municipal buildings, and nursing homes.

The evaluation results show varying levels of agreement with the PSD assumptions. Lighting operation at restaurants and medical facilities generally aligned with the PSD assumptions, but the evaluation results differed from the PSD for lighting fixtures at office and manufacturing facilities.

Because the evaluation sample was not designed to achieve statistical significance on lighting operating hours by building type, the evaluation team does not recommend revision of the PSD with this study's findings. However, should the PSD's lighting operating hours be revised in future iterations, we recommend pooling this study's results with other Connecticut-specific research to strengthen the overall data set.

4.5.2 Condensing Boilers

The evaluation sample included 18 projects with space heating measures, many of which involved an upgrade to higher-efficiency condensing boilers. For safely accessible and measurable boilers, and in particular for projects for which gas bills were unavailable or savings represented less than 10% of the annual billed consumption, the evaluators metered the combustion air fan amperage to determine annual full-load operating hours (FLH) values after correlation with weather conditions. The evaluators metered boilers at seven such projects. When possible, the evaluators also metered the return water temperature of the heating hot water distribution piping to calculate the average boiler efficiency based on manufacturer performance data. Differences in operating conditions was the leading driver of the lower gas RR; Table 4-9 examines differences in FLH and condensing boiler efficiency between the evaluators' findings and the PSD's recommendations.

Table 4-9. Comparison of Evaluated Condensing Boiler Operation with PSD Assumptions

Parameter	Count of Metered Projects	2017 PSD Average	Evaluation Results (Weighted by Boiler Size)
Annual full-load hours	7	1,262	1,883
Boiler efficiency	5	95.0%	89.8%

The evaluators found that rebated condensing boilers operate 49% more hours per year than assumed by the program, increasing savings, but operate with only 60% of the expected efficiency gain due to lower efficiency as a consequence of higher-than-anticipated return water temperature. The latter difference more than offsets the former. Again, as the evaluation sample was not designed to produce statistically significant operating data for condensing boilers, we recommend that these findings be pooled with other Connecticut-specific research if the condensing boiler measure is updated in future PSDs.

5 Conclusions and Recommendations

This section highlights the study's major findings and concludes with nine recommendations to improve the SBEA program moving forward. Table 5-1 summarizes the impact evaluation results from this study.

Table 5-1. SBEA Impact Evaluation Results: Electric and Natural Gas Savings

Metric	Total Reported Savings	Total Evaluated Savings	Evaluated Gross RR	Relative Precision
Annual electric energy savings (kWh)	108,518,874	111,360,123	1.03	8.0%
Summer on-peak demand savings (kW)	14,842	17,616	1.19	10.1%
Summer seasonal demand savings (kW)	14,842	16,847	1.14	10.5%
Winter on-peak demand savings (kW)	15,222	15,491	1.02	9.1%
Winter seasonal demand savings (kW)	15,222	15,853	1.04	8.9%
Annual natural gas savings (MMBtu)	37,075	28,404	0.77	17.4%

ERS analyzed the SBEA program's achieved electric and natural gas savings among a sample of 99 projects completed between 2013 and 2015. During this effort, the evaluation team also identified opportunities to improve program effectiveness and savings estimation in the future, in hopes of narrowing the variation in RRs. The conclusions and recommendations are as follows:

- **Conclusion 1** – The SBEA Program generates significant energy and peak demand savings, as is evident in Table 5-1. The evaluators determined higher levels of total electric energy and peak demand savings than anticipated by the program. However, the evaluators determined 23% lower natural gas savings than reported by the program, mostly due to differences in equipment operation unforeseen by the PSD's recommendations. Lighting measures remain a focus of the SBEA program, accounting for 90% of electric energy savings; the evaluators determined that the program saves 9% more electric energy and 19% more summer seasonal peak demand from such measures than anticipated by the program. Non-lighting measures did not perform as well, saving 28% less electric energy than anticipated by the program.
- **Conclusion 2** – The Connecticut PSD provides reliable and cost-effective savings estimates for many measures offered by the SBEA, including lighting, refrigeration, packaged HVAC, boiler, and DHW measures. Overall, RRs for projects with such measures generally did not deviate significantly from one. Non-lighting measures, which represented about 19% of the program's total energy savings, proved more difficult to predict than lighting measures and resulted in RRs significantly lower than the lighting

RRs. An objective of this impact evaluation was to compare the PSD's measure algorithms and assumptions with the evaluation findings and to subsequently provide recommendations to improve the PSD. However, given the evaluation results and key drivers of the RRs—in general, reductions in savings were most typically due to unanticipated, site-specific characteristics, such as overridden setpoints or hours of use—the evaluators do not recommend measure-level changes to the PSD at this time.

- **Conclusion 3** – ERS observed variation in the estimates of lighting fixture wattages among the SBEA contractors. In particular, the preexisting fixtures upgraded by the SBEA—typically linear fluorescents—featured ballasts that convert most, but not all, electric energy to illumination. This ballast inefficiency is captured by a fixture wattage value that is often higher than the total wattage of the lamp(s). It was not clear if ballast wattage was factored in to the vendor's estimates. Based on ERS's review of project files supplied by program administrators, the contractors' derivation of fixture wattages was often unclear and sometimes varied from contractor to contractor.
  - **Recommendation 1** – The Connecticut PSD should be enhanced to include a Connecticut-specific fixture wattage table that encompasses all lighting technologies typically installed or removed through program activity. This fixture wattage standard would eliminate variation among SBEA contractor assumptions. Such a fixture wattage table is prevalent among many states' technical reference manuals, including those for Massachusetts, New York, and Pennsylvania. The lighting market is evolving rapidly with the emergence of cost-effective LED tubes, and so the fixture wattage table should be revisited annually with each iteration of the PSD.
- **Conclusion 4** – In order to develop evaluation results most relevant to the program moving forward, ERS examined changes in the PSD from 2013 to the present and found that only three measures have undergone changes that affect the FRR for natural gas. The evaluators found no changes for electric measures. Presuming that the measure mix and other non-PSD considerations remain constant in the future compared to the 2013–2017 program years, the slightly lower reported savings from mapping to the 2017 PSD leads to an increase in the gas FRR by 1% compared to the evaluation's retrospective RR.
  - **Recommendation 2** – For electric projects, evaluation results and RRs are directly applicable to SBEA participants moving forward. For natural gas projects, the program should apply a 78% RR, not a 77% RR, moving forward.

