C20 Impact Evaluation of Energy Conscious Blueprint Program Years 2012-2013

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FINAL REPORT

Presented To:

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1. EXECUTIVE SUMMARY

Introduction

This report presents the outcomes of the evaluation of Connecticut's 2012-2013 Energy Conscious Blueprint (ECB) Program. The evaluation contractor team (hereafter referred to as "the evaluation team"), led by EMI Consulting, designed this evaluation in collaboration with the Connecticut Consultant to the Energy Efficiency Board (EEB) Evaluation Committee.

Per the 2012 Conservation and Load Management Plan, the objective of the ECB program is "to maximize electric and natural gas energy savings for 'lost opportunity' projects, at the time of initial construction/major renovation, or when equipment needs to be replaced or added."

Program stakeholders, including the EEB and the Program Administrators (PAs), are prioritizing this evaluation because a significant portion of the EEB program portfolio savings is attributed to the ECB program: 13% of energy savings for electricity and 28% for natural gas.[1] This impact evaluation verifies the savings claimed by the ECB program; reducing savings uncertainty and planning risk, and provides current information to assess needed changes to the Program Savings Document (PSD) that guides reported energy and demand savings.

Description of Objectives

The overall objective of this impact evaluation was to estimate the energy saved by the program (both electricity and natural gas) and the reduction in electrical peak demand. The impact evaluation emphasized high impact measures that account for a majority of the program savings; therefore representing the greatest aggregate risk in regard to progress toward energy savings and demand reduction goals. The evaluation research achieved the following overarching objectives:

- Evaluate the savings impacts of electric and natural gas projects to produce overall, statewide savings realization rates, relative to both gross and net savings estimates claimed from the program period beginning on January 1, 2012 and continuing through October 31, 2013;
- Characterize non-energy impacts as reported by participants;
- Calculate and recommend "forward-looking" overall realization rates using the 2015 Program Savings Document (PSD);
- Assess the accuracy of methods used by vendors in estimating savings for complex "custom" projects and recommend changes, if needed; and
- Undertake a pilot study to ascertain market baseline efficiencies for HVAC and lighting equipment installed by HVAC and lighting vendors in Connecticut through vendor surveys.

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[1] Per the Energize CT Dashboard in 2012: ECB annual energy savings of 41.1 million kWh of 307 million kWh and 1 million CCF of 3.6 million CCF.

Impact Evaluation Methods

The evaluation team used on-site measurement and verification (M&V) for a representative sample of projects as the primary method of data collection and to develop ex post (evaluated) savings estimates.[2] Field staff visited participant sites to conduct interviews, measure key assumed inputs, and meter long-term usage patterns.

To complete the impact evaluation, the evaluation team first compared estimated evaluated savings values to reported savings values (estimated savings prior to evaluation) to determine realization rates for each sampled measure.[3] Next, the team weighted and aggregated these measure-by-measure realization rates to create an overall, program-level realization rate. Finally, the evaluation team calculated forward-looking realization rates using assumptions in the 2015 PSD, as opposed to the 2012-2013 version of the PSD.

Realization rates are the most critical output from an impact evaluation for the following reasons:

1. An estimate of the evaluated savings can be obtained from the program period of interest, or any more current year, where the program's methodology for estimating savings has not changed substantially. This is achieved by multiplying the program's claimed/tracking system estimate of savings by the realization rate from the evaluation.
2. The realization rate provides information on how well the program is estimating savings, and it helps to identify areas where the program could improve or should investigate methods and assumptions used in estimating measure-level, measure category-level, and program-level savings claims.
3. Targeting the realization rate, rather than absolute savings estimates, reduces variability influenced by the magnitude of savings, facility type, or scope of measure. This approach also allows sampling to be accomplished in a more efficient and cost-effective manner.

Results

The ECB program impact evaluation results presented in this report are based on a sample of 189 measures; 146 of these were electric measures and 43 were natural gas measures. The individual measure populations for each measure grouping are provided in Table 1-1. Table 1-2, Table 1-3, and Table 1-4 in this section summarize the impact evaluation's principal findings, comparing ex post (evaluated) savings estimates to reported (utility program tracking system) savings estimates. Greater detail on adjustments made to the savings based on evaluation findings are provided in Section 4 of this report.

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[2] "Ex post" refers to the evaluated or measured savings estimate.

[3] "*Reported*" refers to the savings estimate when the project was completed; this is the value in the tracking data.

Table 1-1. Reported Annual Energy Savings by Measure Category and Corresponding Sample Points

Measure Group	Measures in Population	Population Energy Savings	Sampled Measures	Portion of Savings Sampled
Compressed Air	275	23,217 MWh	26	51%
HVAC	872	14,179 MWh	57	25%
Lighting	318	19,554 MWh	32	33%
Process	218	14,367 MWh	21	31%
HPBD/Other	50	4,569 MWh	10	77%
Overall Electric Savings	**1,733**	**75,885 MWh**	**146**	**39%**
Gas-Boiler	131	346,682 therms	17	31%
Gas-Other	158	631,733 therms	26	67%
Overall Gas Savings	**289**	**978,415 therms**	**43**	**54%**

Table 1-2 provides a summary of the annual energy savings for the 2012-2013 ECB program. The aggregate, weighted electric energy realization rate is 84% with relative precision of ±21% at the 90% confidence level, while the gas energy realization rate is 78%, with relative precision of ± 15%. The forward-looking realization rates are also included, showing what the realization rates would have been if the *reported* calculations had been performed using the 2015 PSD. Only lighting realization rates changed, leading to a change for the overall electric realization rate. For overall annual energy savings, it is customary to target ±10% relative precision at the 90% confidence interval in Connecticut energy efficiency program evaluations. The impact evaluation for the 2012-2013 ECB program did not meet this goal for program-level electric or gas energy savings. The target at the measure category level was ±20% at the 90% confidence level, which was achieved for four of the five electric measure groups (Compressed Air, HVAC, Lighting, and HPBD/Other) and both of the gas measure groups (Gas-Boiler and Gas-Other). The precision of the impact findings is generally lower than the target as a result of very high variability in measure-specific realization rates, which were much higher than anticipated in the sample designs.