- **Conclusion 5** – While lighting measures are a focus of the SBEA program, non-lighting measures comprise approximately 19% of reported site energy savings on a Btu basis. The performance of non-lighting measures is difficult to predict prescriptively, as facility-specific characteristics often influence the actual savings. The evaluators found that non-lighting measures saved 28% and 23% less electric energy and natural gas, respectively, than anticipated by the program. Non-lighting measures such as EMSs and vending machine controls were sometimes found by the evaluators not to be installed at all or to be overridden or not functioning as intended, in some cases due to lack of customer training, awareness, or desire for the measure in the first place. For five sampled condensing boiler measures, the evaluators found higher return water temperatures that led to lower operating efficiencies, perhaps due to oversizing. Such savings discrepancies appear to be driven more by incomplete implementation than by overly optimistic savings estimates.
  - **Recommendation 3** – To diversify and expand program offerings, and to maximize savings, the SBEA should invest in contractor training to appropriately identify non-lighting measures, educate customers on their operation, and inform those customers of the benefits of high-efficiency equipment when maintained. Non-lighting measures should be a core objective for the program and its contractors. The most recent SBEA process evaluation,[25] completed in parallel with this impact study, provided a similar recommendation on recruiting and training contractors to be qualified to identify and sell non-lighting measures among small business tenants and building owners. Such training will proactively prepare the program for the future landscape of Connecticut small businesses, among which the natural penetration of LED lighting technology is expected to grow and offer fewer opportunities for lighting savings. Contractor training will also lead to higher savings per incentive dollar, particularly for HVAC measures that benefit from quality installation and right-sizing. In the case of condensing boilers, training both contractors and customers on the importance of low return water temperature is critical to achieving and maintaining expected savings, and is a training topic area of need that ERS has identified in multiple states.

[25] "C1639: Process Evaluation of the Connecticut Small Business Energy Advantage (SBEA) Program," June 2017, page IV. https://www.energizect.com/sites/default/files/C1639_SBEA%20Process%20Evaluation%20Report__Final_6.30.17.pdf

- **Conclusion 6** – The evaluators experienced difficulties in obtaining sufficient and reliable utility billing data to conduct a program-wide analysis of natural gas savings. The evaluators could not obtain gas billing data for 41% of the program participants over the evaluation time frame. This unfulfilled request led the evaluators to forgo a planned program-wide billing analysis approach for all program participants, not just those in the sample. After a second billing data request among 10 gas projects in the sample for which the data was particularly desired, the evaluators could not collect reliable sets of pre-project and post-project utility billing data to undertake a site-specific billing analysis or calibration of the engineering model. As a result, among these 10 projects, the evaluators were forced to employ an alternative analysis approach, often at a lower evaluation rigor. In some cases, particularly for one utility, basic billing data was not available from their billing system due to recent combinations of systems from multiple companies, while some facilities featured complex utility account configurations that complicated their potential for billing analysis.
  - **Recommendation 4** – The program should better associate utility account numbers and archive utility billing data for participating SBEA customers, starting at least a year prior to the program application date. This archive will potentially allow for a program-wide billing analysis approach for evaluating natural gas savings, which could be worth exploring as a more economical approach than site-specific M&V. At the very least, more extensive billing data will bolster site-specific analysis, through pre-/post-retrofit comparison and/or calibration of engineering models with actual consumption data. When processing natural gas applications, the SBEA program and its contractors should more diligently establish protocols for assigning tenant-specific gas usage from master-metered or shared natural gas accounts.
- **Conclusion 7** – Similarly, for an estimated 30% of projects in the sample, the evaluators had difficulties in obtaining sufficient project files from the utilities in a timely manner or at all. Multiple project file requests were submitted throughout the evaluation to attempt to fill these data gaps. This lack of project information, particularly basic installation information and savings calculations, inhibited the evaluators from familiarizing themselves on the project scopes, developing M&V plans, and identifying detailed discrepancies for explaining the site-level RRs. The evaluators learned that utilities discard key project files, such as post-installation inspection reports, after 12 months have passed since project closeout. These difficulties were experienced with each utility.

- ➢ **Recommendation 5** – The utilities should adopt a more comprehensive method to digitally archive any relevant project files, such as pre- and post-installation inspection reports, particularly for non-lighting measures. These systems will provide more transparency and will allow the utilities to more quickly and cost-effectively deliver project files in future evaluations. The savings calculations for all non-lighting projects should be reviewed by company technical staff and archived in a central place available to all for later review.

- ❑ **Conclusion 8** – The SBEA program's lighting installations often claimed HVAC interactive savings that differed from evaluator findings, claiming interactivity for only 63% of the tracked lighting measures compared to the evaluators' 83%, thereby underclaiming interactive effects. But in some instances the SBEA claimed HVAC interactive savings for lighting fixtures found by the evaluators in spaces not mechanically cooled, such as basements and mechanical rooms. Overall, these two effects led to a 3% reduction in kWh RR for lighting measures.

  - ➢ **Recommendation 6** – The program's administrators and implementers should uniformly assess each lighting measure for potential HVAC interactivity and, through improved screening and inspection protocols, only claim interactive HVAC savings for fixtures installed in conditioned spaces. This recommendation is consistent with the prior impact evaluation's recommendation #5.

- ❑ **Conclusion 9** – The evaluators found three instances of unrealistically high savings percentages claimed by reported measures. For example, a sampled gas project with only one measure, an EMS, claimed savings that reflected a 54% reduction in pre-project gas consumption at the facility. In another example, a sampled electric project included an EMS measure that claimed reported savings representing approximately 120% of the facility's cooling kWh evident in its monthly billing data.

  - ➢ **Recommendation 7** – For high-savings projects and/or those with complex measures such as EMSs, the SBEA program administrators and implementers should cross-reference at least the most recent year of monthly utility bill data to "sanity check" savings before reporting. If savings are above a certain percentage of annual usage they should be reviewed by program administrator technical staff. The billing data archive recommendation complements this one.

Appendix A: Evaluation Methods

This appendix supplements the evaluation methodology overview provided in Section 3.

A.1 Performance Measurement

ERS's typical metering approach by measure category is illustrated in Table A-1 and further described in the paragraphs following.

Table A-1. Most Prevalent M&V Methods by Measure Category

Measure Category	IPMVP Option A	IPMVP Option B	IPMVP Option C	Verification
Interior lighting	✓			
Exterior lighting		✓		
Packaged cooling		✓		
Energy management system (EMS)			✓	✓
Refrigeration		✓		✓
Motor/variable frequency drive (VFD)		✓		
Space heating: boilers		✓	✓	✓
Space heating: furnaces			✓	✓
Domestic hot water (DHW) fixtures				✓

Summaries of the IPMVP options and their applicability to SBEA measures are provided below.

IPMVP Option A: Partially Measured Retrofit Isolation – For SBEA projects impacting interior lighting fixtures, ERS field engineers deployed a sample of lighting on/off loggers to ascertain the run time and peak coincidence of upgraded lighting fixtures. Option A data logging typically lasted 6–8 weeks. Other parameters impacting the lighting energy savings equation, such as fixture wattage, were stipulated based on our on-site inspection and inventory.

IPMVP Option B: Retrofit Isolation – With the assistance of licensed electricians, evaluators deployed current transformers (CTs) with HOBO data loggers within the electrical panels powering key equipment impacted by the project. Option B data logging typically lasted 6–8 weeks and was used for projects with HVAC, motor/VFD, exterior lighting, and/or refrigeration measures.

- **IPMVP Option C: Whole Facility** – The evaluators employed an analysis of utility billing data for projects that met one or more of the following conditions: (1) reported impacts constituted at least 5% of the pre-project annual consumption; (2) no other projects or occupancy fluctuations that might impact the billed consumption occurred at the facility in the pre/post billing period; (3) equipment affected by the project could not be economically metered; (4) the project featured multiple interactive measures; and (5) the pre- and post-project utility bills demonstrated a strong correlation with logical independent variables such as cooling degree days, heating degree days, or facility production data.
- **Verification** – For projects with inaccessible or unmeasurable equipment, or for measures that constituted a low percentage of the project or program total energy savings, the evaluators collected relevant information as summarized in Section 3.2.2, reviewed the ex ante analysis for compliance with the Connecticut PSD, and updated the savings algorithm with revised parameters.

A.2 Measurement & Verification and Analysis Approach by Measure

Table A-2 addresses ERS's ideal M&V and analysis approach for three example non-lighting measure groups. Note that, in some cases, ERS field engineers were not able to execute this ideal approach due to on-site circumstances or unfavorable weather conditions. Site-specific methodology can be found in Appendix G.

Table A-2. Evaluation Approach for Other Non-Lighting Electric Measures

Measure Category	Prevalent Measures	M&V and Analysis Approach
Refrigeration	Electronically commutated motors (ECMs) for evaporator fans Advanced evaporator fan controls Automatic door heater controls	Disassemble the impacted refrigeration case. Attempt to isolate the affected electrical circuit(s) (typically fan motors and/or door heater). Deploy a low-amperage CT on the appropriate electrical circuit(s) if identifiable and safely accessible. In some cases, the impacted circuit(s) could not be isolated due to inaccessibility or vague wiring diagrams. For metered cases, analyze amperage data to determine the typical operating schedule. Assess potential dependencies on weather or schedule. Calculate coincidence factors and annual full-load hours from extrapolated profile. Revise PSD algorithm with verified system characteristics and measured hours and coincidence factors. For measures that could not be fully metered, update the PSD algorithm with project-specific information gathered during the site visit.
Motors/VFDs	VFD on supply or exhaust fans VFD on air compressor	Deploy a CT in the electrical panel serving the affected motor. Spot-measure the voltage, amperage, power factor, and wattage at time of deployment. After 4–6 weeks, retrieve CT(s) and repeat spot measurements. Analyze amperage data, assessing correlations with hourly outside air temperature (OAT) data and/or facility schedule. Calculate the motor load of impacted motors using manufacturer efficiency specifications and load factor estimates. Determine the baseline power requirement (preexisting or code-compliant unit(s) of comparable size) for delivering the same motor load. Calculate savings as the difference between the baseline energy usage and installed energy usage, extrapolated over a full year based on independent variable(s). For measures that could not be fully metered, update the PSD algorithm with project-specific information gathered during the site visit.

Measure Category	Prevalent Measures	M&V and Analysis Approach
Packaged cooling	High-efficiency rooftop units	When safely accessible, deploy CT(s) in the electrical panel serving the HVAC unit. Spot-measure the voltage, amperage, power factor, and wattage at time of deployment. In some cases, the HVAC units were not operating due to timing of the site visit (fall and winter, predominantly). For metered units, retrieve CT(s) and analyze amperage data, assessing correlations with hourly OAT data and/or facility schedule. Calculate the cooling load or operating hours of installed unit(s) using manufacturer efficiency specifications. Determine the baseline power requirement (preexisting or code-compliant unit(s) of comparable size) for supporting the same cooling load. Calculate the savings as the difference between the baseline energy usage and installed energy usage, extrapolated over a full year based on independent variable(s). For measures that could not be fully metered, update the PSD algorithm with project-specific information gathered during the site visit.