Table 1-2. Energy Conscious Blueprint Program Energy Savings – Program Period Jan 2012 through Oct 2013

Measure Group	Units	Reported	Evaluated	Weighted Realization Rate	Rel. Prec. (90% Confidence)	Forward Looking Realization Rate
Compressed Air	MWh	23,217	11,376	49%	± 18%	49%
HVAC	MWh	14,179	12,052	85%	± 22%	85%
Lighting	MWh	19,554	21,510	110%	± 20%	116%
Process	MWh	14,367	14,654	102%	± 25%	102%
HPBD/Other	MWh	4,569	4,386	96%	± 18%	96%
Electric Overall	**MWh**	**75,885**	**63,978**	**84%**	**± 21%**	**86%**
Gas-Boiler	therms	346,682	332,815	96%	± 14%	96%
Gas-Other	therms	631,733	429,578	68%	± 15%	68%
Gas Overall	**therms**	**978,415**	**762,393**	**78%**	**± 15%**	**78%**

Table 1-3 presents a similar summary of summer peak demand impacts for electric projects. The electric summer seasonal demand weighted realization rate is 85% with a relative precision of ±20% at the 80% confidence level. For demand reduction values, sampling must achieve statistical accuracy and precision of no less than 80% confidence level and ±10% relative precision (80/10) in order to comply with ISO New England's M-MVDR. As with electric energy savings, high variability in measure-specific realization rates prevented the evaluation team from meeting this objective with summer demand realization rates for each measure group and at the overall program level. This is driven in part by a number of entries of "zero" in the Companies' tracking databases for summer demand savings, which was the case for 20 of the 146 measures evaluated. Project measure-specific realization rates for summer seasonal demand impacts were highly variable ranging from -104% to 1157%.[4]

[4] The negative realization rate (-104%) is for a measure with 50 kW reported summer seasonal peak demand savings that actually had increased summer seasonal peak demand of 52.09 kW as evaluated. The extraordinarily high realization rate is a project with 0 kW reported for summer seasonal peak demand savings that was evaluated to have 46.32 kW of summer seasonal demand savings. This measure is one where we replaced the assumed 0 kW with 1 kW in order to be able to meaningfully include it in the analysis (dividing by a reported value of 0 kW results in a realization rate of infinity). See Appendix F for more details on treatment of negative and zero reported savings.

Table 1-3. Energy Conscious Blueprint Program Summer Demand Savings – Program Period Jan 2012 through Oct 2013

Measure Group	Reported (MW)	Evaluated (MW)	Weighted Realization Rate	Rel. Prec. (80% Confidence)	Forward Looking Realization Rate
Compressed Air	2.997	1.648	55%	± 11%	55%
HVAC	4.069	2.685	66%	± 20%	66%
Light	3.708	4.227	114%	± 16%	121%
Process	2.707	2.842	105%	± 35%	105%
HPBD/Other	0.584	0.572	98%	± 22%	98%
Electric Overall	**14.064**	**11.975**	**85%**	**± 20%**	**87%**

The relative precision reported in Table 1-3 is based on a two-tailed hypothesis test. Using this test, the relative precision represents the band around the mean (both positive and negative) where the actual value is likely to be in the population. The real concern with the precision of energy savings is that the actual value could be lower than the evaluated value. There is less concern if actual savings are higher than the evaluated value. Therefore, a one-tailed test that indicates the probability that the actual savings are lower than the evaluated savings is what is most critical. **Using the one-tailed test we can report with 80% confidence that the actual summer seasonal demand savings could be up to 10% lower than the evaluated value (80% confidence/10% relative precision).** That is, we can say with 80% confidence that the actual realization rate is not less than 75%, given our evaluated realization rate of 85%.

Table 1-4 summarizes the winter peak demand impacts. The electric winter seasonal demand realization rate is 90% with relative precision of ±25% at the 80% confidence level. Once again, as a result of high variability in measure-specific realization rates, which was driven in part by several entries of "zero" in the Companies' tracking data where measureable winter demand savings were evaluated, winter demand realization rates do not achieve the M-MVDR objective for confidence and precision (80/10). In total, there were 52 measures (of 146) for which the reported winter seasonal demand values were zero or missing; of these, 17 were found to have non-zero evaluated winter seasonal demand values. Realization rates for winter seasonal demand impacts were highly variable ranging from -0.6% to 1137%.[5]

[5] The negative realization rate (-0.6%) is for a measure with 3.2 kW reported winter seasonal peak demand savings that actually had increased winter seasonal peak demand of 0.02 kW as evaluated. The extraordinarily high realization rate of 7989% is a project with 0 kW reported winter seasonal peak demand savings that was evaluated as having 79.89 kW of savings. This measure is one where we replaced the assumed 0 kW with 1 kW in order to be able to meaningfully include it in the analysis (dividing by a reported value of 0 kW results in a realization rate of infinity). See Appendix F for more details on treatment of negative and zero reported savings.

Table 1-4. Energy Conscious Blueprint Program Total Winter Demand Savings – Program Period Jan 2012 through Oct 2013

Measure Group	Reported (MW)	Evaluated (MW)	Weighted Realization Rate	Rel. Prec. (80% Confidence)	Forward Looking Realization Rate
Compressed Air	2.789	1.618	58%	± 11%	58%
HVAC	1.229	1.327	108%	± 36%	108%
Light	2.661	2.980	112%	± 20%	113%
Process	2.283	2.534	111%	± 41%	111%
HPBD/Other	0.805	0.362	45%	± 29%	45%
Electric Overall	**9.768**	**8.822**	**90%**	**± 25%**	**91%**

Similar to the summer demand savings, the relative precision reported in Table 1-4 is based on a two-tailed hypothesis test. **Using the one-tailed test we can report with 80% confidence that the actual winter seasonal demand savings may be up to 13% lower than the evaluated savings (80% confidence/13% precision).** That is, we can say with 80% confidence that the actual realization rate is not less than 77%, given evaluated realization rate of 90%. This still does not meet the requirements of the M-MVDR.

Recommendations/Conclusions

Based on these results, the evaluation team identified the following five main conclusions from this research.

1. In general, 2012-2013 ECB electric measures are performing well. However, costly calculation errors in reported savings analyses on some of the largest measures (in particular compressed air and HVAC measures) resulted in substantial downward adjustments to evaluated savings; ultimately driving down the measure group-level and overall program-level electric energy and demand savings realization rates. These errors ranged from simple math errors to failure to use prescriptive methodologies and assumptions from the Connecticut PSD. Documentation adjustments accounted for approximately 62.8% of all downward electric energy savings adjustments made. Documentation adjustments also accounted for approximately 50.6% of all downward electric demand savings adjustments and 39% of all downward gas energy savings adjustments. The combined effects of all downward documentation adjustments resulted in gross[6] savings reductions of 10,590,853 kWh and 216,022 therms. Given the magnitude of these potentially avoidable adjustments, it is recommended that the program-administrator-engineering-review-process be adjusted in order to improve the accuracy and consistency of claimed savings estimates.
2. In order to streamline project qualification for Program Administrators and to facilitate ongoing evaluations, program participants should be required to submit program documentation in electronic form. In addition, as a condition for incentive payment,

[6] Net reduction in savings from upward and downward documentation adjustments for electric energy was approximately -9,916,727 kWh.

participants should be required to provide copies of all calculations in forms readily checked using computer-based tools without manual transcription.