A.3 Site-Specific Billing Analysis

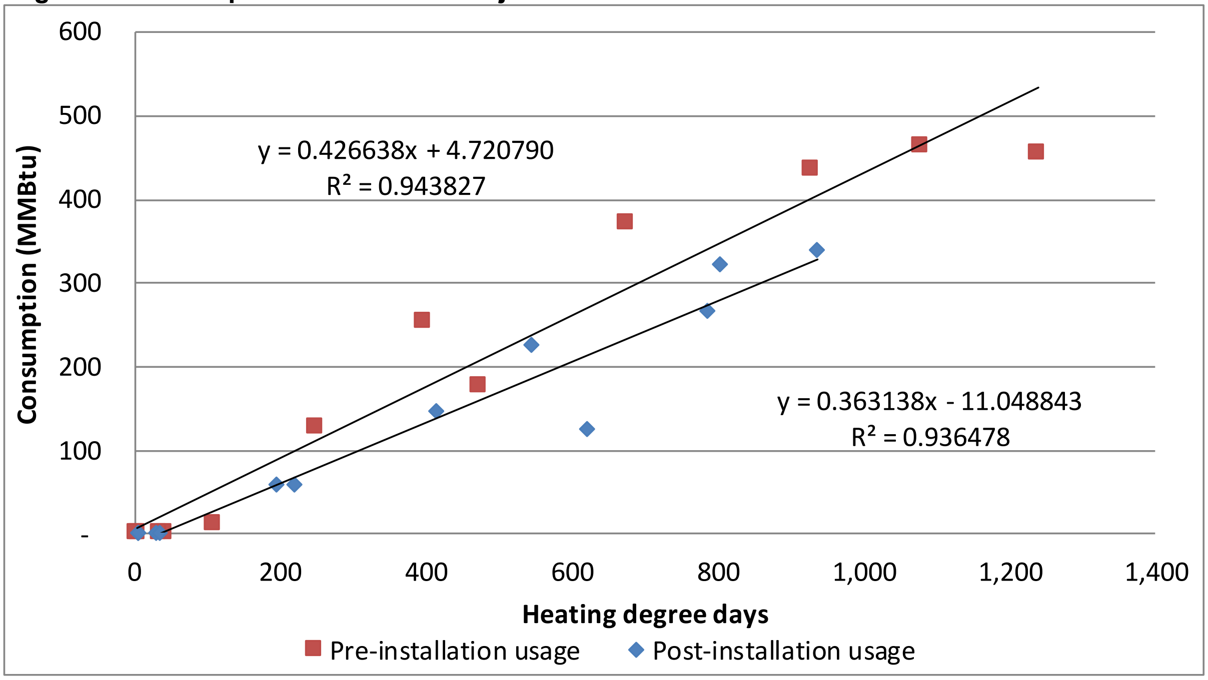
When it was appropriate, the evaluators employed an analysis of pre- and post-project utility consumption to assess the project savings. Typically, a simple comparison of the two sets of bills was not appropriate, as the independent variables governing consumption during the pre- and post-project periods (e.g., weather conditions) were often unequal. Therefore, the evaluators utilized a normalized billing analysis approach for fair calculation of project savings.

During the on-site inspection and subsequent analysis, ERS engineers determined which independent variable(s) affected the energy usage of the facility's impacted mechanical systems. Typically, for HVAC measures, this independent variable was weather conditions, quantified in the form of monthly degree days.[26] For example, a project that involves the installation of a high-efficiency boiler should demonstrate a clear reduction in normalized, facility-wide natural gas consumption. ERS's normalization process begins with a correlation of monthly gas

[26]Degree days measure how long (in days) and how different (in degrees) the OAT differs from a facility's "balance point," or the OAT at which cooling or heating systems are activated. Cooling degree days (CDD) and HDD are typically calculated using a balance point between 55°F and 65°F, depending on the facility type.

consumption with historical monthly heating degree days[27] (HDD) for pre- and post-project periods; pre-/post- correlations for an example boiler project are illustrated in Figure A-1.

Figure A-1. Example Pre- and Post-Project Correlations between Natural Gas MMBtu and HDD



Next, the typical monthly HDD were determined using typical meteorological year[28] (TMY) weather data for the weather station most proximate to the participating small business. The pre-/post- correlations were applied to the TMY HDD to determine normalized gas usage before and after the project. Project savings are therefore determined by subtracting the post-project normalized gas consumption from the pre-project normalized gas consumption. In this manner, the evaluators completed the billing analyses normalized to a variety of relevant independent variables, such as cooling degree days (CDD), HDD, and facility production data.

[27]Historical weather data was retrieved using National Oceanic and Atmospheric Administration (NOAA) hourly weather data for the weather station most proximate to the participating facility.

[28] TMY data reflects a 30-year collection of hourly weather data specifically selected to represent short-term weather patterns while still reflecting long-term monthly or annual averages at each weather station.

Appendix B: Seasonal Peak Savings Calculation

One objective of the SBEA impact evaluation is the assessment of peak savings using two different peak definitions, as stipulated by ISO New England: on-peak and seasonal peak. On-peak demand is defined strictly by month, day, and hour (see Section 3.3.4), but seasonal peak takes into account historical electric grid loading compared with a predicted system capacity. This appendix describes the evaluators' calculation of summer and winter seasonal peak demand savings.

B.1 Summer Seasonal Peak Demand Savings

The evaluators referenced the following data to calculate the summer seasonal peak demand savings:

- ❑ Actual hourly grid loading data from ISO New England for 2016[29]
- ❑ ISO New England peak load forecast for 2016[30]
- ❑ National Oceanic and Atmospheric Administration (NOAA) hourly Hartford historical weather data for 2016[31]
- ❑ Typical meteorological year (TMY3) data for Hartford[32]

The calculation method is explained in the following steps:

1. The evaluators identified the predicted seasonal peak estimate from the 2016 peak load forecast (b, above) as 27,081 kW. The seasonal peak definition considers any grid loading exceeding 90% of this forecasted maximum; therefore, any historical loading above 24,373 kW is considered in the analysis.
2. The hourly grid loading data (a) was filtered to reflect only the days considered in the ISO New England definition of seasonal peak: summer non-holiday weekdays in June, July, and August.

[29] https://www.iso-ne.com/static-assets/documents/2016/02/smd_hourly.xls

[30] https://www.iso-ne.com/isoexpress/web/reports/load-and-demand/-/tree/season-peak-hour-data

[31] https://www.ncdc.noaa.gov/cdo-web/datasets/LCD/stations/WBAN:14740/detail

[32] http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/data/tmy3/725080TYA.CSV

3. The evaluators identified 13 hours when historical grid loading exceeding 90% of the forecasted maximum: 1 hour on July 22, 6 hours on August 11, and 6 hours on August 12. These instances occurred between 1:00 p.m. and 7:00 p.m.
4. The evaluators therefore defined the hourly range of potential peak loading as between 1:00 p.m. and 7:00 p.m. on summer non-holiday weekdays in June, July, and August. Over these 455 hours in 2016, the evaluators correlated historical grid loading (in kW) with two weather-based variables that the ISO New England considers in peak forecasting:
   i. Total heat index (THI), which considers current temperature and dew point conditions, as follows:

$$THI = 0.5 \times DBT + 0.3 \times DPT + 15$$

   where,

   THI = Total heat index

   DBT = Dry-bulb temperature at a given hour (°F) per data source (c)

   DPT = Dew point temperature at a given hour (°F) per data source (c)

   ii. Weighted heat index (WHI), which considers current THI as well as THIs from the prior two days, as follows:

$$WHI = 0.59 \times THI_{di,hi} + 0.29 \times THI_{d(i-1),hi} + 0.12 \times THI_{d(i-2),hi}$$

   where,

   WHI = Weighted heat index

   $THI_{di,hi}$ = THI for a given day and hour

   $THI_{d(i-1),hi}$ = THI for the same hour, one day prior

   $THI_{d(i-2),hi}$ = THI for the same hour, two days prior

5. The correlation among hourly grid loading, THI, and WHI was then used to identify the minimum THI and WHI values that lead to a grid kW that exceeds 90% of the forecasted capacity. These thresholds were identified as THI = 81.3°F and WHI = 79.6°F.
6. Using TMY data (d), the evaluators next identified 19 hours in a typical year of Hartford weather during which the dry-bulb temperature and dew point at a given hour (as well as the prior two days' dry-bulb temperatures and dew points) were sufficiently high to cause the THI and WHI to exceed 81.3°F and 79.6°F, respectively. Only these hours were

considered in the calculation of summer seasonal peak savings for a given measure or project.

B.2 Winter Seasonal Peak Demand Savings

The calculation of winter seasonal peak closely resembled that of summer but in a more simplified manner. ISO New England forecasted the 2016 winter grid capacity as 21,055 kW, leading to a 90%-of-peak value of 18,950 kW. Winter seasonal peak is defined by nonholiday weekdays in December and January; examining actual 2016 data over these months, the evaluators identified 7 hours when the grid load exceeded 90% of the forecasted maximum. These hours encompassed 6:00 p.m. to 8:00 p.m. Considering only those hours, the evaluators developed a correlation between the actual grid loading and actual dry-bulb temperature from the data source (c); the correlation led to a dry-bulb threshold of 19.5°F. TMY data shows that Hartford’s temperature dips below this threshold nine times between 6:00 p.m. and 8:00 p.m. and between December and January in a typical year, and these 9 hours were considered in the calculation of winter seasonal peak savings.

Appendix C: Additional Results

This appendix supplements Section 4 with additional evaluation results.

C.1 Electric Results by Segment

In order to represent non-lighting electric measures in the evaluation sample, ERS segmented the population of 2013–15 electric projects into two groups: (1) lighting-only projects and (2) projects with at least one non-lighting measure. As lighting measures were included in over 99% of the projects in the population, all sampled electric projects contained at least one lighting measure. The results by each evaluation segment are presented in Table C-1.

Table C-1. Comparison of SBEA Reported and Evaluated Electric Savings by Sample Segment

Segment	Savings Metric	Total Reported Savings	Total Evaluated Savings	Evaluated Gross RR	Relative Precision
Lighting-only projects	Annual energy savings (kWh)	67,028,859	71,198,134	1.06	8.2%
	Summer on-peak demand savings (kW)	9,455	11,509	1.22	15.4%
	Summer seasonal demand savings (kW)	9,455	11,103	1.17	17.0%
	Winter on-peak demand savings (kW)	10,114	11,091	1.10	11.5%
	Winter seasonal demand savings (kW)	10,114	11,151	1.10	11.6%
Projects with non-lighting measure(s)	Annual energy savings (kWh)	41,490,014	41,024,157	0.99	14.3%
	Summer on-peak demand savings (kW)	5,387	6,220	1.15	13.4%
	Summer seasonal demand savings (kW)	5,387	5,890	1.09	12.2%
	Winter on-peak demand savings (kW)	5,107	4,643	0.91	13.6%
	Winter seasonal demand savings (kW)	5,107	4,890	0.96	12.9%

Lighting savings represented over 90% of the SBEA's total kWh savings overall, and, even within the second segment, lighting savings represented 72% of the total kWh. Therefore, it is not surprising that the two sampling segments featured similar results, with the lighting-only projects performing slightly better than the projects with at least one non-lighting measure. As non-lighting measures were found to be more difficult to predict than lighting measures (see Table 4-3 in the body of the report), results for the projects with non-lighting measure(s) were slightly less precise than the lighting-only projects' results.

C.2 Results by Measure Group

Next, the evaluators examined the results by whether the sampled project contained a prominent[33] measure group or not. While Table C-2's results are at the project level and do not isolate the specific measure's impacts,[34] they nonetheless indicate how certain measures contributed to the overall realization rates. Please note that, since lighting measure performance was assessed in Section 4.1.1, it is not addressed in Table C-2.

Table C-2. Examination of SBEA Project-Level Results by Measure Group

RRs for Projects with Measures	Refrigeration	EMS/ Thermostat	Space Heating	Low-Flow Devices
Project Count	**23**	**23**	**18**	**12**
Electric kWh	1.04	0.66		
Summer on-peak kW	1.38	1.03		
Summer seasonal kW	1.35	1.05		
Winter on-peak kW	1.13	0.85		
Winter seasonal kW	1.15	0.88		
Gas		0.57	0.90	1.09

Projects with EMS or thermostat measures performed markedly worse than sampled projects overall, particularly for electric or gas energy. EMS and thermostat measures most typically feature site-specific preexisting conditions as a baseline, thereby making prescriptive-savings estimations difficult.

On the other hand, refrigeration measures performed similar to sampled projects overall for kWh and markedly better for summer peak kW. Refrigeration equipment typically features low variability in performance and operating hours and is therefore conducive to prescriptive-savings estimations.

[33] Only non-lighting measures with 12 or more instances within the evaluation sample are examined in this section.