3. Final building simulation files were excluded from the documentation provided for review for all five of the High Performance Building Design (HPBD) projects evaluated. In the absence of having the final simulation model for each site, the evaluation team was forced to develop its own building energy simulation model. This model was based upon project documentation and what information could be collected from the program participant as well as design architects and engineers involved on the project. The research team recommends that the program require participants to provide the final building simulation files that were used to calculate reported energy savings as a condition of payment for all future HPBD projects/measures.
4. The natural gas realization rates for energy were 78%. This difference is primarily driven by downward documentation and operational adjustments assessed on non-boiler projects (Gas-Other) resulting from baseline estimates that did not reflect previous site operations, simple mathematical errors in claimed savings estimates, and one project for which the amount of available process cooling was vastly overstated. The overall realization rate for Gas-Boiler energy was 96.2%; however, substantial off-setting documentation and operational adjustments were assessed on the projects evaluated and several recommendations have been made to improve upon the accuracy of claimed savings for the condensing boiler. These recommendations include a revision to the 2015 PSD assumptions used to estimate operating efficiency and enhancements to the existing program application form.
5. Future Energy Conscious Blueprint impact evaluations should use error ratios (e.r.) found in this study for all measure groups to ensure meeting the desired precision for electric energy and demand savings, as well as natural gas energy savings. The evaluation team found that the realization rates for projects in this program were highly variable. The evaluated e.r. values for the Compressed Air, HVAC, HPBD/Other, and Process measure groups were much higher than the a priori estimates of 0.5. The evaluation team recommends for future studies adjusting these e.r. values to those found in this evaluation. Such an adjustment will result in a greater emphasis on non-lighting project sites, which have higher variability.

2. INTRODUCTION

During the evaluation period[7], the Connecticut electric utilities United Illuminating (UI) and Eversource[8] provided incentives for 986 energy efficiency projects[9] (1,733 combined measures) delivered via the Energy Conscious Blueprint (ECB) program in 2012-2013. In aggregate, these projects reported annual energy savings of 75.9 GWh. In addition, Southern Connecticut Gas (SCG) and Connecticut Natural Gas (CNG) of UI, Inc., and Yankee Gas of Eversource provided incentives for 235 projects (299 measures) and reported an aggregate annual savings of 978,414 therms. Table 2-1 provides a breakdown of reported annual energy and demand savings for projects that occurred in Program Year 2012 and projects that occurred in Program Year 2013.

Table 2-1. Reported Annual Energy and Demand Savings by Program Year

Program Year	Number of Electric Measures	Annual Electric Energy Savings (GWh)	Annual Electric Summer Demand Savings (MW)	Annual Electric Winter Demand Savings (MW)	Number of Gas Measures	Annual Gas Energy (therms)
2012	1,038	37.90	7.52	4.53	168	557,322
2013	695	37.99	6.54	5.24	131	421,092

Program stakeholders, including the Connecticut Energy Efficiency Board (EEB) and the Program Administrators (PAs), are prioritizing this evaluation because a significant portion of the EEB program portfolio savings is attributed to the ECB program: 13% of electric energy savings and 28% of natural gas savings.[10] The most recent evaluation of the ECB program evaluated the 2009 program. This impact evaluation verifies the savings claimed by the ECB program – reducing savings uncertainty and planning risk – and provides current information to assess needed changes to the Program Savings Document (PSD) that guides reported energy and demand savings.

This impact evaluation determined direct results of the program's activities: evaluating both energy and demand savings against values reported in the program tracking system. This evaluation was conducted to determine overall realization rates and areas where assumptions and ascribed savings values differ from those measured in the field.

2.1 Program Description and Population Summary

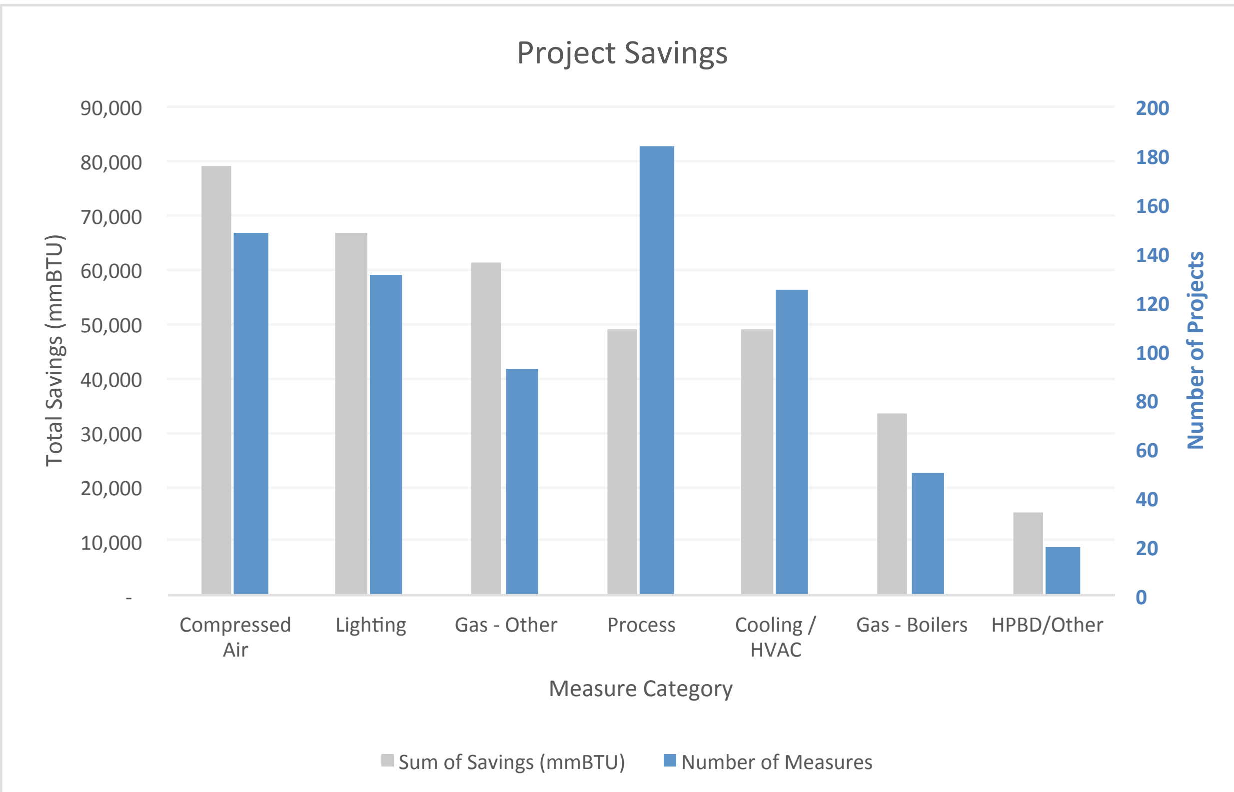
Per the 2012 Conservation and Load Management Plan, the objective of the ECB program is "to maximize electric and natural gas energy savings for 'lost opportunity' projects, at the time of initial construction/major renovation, or when equipment needs to be replaced or added." The program seeks to accomplish this by working with new construction trade allies (e.g., contractors, architects, engineering firms) to raise awareness of energy efficient technologies and whole-

[7] The impact evaluation period includes project completed between January 1, 2012 and October 31, 2013.
[8] Eversource is the electric utility previously called Connecticut Light & Power (CL&P)
[9] 986 projects in the tracking data include savings.
[10] Per the Energize CT Dashboard in 2012: ECB annual energy savings of 41.1 million kWh of 307 million kWh and 1 million CCF of 3.6 million CCF.

building design practices and assist these allies in illustrating to property developers and owners the benefits of energy efficiency during initial construction.

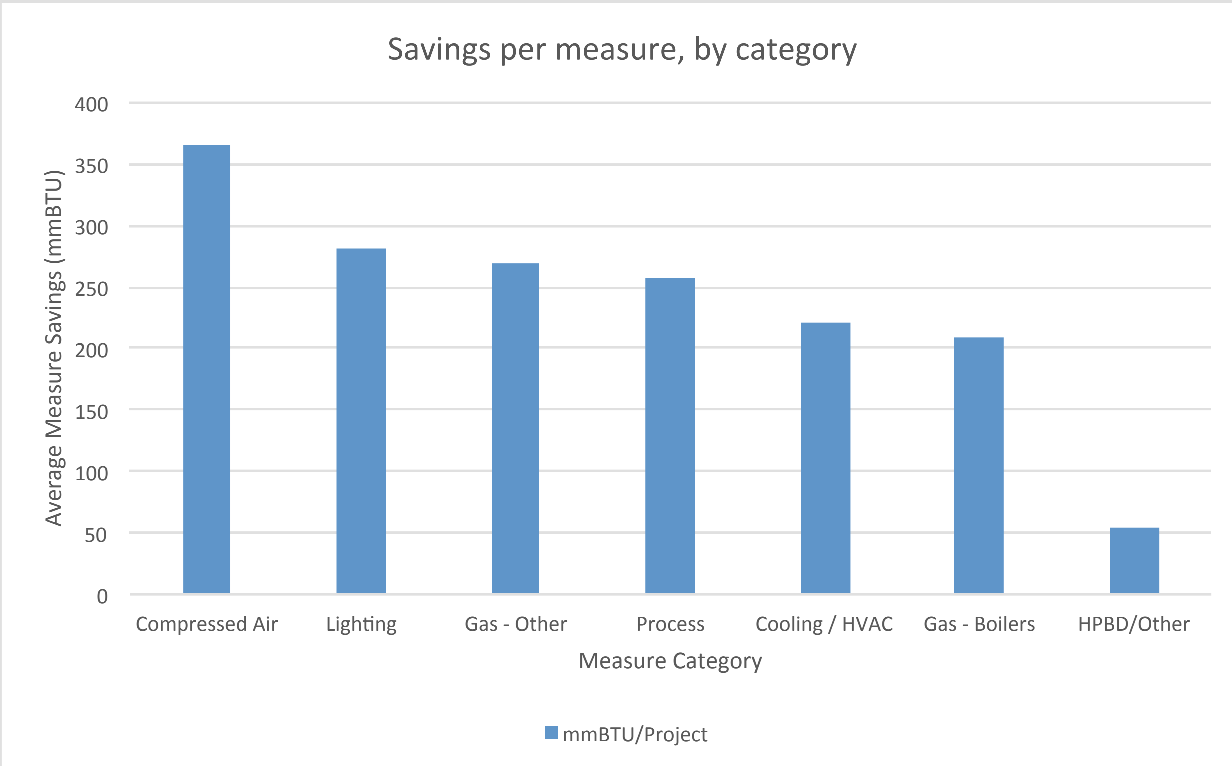
The research team analyzed the program tracking data in order to provide a summary of program savings and measures. The tracking data for the impact evaluation, or the program population, includes program participants that completed projects between January 2012 and October 2013. Program participants in this time period achieved over 356,000 mmBTU in annual energy savings from 1,221 projects. Figure 2-1 illustrates the total annual energy savings and total number of measures by category. Figure 2-2 illustrates the average energy savings per implemented measure. Compressed Air, Lighting, and Gas measures had the greatest average per-measure savings.

Figure 2-1: Cooling technologies represent the greatest number of measures, while process measures account for the most energy savings.



Note: Savings values reported in this figure do not include measures with zero or negative savings values for administrative adjustments and incentive caps.

Figure 2-2. On a per-measure basis, heating measures result in the greatest energy savings, closely followed by process and lighting measures.



2.2 Evaluation Objectives

The impact evaluation emphasized high impact measures that account for a majority of program savings; therefore representing the greatest aggregate risk in regards to progress towards energy savings and demand reduction goals. Electric and natural gas projects were split into major measure groups and stratified by size. More detail on the stratification and sampling plan is provided in the methodology section. The objectives of this impact evaluation are as follows:

- Evaluate the savings impacts of electric and natural gas projects to produce overall, statewide savings realization rates relative to gross savings estimates claimed by the programs for 2012-2013 program activity. This rate includes the following adjustment factors:
  - Documentation adjustment—reflects discrepancies in program documentation
  - Technology adjustment—reflects discrepancies between the equipment listed in the program tracking data and the equipment identified in the field
  - Quantity adjustment—reflects discrepancies between the quantity or size of the documented equipment versus the equipment observed in the field
  - Operational adjustment—reflects discrepancies between the operational conditions identified in the program documentation and what was observed in the field
  - Coincident adjustment—reflects differences between connected and coincident/diversified demand impacts

    - Interactive (Heating and Cooling) adjustment—reflects differences in savings due to the observed interaction between the installed equipment and other systems
- Characterize non-energy impacts as reported by participants
- Calculate and recommend “forward-looking” overall realization rates using the 2015 Program Savings Document (PSD)
- Assess the accuracy of methods used by vendors in estimating savings for complex “custom” projects and recommend changes, if needed.
- Undertake a pilot study to ascertain market baseline efficiencies for HVAC and lighting equipment installed by HVAC and lighting vendors in Connecticut through vendor surveys.