[34] As evaluation sampling, and in some cases site-specific analysis, occurred at the project level, evaluators could not determine credible measure-level findings from the project-level RRs. Instead, Table C-2 presents the project-level RRs organized for those projects containing prominent measure groups.

This appendix supplements Section 4 with additional analysis of the reasons behind the realization rates (RRs) for electric and natural gas savings. The evaluators grouped these reasons into five discrepancy categories, which are defined in Section 3.3.5.

D.1 Key Differences Influencing the Electric Demand Realization Rates

Section 4.1 examines the electric evaluation results as well as the key contributing factors behind the kWh RRs. In this section, we similarly examine contributing factors for the summer and winter seasonal peak kW RRs, starting with the overall summer seasonal peak kW in Figure D-1.

Figure D-1. Key Drivers Behind Overall Summer Seasonal Peak Demand RR

Discrepancy Category	Negative Impact		Positive Impact		Overall	
	# Instances	Impact on RR	Impact on RR	# Instances	Impact on RR	# Instances
Documentation	11	-4.2%	46.8%	43	42.7%	54
Technology	17	-0.6%	0.0%	8	-0.6%	25
Quantity	4	-1.1%	0.0%	3	-1.1%	7
Operation	37	-39.1%	8.0%	17	-31.0%	54
HVAC Interactivity	17	-2.3%	5.9%	33	3.6%	50
Total	**86**	**-47.3%**	**60.8%**	**104**	**13.5%**	**190**

To investigate the contributing factors further, we examined the lighting and non-lighting breakdowns in Figures D-2 and D-3.

Figure D-2. Key Drivers Behind Lighting Summer Seasonal Peak Demand RR

Discrepancy Category	Negative Impact		Positive Impact		Overall	
	# Instances	Impact on RR	Impact on RR	# Instances	Impact on RR	# Instances
Documentation	13	-5.0%	54.2%	41	49.2%	54
Technology	17	-0.7%	0.0%	8	-0.7%	25
Quantity	3	-1.3%	0.0%	3	-1.3%	6
Operation	37	-39.7%	7.3%	17	-32.4%	54
HVAC Interactivity	19	-2.7%	6.4%	31	3.7%	50
Total	**89**	**-49.5%**	**68.1%**	**100**	**18.6%**	**189**

Figure D-2 illustrates that two high-impact categories somewhat canceled each other out, leading to a summer seasonal peak kW RR of 119% for the lighting measures.

- The evaluators found 41 instances of improper **documentation** that led to more summer peak savings than anticipated by the program. Specifically, of the 1,846 lighting measures assessed in this study, the evaluators found 234 instances of fixture upgrades that led to actual summer peak savings but claimed zero summer peak savings in the tracking data. Such issues arose in 35 of the 54 sampled electric projects. The evaluators could not determine the exact cause of this discrepancy but have attributed it to systematic errors in tracking project savings, classified in the documentation category.

- On the other hand, the evaluators found differences in **operation** that led to a 32% reduction in the evaluated summer peak savings. Such differences are not unusual for direct-install lighting measures that reference fixed coincidence factors (CFs) from the PSD. Per Table 4-7, through performance metering of rebated lighting fixtures, the evaluators found lower average summer peak CFs for the two most prominent facility types in the sample: restaurant (27% lower summer peak CF than the 0.78 recommended in the PSD) and office (17% lower than the PSD's 0.70).
- Finally, differences in **HVAC interactivity** assumptions led to slightly higher evaluated savings. The evaluators calculated a higher summer peak kW interactivity factor, on average, than that recommended in the PSD.

Next, we examined the summer seasonal peak kW RR for non-lighting measures.

Figure D-3. Key Drivers Behind Non-Lighting Summer Seasonal Peak Demand RR

Discrepancy Category	Negative Impact		Positive Impact		Overall	
	# Instances	Impact on RR	Impact on RR	# Instances	Impact on RR	# Instances
Documentation	1	-0.1%	4.4%	8	4.4%	9
Technology	1	0.0%	0.0%	0	0.0%	1
Quantity	1	-0.3%	0.0%	0	-0.3%	1
Operation	5	-35.6%	13.9%	10	-21.7%	15
HVAC Interactivity	0	0.0%	2.9%	6	2.9%	6
Total	**8**	**-36.0%**	**21.2%**	**24**	**-14.8%**	**32**

- Differences in **operation** were the most impactful contributor to the 85% RR, in both positive and negative directions and overall. While such differences resulted in a 22% reduction to the RR, the evaluators found half as many instances of negative impact as positive. Two similar sampled projects provide examples of drastic operational differences driving the overall reduction in RR. The evaluators found that the projects' rebated variable frequency drive (VFD) measures were installed at the participating facilities, but the metered data indicated that the impacted motors still operated in an on/off pattern with no evidence of variable speed. Upon interviewing the facility contacts, the evaluators found that the VFDs were installed only to provide soft-start capability for motor maintenance purposes. These two example projects led to zero peak demand savings, significantly impacting the overall program-wide peak demand RRs.

- **HVAC interactivity** positively affected the non-lighting summer peak kW RR, most notably for refrigeration measures, for which impacts can influence the facility's overall cooling load. Such interactive impacts were not properly accounted for within the tracking savings for six sampled projects, resulting in an underestimation of the refrigeration measures' true savings.

Next, we examined similar breakdowns for the winter seasonal peak demand RRs, starting with the overall winter seasonal peak kW RR examined in Figure D-4.

Figure D-4. Key Drivers Behind Overall Winter Seasonal Peak Demand RR

Discrepancy Category	Negative Impact		Positive Impact		Overall	
	# Instances	Impact on RR	Impact on RR	# Instances	Impact on RR	# Instances
Documentation	26	-8.1%	8.3%	28	0.2%	54
Technology	13	-0.5%	0.1%	11	-0.3%	24
Quantity	3	-1.1%	0.0%	3	-1.1%	6
Operation	22	-23.6%	28.7%	32	5.1%	54
HVAC Interactivity	0	0.0%	0.2%	6	0.2%	6
Total	**64**	**-33.2%**	**37.4%**	**80**	**4.1%**	**144**

To investigate the contributing factors further, we examined the lighting and non-lighting breakdowns in Figures D-5 and D-6.

Figure D-5. Key Drivers Behind Lighting Winter Seasonal Peak Demand RR

Discrepancy Category	Negative Impact		Positive Impact		Overall	
	# Instances	Impact on RR	Impact on RR	# Instances	Impact on RR	# Instances
Documentation	27	-9.3%	9.1%	27	-0.3%	54
Technology	13	-0.5%	0.1%	11	-0.4%	24
Quantity	3	-1.2%	0.0%	3	-1.2%	6
Operation	22	-21.1%	31.3%	32	10.2%	54
HVAC Interactivity	0	0.0%	0.0%	0	0.0%	0
Total	**65**	**-32.1%**	**40.5%**	**73**	**8.4%**	**138**

- Differences in **operation** were once again the leading contributor to the 108% winter seasonal peak kW RR for lighting measures. Per Table 4-7, the evaluators found that four of the five most prevalent facility types in the sample had higher average metered winter CFs than recommended in the 2017 PSD: restaurants had 8% higher than the 0.64 recommended by the PSD, manufacturing had 25% higher than the PSD's 0.43, medical had 8% higher than the PSD's 0.62, and other had 25% higher than the PSD's 0.43.

Next, we examined the winter seasonal peak kW RR for non-lighting measures.

Figure D-6. Key Drivers Behind Non-Lighting Winter Seasonal Peak Demand RR

	Negative Impact		Positive Impact		Overall	
Discrepancy Category	# Instances	Impact on RR	Impact on RR	# Instances	Impact on RR	# Instances
Documentation	0	0.0%	3.4%	7	3.4%	7
Technology	1	0.0%	0.0%	0	0.0%	1
Quantity	0	0.0%	0.0%	0	0.0%	0
Operation	5	-46.1%	13.6%	9	-32.6%	14
HVAC Interactivity	0	0.0%	1.9%	6	1.9%	6
Total	**6**	**-46.1%**	**18.8%**	**22**	**-27.3%**	**28**

- Again, differences in **operation** were the key driver, reducing the non-lighting winter seasonal peak kW RR by 33%. The two example VFD projects described after Figure D-3, above, also significantly impacted the winter peak RR with winter peak demand savings reduced to zero.
- Seven instances of incorrect tracking (classified as **documentation**) increased the RR by 3%. The evaluators found instances of refrigeration measures listed in the tracking database, verified as installed and operable but not claiming any reported winter peak kW savings. It is not clear why the program claimed zero winter peak savings for such measures. Performance of refrigeration measures typically does not vary significantly with hour of day, and the evaluators found that the example measures led to savings during the evening and nighttime hours.

D.2 Key Differences Influencing the Natural Gas RRs

Section 4.2 identifies the key contributing factors to the overall natural gas RR. In this section, we examine the RRs for two groups of gas measures: space heating and domestic hot water (DHW). Figure D-7 breaks down the RR for the "Space Heating Only" segment defined in the evaluation sample design.

Figure D-7. Key Drivers Behind Natural Gas RR: Space Heating Only Segment

	Negative Impact		Positive Impact		Overall	
Discrepancy Category	# Instances	Impact on RR	Impact on RR	# Instances	Impact on RR	# Instances
Documentation	6	-11.6%	3.1%	8	-8.6%	14
Technology	4	-1.0%	0.7%	2	-0.3%	6
Quantity	1	0.0%	0.0%	0	0.0%	1
Operation	22	-41.4%	14.1%	12	-27.3%	34
HVAC Interactivity	1	-0.3%	0.0%	0	-0.3%	1
Total	**34**	**-54.4%**	**17.9%**	**22**	**-36.5%**	**56**

- Differences in **operation** led to a 27% reduction in the space-heating-only RR. The highest-impact differences in operation within the evaluation sample each involved energy management system (EMS) measures. The evaluators often found differences between the systems' actual control strategies and those documented in project files. In some cases, the evaluators found unusually high tracking savings claims (e.g., 30%–50% of pre-project billed natural gas consumption).
- One major difference in **documentation** contributed to that category's 9% reduction in space heating RR. In one project, the evaluators found an order-of-magnitude difference between the program-documented algorithm and assumptions (leading to a calculated savings value of 75 MMBtu) and the tracked savings value of 803 MMBtu.

Next, as illustrated in Figure D-8, the evaluators examined another segment considered in the natural gas sample: projects with at least one DHW measure. Such projects featured a segment-level RR of 116%, nearly 40% higher than the overall natural gas RR.

Figure D-8. Key Drivers Behind Natural Gas RR: Projects with DHW Measures

	Negative Impact		Positive Impact		Overall	
Discrepancy Category	**# Instances**	**Impact on RR**	**Impact on RR**	**# Instances**	**Impact on GRR**	**# Instances**
Documentation	7	-0.6%	18.7%	3	18.0%	10
Technology	0	0.0%	0.3%	1	0.3%	1
Quantity	5	-7.6%	1.1%	2	-6.5%	7
Operation	2	-2.6%	7.2%	1	4.5%	3
HVAC Interactivity	0	0.0%	0.0%	0	0.0%	0
Total	**14**	**-10.9%**	**27.3%**	**7**	**16.4%**	**21**

- Differences in **documentation** were the primary contributor of the higher segment-level RR. For one sampled DHW project, for example, the evaluators found that the 2015 PSD (active at the time of this project's implementation) recommended a per-unit savings value for low-flow fixtures considerably higher than that reflected in tracked savings. The evaluators believe the tracked per-unit savings assumption was an error.
- On the other hand, differences in **quantity** reduced the DHW segment's RR by nearly 7%. The primary driver was a project involving the installation of 146 faucet aerators at a country club. Shortly after the project, all aerators were removed and replaced with the preexisting equipment after complaints from club members, thereby reducing the measure's savings to zero.

Appendix E: Forward-Looking Realization Rate

This appendix describes the evaluators' research supporting the calculation of forward-looking realization rates (FRRs).

E.1 Review of 2013–2017 Program Savings Documents

The objective of the FRR calculation is to determine prospective evaluation results after accounting for changes in the Connecticut Program Savings Documents (PSDs) since the evaluation timeframe of 2013–15 compared with the most recent version (2017). The evaluators therefore reviewed all PSDs since 2013, comparing the differences among all measures included in the evaluation sample. Table E-1 outlines these differences by PSD version and by measure.