3. METHODOLOGY

To address the objectives above, the evaluation team developed sampling frames and procedures specific to each aspect of the evaluation. This section describes the methodology for conducting the on-site measurement and verification, sampling and stratification, and performing the analysis of collected data.

3.1 On-Site Measurement and Verification (M&V) Methods

The objective of on-site measurement and verification was to collect data needed to develop realization rate adjustment factors that could then be applied to the program savings to estimate gross evaluated savings for energy and demand. On-site M&V activities included metering energy consumption, hours of operation, lighting levels, and occupancy status. On-site interviews were also conducted.

On-site M&V consists of the following steps:

1. Identify a representative sample. See the sections below.
2. Obtain project files (as practical) from the electric and gas utilities (Eversource and UI). The evaluation team received electronic project documentation for each sampled project, including the savings estimates from the utility ECB program tracking systems. Also received were the approved calculation methods used by participants to produce the ex-ante and tracking system savings estimates for each measure. The team reviewed all documentation and savings calculations to verify appropriate estimate calculation methods were applied, and to the extent practical, attempted to replicate calculations, compare results and check for calculation errors.
3. Finalize M&V plans. This step included developing an on-site data collection protocol for each project, while taking into consideration project complexity, savings magnitude, measure technologies, and access to critical parameter measurement. Protocols varied for each project depending on the type of equipment installed. In general, the protocols included: customer interviews; on-site data collection with instrument installation guidelines; specific instructions for how many power or energy measurements and/or data loggers to use; and instructions whether to use spot power measurements, extended-duration power metering, equipment run-time loggers or some combination of these.
4. Contact customers to arrange site visits. During this step, the evaluation team called sample participants to recruit them for the study. A proportion of sample participants could not be recruited for on-site M&V for a variety of reasons. These include an inability to contact a participant or participants unwilling to allow site visits, and other reasons. These were replaced with backup sites to ensure that the sample representation remained consistent with the sampling plan.
5. Conduct on-site assessments. These assessments followed the methods outlined in the International Performance Measurement & Verification Protocol (IPMVP) and the ISO

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New England M-MVDR[11]. The IPMVP outlines four evaluation methods, which are described in Figure 3-1 below.

Figure 3-1: Summary of International Performance Measurement & Verification Protocol (IPMVP) Evaluation Methods

IPMVP Option	Used for	Examples
A. Retrofit Isolation with Key Parameter Measurement	Calibrating energy models where metering all points is cost-prohibitive for the amount of savings, or not possible.	Spot check on lighting power plus logging hours of usage; using an on/off logger to estimate packaged air conditioning unit load.
B. Retrofit isolation with All Parameter Measurement	Determining loading and duty cycle for measures that have significant savings and where all significant parameters can be metered.	Determining the duty cycle of a variable frequency drive; measuring the duty cycle and output of a large chiller.
C. Whole Facility	Projects that are expected to save at least 10% of facility / meter consumption.	Multiple measure / comprehensive facility projects such as retrocommissioning, new control systems, or major system replacements or upgrades.
D. Calibrated Simulation	New construction primarily, or major retrofit projects and complex projects that are expected to save less than 10% of the facility / meter consumption.	New construction and retrocommissioning projects where the quantity of affected equipment and systems results in prohibitively expensive alternative M&V methods.

The specific approach taken for each project was based on criteria such as:

a. Which measure performance parameters may reasonably be considered invariant when the measure is reducing energy use and demand
b. Expected impacts (sensitivity and risk) associated with uncertainty in each of the measure's parameters included in the performance calculation
c. Availability and physical accessibility of performance parameters for measurement
d. Cost to determine a performance parameter versus impact on accuracy, etc.

Sampling and Stratification

Energy efficiency projects were initially sampled to evaluate at the project level. The selection of projects for the sample is based upon the measure type savings at that project (as described below). Once selected, all individual measures in each sampled project were evaluated. After measurement, verification and measure data analysis were completed, all individual measures were regrouped by end-use type, stratified and statistically analyzed in these groups. The impacts were then reported by end-use groups. This section covers the sample design and then the post-stratification.

[11] http://www.isone.com/rules_proceds/isone_mnls/m_mvdr_measurement_and_verification_demand_reduction_revision_4_06_01_12.doc

Sample Design

The sample design was based on projects and organized into groups by the measure in the project with the maximum savings.[12] For electric projects, these groups were compressed air, cooling, lighting, process, and other. For gas projects, these groups were boiler and other. In both cases, the starting point for developing the sample was the goal of achieving 90% confidence at 10% relative precision for annual energy savings, assuming overall error ratios of 0.5.

Within measure groups, projects were stratified by reported total project annual energy savings into 5 sub-strata per group. The smallest projects that together represented less than 5% of savings constituted a stratum with no projects in the sample. These projects are too small to make a difference in reliability so the expenditures only increase the overall evaluation costs. There were three random strata representing the majority of savings, and a certainty (also known as census) stratum of large projects. For electric projects, one project was added to the certainty strata with very high summer demand savings in order to achieve the ISO-NE requirement of 80% confidence at 10% relative precision. Stratum break points were determined through the method presented by Lavallée and Hidiroglou (1988)[13] for obtaining the break points with distributional assumptions similar to those of Dalenius and Hodges (1959)[14].

The evaluation team evaluated all measures when performing on-site M&V for each project. The energy savings resulting from each measure were evaluated independently (to the extent possible[15]).

The achieved sample of projects differed slightly from our initial sample projects. This is because not all projects in our initial sample could be evaluated. Reasons that the research team could not evaluate projects varied by project; however, the most common explanation was that site contacts were not able to schedule visits. When we could not schedule site visits with the initial sample project, we randomly selected alternate projects that were included in the samples. For very large projects, more than one alternate project would be needed in order to cover equivalent annual energy savings. The achieved sample ultimately included 66 electric projects and 30 gas projects, as shown in Table 3-1 and Table 3-2.[16]

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[12] Individual measures within projects were assigned to the various measure groups based upon key data fields from each of the CL&P and UI databases. The UI data contained variables representing the project description (descript), measure code (prodnum), a measure description (proddesc), measure type (faciluse), and quantity installed (prodqty). The CL&P data contained variables for the project description (proj_phase_txt), project phase (proj_phase_txt), measure description (meas_dsc), installed quantity (units_instld_qty), and measure type (bnft_type_cd). For both utilities this information was relatively complete, but the information was not consistent across utilities. Sometimes this information was found to be inaccurate during project documentation review.

[13] Lavallee, P., & Hidiroglou, M. (1988). On the Stratification of Skewed Populations. *Survey Methodology, Volume 14* (1), pp. 33-43.

[14] Dalenius, T., & Hodges, J.L. (1959). Minimum Variance Stratification. *Journal of the American Statistical Association*, pp. 88-101.

[15] Savings resulting from High Performance Building Design and calibrated simulation projects were often interdependent and could not be disaggregated due to insufficient documentation.

[16] During sampling, project documentation was requested from the utilities for the sample and a backup of equal size. The backup project documentation was used to identify projects to replace those that could not be scheduled.

Table 3-1. Electric Sample Target and Achieved

Measure Group	Stratum	Sample Type	Population Projects	Portion of Annual Savings	Original Sample Target	Achieved Sample *
Compressed Air	1	None	27	0.63%	0	0
Compressed Air	2	Random	48	2.70%	3	3
Compressed Air	3	Random	29	3.83%	4	4
Compressed Air	4	Random	25	6.49%	4	**5**
Compressed Air	5	Census	3	2.66%	3	**2**
Cool	1	None	159	0.30%	0	0
Cool	2	Random	118	1.12%	2	**4**
Cool	3	Random	55	1.69%	3	**5**
Cool	4	Random	23	2.12%	3	**5**
Cool	5	Census	6	2.24%	6	**5**
Light	1	None	84	1.08%	0	0
Light	2	Random	62	3.18%	3	**4**
Light	3	Random	35	6.27%	3	3
Light	4	Random	19	9.61%	3	3
Light	5	Census	4	6.74%	4	4
Other	1	None	102	1.03%	0	0
Other	2	Random	29	2.51%	2	2
Other	3	Random	19	5.66%	2	**3**
Other	4	Random	6	4.30%	3	**4**
Other	5	Census	3	5.22%	3	3
Process	1	None	73	1.68%	0	0
Process	2	Random	32	4.04%	1	1
Process	3	Random	16	5.76%	2	2
Process	4	Random	7	5.94%	2	2
Process	5	Census	2	13.18%	2	2
Overall	**-**	**-**	**986**	**100.0%**	**58**	**66**

* Bold values indicate a change

Table 3-2. Gas Sample Target and Achieved

Measure Group	Stratum	Sample Type	Projects	Portion of Annual Savings	Original Sample Target	Achieved Sample *
Boiler	1	None	4	0.10%	0	**1**
Boiler	2	Random	71	9.50%	4	4
Boiler	3	Random	23	12.20%	4	4
Boiler	4	Census	4	6.10%	4	**2**
Other	1	None	14	0.20%	0	**3**
Other	2	Random	95	13.40%	5	5
Other	3	Random	17	17.80%	6	6
Other	4	Census	7	40.80%	7	**5**
Overall	**-**	**-**	**235**	**100.0%**	**30**	**30**

* Bold values indicate a change

Post-stratification

Prior to aggregating the results at the program level, the research team applied post-stratification to the evaluated sample as well as the total relevant program population. Post-stratification is generally done in order to reconcile known differences between the proportions of a stratified sample and the population that the sample seeks to represent (post-stratification has been covered in literature).[17] [18] [19] The general concept is to calculate a weighting for each case of the achieved sample based on the number in the population that the sample represents. This method is essential in stratified designs because the portion of each stratum that is sampled is not the same. For example, the majority of cases are in strata 2, but the majority of sampled cases are from stratum 4 or 5 because these strata represent larger projects; therefore, the case weights for stratum 2 will be higher than those for stratum 4 or 5.

As indicated in the evaluation plan, the post-stratification was based on measure end-use types rather than projects.[20] The effectiveness of the post-stratification adjustment depends on the availability of true population parameters. In our case, we reviewed data collected in the field regarding the measures included in our sample to determine how to re-classify measures into more accurate measure groups by end-use. That is, we were able to re-classify many measures initially identified as "other" as more specific measure types (HVAC, Lighting, etc.). Given this improved understanding of how the program database variables aligned with the measures actually installed in the field, we also re-classified measures that were initially categorized incorrectly in the overall population data set. In addition, we expanded the cooling measure group to represent all HVAC measures. After redefining the measure groups, it was necessary to

[17] Cochran, W.G. (1977) *Sampling Techniques, 3rd Edition*. New Dehli, India: Wiley.
[18] Neyman, J. (1934). "On the Two Different Aspects of the Representative Method: The Method of Stratified Sampling and the Method of Purposive Selection". *Journal of the Royal Statistical Society, Vol. 97* (No. 4), pp. 558-625.
[19] Stephan, F.F. (1941) "Stratification in representative sampling". *Journal of Marketing* 6(1), pp. 38-46.
[20] For comparison, Appendix G shows the findings if we had retained the original sample structure by project and maximum measure group rather than reorganizing into measures.

re-stratify the population of measures in order to conduct post-stratification, the process where we calculate case weights based on the achieved sample.

The break points for each post-stratified stratum were established based upon the reported annual energy savings at the measure level. Because of the variation in measure group annual savings, break points differ by measure group. For each measure group, there were three steps to re-stratifying after the new measure groups were defined:

1. The "Take None" stratum was redefined as any individual measure with reported savings of *less than* 2% of the total for that measure group. An exception was made for measures that were included in our sample because they were part of a larger project included in the sample.
2. The "Census" stratum was redefined as measures that represent a larger portion of savings than typical measures for that group. The portion of savings represented by this stratum and individual projects in this stratum varied by measure group, but in all cases, each measure represented more than 4% of annual savings for that measure.
3. The "Random" strata were then split to have relatively equal shares of the remaining annual savings.

All measure groups except for the "Other" group (which had 3) had 4 strata in addition to the "take none" stratum. The post-stratified program population and sample for electric measures is summarized in **Table 3-3**; a similar summary for natural gas is provided in **Table 3-4**.