Note: Measures in bold indicate those requiring further analysis, as described in Table E-2, on page E-4.

Table E-1. Changes among PSD Versions by Measure, 2013–2017

Measure Category	Measure	2017 PSD Changes Since Last Version	2016 PSD Changes Since Last Version	2015 PSD Changes Since Last Version	2014 PSD Changes Since Last Version
Lighting	Retrofit	Added text in measure description to take into account any anticipated energy code changes in Connecticut. Additionally, inserted Table 2A, lighting power density (LPD) using building area method based on IECC 2012.	No changes.	Added exterior lighting savings algorithm.	Added footnote regarding spaces requiring occupancy sensors per code.
HVAC Cooling	**Unitary A/C & Heat Pumps**	**Updated Tables 1 and 2 for IECC 2012 code; added Tables 1A and 2A for new IECC 2012 code.**	**No changes.**	**No changes.**	**No changes.**
	Setback Thermostat	No changes.	No changes.	No changes.	No changes.
	Duct Sealing	No changes.	No changes.	No changes.	No changes.
	GSHP/ WSHP	No changes.	No changes.	No changes.	No changes.

Gas Measures	**Boiler and Furnace**	**Referenced ASHRAE 90.1-2010 baseline, which is equivalent to ASHRAE 90.1-2007.**	**Added average EFLH for upstream program.**	**Adjustment factor added: 1.0 for noncondensing and 0.97 for condensing.**	**Added Footnote 1. Peak day factors and full load hours were developed by third-party engineers (Fuss & O'Neill, Manchester, CT) in 2008 using a temperature bin analysis.**
	Radiant Heater	Referenced ASHRAE 90.1-2010 baseline, which is equivalent to ASHRAE 90.1-2007.	No changes.	No changes.	No changes.
	DHW Heater	**Updated Table 1 in accordance with 2012 Commercial Buildings Energy Consumption Survey (CBECS) data provided by the U.S. Energy Information Administration.**	**Assigned Ref 1 - ASHRAE 90.1 2007**	**No changes.**	**No changes.**
	Pipe Insulation	No changes.	No changes.	No changes.	Editorial changes.
	DHW Fixtures	No changes.	No changes.	No changes for spray valves. Added options for showerhead and aerator.	Changed measure title and added showerheads and faucet aerators.
	Steam Trap	**No changes.**	**No changes.**	**Revised EFLHs to account for plant outages and steam coil control valve cycling. Table 1 was also revised to provide specific enthalpy of evaporation in lieu of the specific enthalpy of the steam. The enthalpy of the saturated liquid would not be lost as a result of a leaking/ failed-open trap.**	**Replaced the four tables, savings based on orifice size, with Napier's equation and Table 1.**

Motor/VFD	**HVAC VFD or RTU Speed Control**	**Added note regarding 2.7 exponent for fan savings, clarified savings methodology, and added fan motor load factor assumption.**	**No changes.**	**No changes.**	**Added constant volume fan baseline and savings factors.**
	Kitchen Hood Controls	No changes.	No changes.	New measure incorporating site-specific inputs.	N/A
	Custom	No changes.	Clarified description of temperature bins.	No changes.	Revised baseline description and provided additional details for temperature and non-temperature-dependent measures.
Refrigeration	Evaporator Fan Controls	No changes.	No changes.	No changes.	Editorial changes.
	Evaporator Fan Motors	No changes.	No changes.	No changes.	Editorial changes.
	Door Heater Controls	No changes.	No changes.	No changes.	Editorial changes.
	Vending Machine Controls	**No changes.**	**No changes.**	**Restored option to determine savings based on measurements and provided examples.**	**Updated calculations to a more prescriptive approach similar to the Ohio and Massachusetts TRMs.**

Table E-2. Required Actions by Measure for FRR Calculation

Measure Category	Measure	Investigation	Conclusion
Lighting	Retrofit	Investigate any sampled projects that employed an LPD-based approach for reported savings calculation. Confirm that reported exterior savings reflect the current PSD algorithm.	Reported savings were not calculated using an LPD approach, and exterior savings were calculated in accordance with the current PSD. **No adjustment needed.**
HVAC Cooling	RTU	Confirm that the reported savings algorithm's baseline efficiencies reflect IECC 2012 instead of IECC 2009.	Evaluators investigated the reported savings for all projects involving packaged or split HVAC systems. All baseline assumptions were in alignment with IECC 2012. **No adjustment needed.**
Gas Measures	Boiler and Furnace	Update algorithm to include the adjustment factor (AF) for condensing system's post-project efficiency.	Evaluators found that all but one project with condensing boiler or furnace measures properly included the AF. **The reported savings for that one project were adjusted accordingly, resulting in a slightly different FRR.**
	DHW Heater	Investigate storage DHW heater sites to determine if the usage rates (ccf per square foot) must be updated to reflect 2012 CBECS data.	No projects in the sample involved storage DHW heaters. Three projects involved tankless DHW heaters, which are not covered under this measure in the PSDs. **No adjustment needed.**
	Steam Trap	Confirm that EFLHs are in alignment with the current PSD recommendations. Confirm that the reported savings reflect the Napier formula.	For the lone steam trap project in the sample, the reported savings were calculated using the 2013 PSD method, not the Napier formula. **Therefore, the reported savings were adjusted accordingly, resulting in a different FRR.**
Motor/VFD	HVAC VFD or RTU Speed Control	Confirm that any projects involving VFDs on constant volume fans incorporate the recommended savings factors.	No projects in the sample involved constant-volume fans as baseline. One project involved a backward-incline fan as baseline and appropriately referenced the PSD savings factors. Other VFD projects involved pumps or other motors analyzed via custom analysis. **No adjustment needed.**
Refrigeration	Vending Machine Controls	Confirm that reported savings follow one of the PSD's two recommended methods: the measurement-based approach or the deemed savings approach.	All vending machine controls projects in the sample followed one of the two recommended methods. **No adjustment needed.**

Based on the above conclusions, only the FRR for the natural gas savings differed from the RR, as outlined in Section 4.4.