Table 3-3. Electric Sample Design by Measure Group and Post-Stratum

Measure Group	Stratum	Sampling	Measures	Total kWh	Portion of Annual Savings	Sample	Case Weight
Compressed Air	1	None	83	455,344	0.60%	0	-
	2	Random	147	5,877,450	7.75%	14	10.50
	3		32	4,672,520	6.16%	5	6.40
	4		11	5,246,631	6.91%	5	2.20
	5	Census	2	6,964,975	9.18%	2	1.00
HVAC	1	None	327	286,466	0.38%	0	-
	2	Random	447	3,836,432	5.06%	36	12.42
	3		86	5,653,394	7.45%	15	5.73
	4		10	3,067,283	4.04%	5	2.00
	5	Census	2	1,335,070	1.76%	1	2.00
Lighting	1	None	93	365,770	0.48%	0	-
	2	Random	170	5,000,205	6.59%	18	9.44
	3		41	6,117,106	8.06%	8	5.12
	4		12	5,437,883	7.17%	4	3.00
	5	Census	2	2,632,966	3.47%	2	1.00
Process	1	None	78	265,970	0.35%	0	-
	2	Random	97	3,557,289	4.69%	8	12.12

Measure Group	Stratum	Sampling	Measures	Total kWh	Portion of Annual Savings	Sample	Case Weight
	3		29	4,253,799	5.61%	5	5.80
	4		10	3,783,177	4.99%	6	1.67
	5	Census	4	2,506,472	3.30%	2	2.00
Other	1	None	29	87,016	0.11%	0	-
	2	Random	16	1,136,764	1.50%	6	2.67
	3		4	1,795,234	2.37%	3	1.33
	4	Census	1	1,549,969	2.04%	1	1.00
Overall	**-**	**-**	**1,733**	**75,885,185**	**100%**	**146**	**-**

Table 3-4. Gas Sample Design by Measure Group and Post-Stratum

Measure Group	Stratum	Sampling	Measures	Total CCF	Portion of Annual Savings	Sample	Case Weight
Boiler	1	None	24	6,628	0.70%	0	-
	2	Random	64	78,896	8.31%	7	9.14
	3		28	94,517	9.96%	4	7.00
	4		12	104,972	11.06%	4	3.00
	5	Census	3	51,245	5.40%	2	1.50
Other	1	None	56	11,812	1.24%	0	-
	2	Random	80	125,331	13.21%	14	5.71
	3		15	124,643	13.13%	5	3.00
	4		5	183,947	19.38%	5	1.00
	5	Census	2	167,005	17.60%	2	1.00
Overall	**-**	**-**	**289**	**948,996**	**100%**	**43**	**-**

3.2 Methods for Data Analysis

For each project, the evaluation team reviewed project documentation, developed a site-specific measurement and verification plan, and conducted site visits. These steps are described briefly below. More detail on the impact evaluation methods used is provided in Appendix A: Impact Methods.

Project Documentation "Desk Review"

The first step in the evaluation process for each project was a desk review of project documentation. The desk review allowed the analyst to become familiar with the project calculations and descriptions, and to check whether the calculations were consistent with the described project and the claimed savings in the tracking system.

Second, the evaluation team reviewed the project calculations. The evaluation team reviewed prescriptive projects (*i.e.*, projects using deemed savings values) to determine if the completed projects were consistent with the prescriptive measures claimed, and to ensure that the method from the PSD was followed correctly. The evaluation team also reviewed the documentation for custom projects for calculation errors, and to ensure that they were completed using applicable engineering principles and practice, appropriate assumptions, and equipment characteristics consistent with the supplied documentation. As part of this process, the analyst, in most cases, replicated the calculations - creating revised *reported* savings estimates - to support *evaluated* measurement and savings estimates. This was also done to identify areas of uncertainty that were then addressed through the site-specific measurement and verification efforts.

In some cases, the revisions to the savings estimates involved substituting verified assumptions into the original calculation. In other cases, where the underlying calculation methods were more complex or it was impossible to determine how the savings estimate was determined, the evaluation team developed an independent calculation of energy savings based on engineering judgment and common energy engineering practices. Finally, the desk review supported the development of a detailed site-specific measurement and verification plan to verify project savings.

Data Collection

After completing a desk review of the project documentation, the evaluation team worked with the utilities and the CT evaluation administrator to gather applicable utility billing data, both before and after project installation. This was done to potentially support site-specific billing analysis (IPMVP Option C) or consumption-calibrated analysis.

Evaluation team engineers conducted on-site data collection visits in order to complete the following:

- Verify that the equipment included in the project was installed as expected and operates as described in the project documentation
- Verify make/model number and relevant performance specifications of equipment involved in the project
- Verify operational parameters such as hours of operation, motor load factors, heating and cooling efficiencies, etc.
- Identify baseline system operation
- Collect instantaneous measurements of equipment performance
- Install data loggers for short or long-term metering

Each site visit included physical inspection of measures and a customer interview to gather information about the project for verification purposes and to gather information about the completed project. The evaluation team used two different approaches for inspecting projects with constant loads (e.g., projects with constant speed fans or pumps) versus projects with significant fluctuations in load (e.g., variable frequency drives, building controls). For projects that serve a constant load, spot measurements of critical parameters such as amps, kW, temperatures and flow rates were taken. However, for measures involving equipment that operate with significant fluctuations in load, the evaluation team installed data loggers for a period of at least two weeks (often longer, depending upon the expected variation). The evaluation team collected

additional data as appropriate, to normalize or extrapolate the data taken over a limited sampling time to represent the expected annual operation. These data could include outdoor air temperatures, production levels, facility schedules, or other factors as required.
The evaluation team used metering equipment that complies with the M-MVDR to complete short and long-term metering. Each type of metering equipment and its specifications are provided in Appendix B: Metering Equipment Used. A summary of the logging equipment deployed to evaluate the 187 total measures included in the sample can be seen in Table 3-5.

Table 3-5. Quantities of Logging Equipment Deployed

Building Automation System Trend Points	Energy Loggers	Amp Loggers	Temperature/Relative Humidity Sensors	Thermocouple	Light Level/Status Sensor	Motor On/Off Sensor
422	123	88	126	4	214	4

When data loggers could not be safely deployed or when metering was not permitted by the customer, inspectors reviewed daily operations and maintenance logs, gathered system set points and operating conditions from central energy management systems, and reviewed the historic trend data, if available. During a site visit, inspectors also commonly requested that customers start collecting real-time energy consumption data. Inspectors followed up with customers several weeks later to obtain the results.

Project-Specific Analysis

To determine evaluated savings, the evaluation team used the data collected through on-site data collection, metering, and/or IPMVP Option C pre-post billing analysis. In most cases, the data were used to develop hourly operating and/or power use profiles for each measure and for each unique day-type of a typical year (e.g., weekday, weekend, holiday, as well as any customer-specific day-types), and/or incidence of outside temperature or "bin methods" for the post-implementation case.

The evaluation team also developed an estimated pre-implementation operation baseline case for each day-type, typically based on the post-implementation metered data, equipment specification data for pre- versus post-measure cases, and a customer interview used to identify differences in operations before and after the measure was installed. The team then applied these day-types to each day of the year, to develop an hourly profile of equipment operation for both the base case (pre-measure) and the post-installation case for an entire year; the resulting profile is called an "8760 model" or load shape. Using this model, the evaluation team calculated both energy and peak demand evaluated savings values based on the difference between pre- and post-implementation conditions (e.g., the operational and coincident adjustment). The construction of the profile and analysis was different for non-weather sensitive and weather sensitive measures; each is described below.

Non-Weather Sensitive Measures

For non-weather sensitive measures, the evaluation team used the short-term data collected to relate the operating characteristics (such as power [kW]) of the affected equipment to other independent driving parameters. These Included time of day, day-type, production levels, operating schedules, and other factors germane to the project operation, performance, and energy use. Parameters used were determined through examination of the original calculations as well as through on-site interviews. Typically, multiple relationships were required to sufficiently account for annual expected operating patterns and variations. The relationships were then annualized based on the expected annual patterns in production, day-type relationships, and other factors to determine the savings for each hour of the year in the 8760 model.

Weather Sensitive Measures

For weather sensitive measures, the evaluation team used the short-term metered data collected to relate the operating characteristics (such as power [kW]) of the affected equipment to outdoor air temperature and humidity levels and/or enthalpy, as applicable. Typically, multiple regression analyses were required for each individual piece of equipment at a site to account for variations in operation for occupied versus unoccupied periods, day-types, in addition to any other factor determined to be important. The evaluation team then used the results of the regression analyses to calculate the expected usages and savings for each hour of the year for that measure at that site using typical meteorological year (TMY3) weather data as the independent driving variable in the 8760 model.

Gross Evaluated Energy Savings

After the development of gross evaluated savings for each sampled measure, the evaluation team extrapolated the measure-specific results to the population of measures. The evaluation team used the realization rates as the basis for extrapolating estimates.

For all measures, the evaluation team weighted the measure group-level realization rates by the 2012-2013 *reported* savings values to account for their relative contribution to the overall savings. Measure group realization weights were calculated using the case weights developed in post-stratification. We applied the realization rates by measure group to the total reported program savings for that measure group.

Gross Evaluated Demand Savings

All peak demand reductions were calculated using an 8,760-hour modeling approach, with the expected demand reductions being calculated for each hour of the year. Using this approach, the summer and winter peak demand reductions were determined by averaging the non-holiday weekday peak hours. The seasonal peak is determined on the hourly system load when greater than or equal to 90% of the expected 50/50 peak load forecast. Therefore, the times and dates for this condition cannot be so easily defined. It has been shown that system load is found to be related to both the time of day, as well as weather conditions. The evaluation team identified the hours appropriate based on the expected 50/50 system peak load for the summer and winter conditions in the *2011-2020 Forecast Report of Capacity, Energy, Loads, and Transmission report.*[21]

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[21] ISO New England. (2011). 2011-2020 Forecast Report of Capacity, Energy, Loads, and Transmission. Retrieved from: http://www.iso-ne.com/trans/celt/report/2011/2011_celt_rprt.pdf

3.3 General Vendor Survey

The purpose of the baseline pilot study general vendor survey was to gather data to estimate the baseline efficiency and market share for each measure category within this program. Vendors were selected randomly from a population of approximately 6,200 lighting and HVAC vendors in Connecticut. Vendors were recruited through a telephone survey and offered a $50 incentive if they completed an online survey. HVAC vendors were asked to fill out an HVAC-specific online survey while lighting vendors were asked to fill out a lighting-specific online survey. All surveys were conducted between March 2015 and May 2015. The survey instruments are presented in Appendix C: General Vendor Survey Instruments.

The target precision for overall baseline efficiency was 10% with 90% confidence. To achieve the desired confidence level, the sample target for the online survey was determined to be 75 lighting vendors and 75 HVAC vendors. Assuming a 50% response rate for the online survey, the target number of completes for the telephone survey was 150 lighting vendors and 150 HVAC vendors.

Responses were only considered from vendors that completed both the telephone and online surveys. HVAC vendors reported units sold by measure type, size, and efficiency. Lighting vendors reported units sold by measure type as well as their thoughts on changes in the energy-efficient lighting market. All vendors reported on the types of projects they implement, their participation and awareness of Energy Conscious Blueprint and Energy Opportunities Programs, and general firmographic information.

4. RESULTS

This section contains the results of the ECB Program impact evaluation. The evaluation team first presents a summary of results for the overall ECB Program (including a summary of the precision of those results). Then findings are presented for each electric (Lighting, HVAC, Compressed Air, Process, and HPBD/Other) and gas (Boiler and Other) measure group. In addition to presenting savings for the program and measure group categories, this section also describes the main drivers in variations between the evaluated and reported savings values.

4.1 Summary of Results

Based on the sample sites, the 2012-2013 ECB Program realization rates for annual energy savings are 84% for electric projects and 78% for gas projects. In addition, the 2012-2013 ECB Program realization rates are 85% for summer demand and 90% for winter demand. The resulting total evaluated energy savings are 63,978 MWh and 762,393 therms. The resulting total evaluated demand savings are 11.98 MW for the summer seasonal peak and 8.82 MW for the winter seasonal peak.[22] These values are summarized in Table 4-1 below.

Table 4-1. Total ECB Program Impact Evaluation Summary

Category	Realization Rate	Evaluated Savings	Relative Precision	Confidence Interval
Electric Energy Savings (MWh)	84%	63,978	+/-21%	90%
Electric Summer Demand Savings (MW)	85%	11.98	+/-20%[23]	80%
Electric Winter Demand Savings (MW)	90%	8.82	+/-25%[24]	80%
Natural Gas Savings (therms)	78%	762,393	+/-15%	90%

4.2 Overall Evaluated Coefficients of Variation and Error Ratios

The evaluation team did not reach the desired confidence and precision of 90/10 for overall program savings (electric and gas). The target of 80/10 for demand savings was also not met. Table 4-2 presents the evaluated coefficient of variation (*c.v.*), error ratio (*e.r.*) and confidence/precision values. As noted in the methodology, the sample was designed to meet the desired confidence and precision based on an assumed error ratio of 0.5 at the overall program level. Based on site-specific realization rates, the evaluation team calculated the evaluated *c.v.* and *e.r.* and confidence/precision values. The methods used for this calculation are given in Appendix A: Impact Methods.[25] The evaluation team recommends using the *c.v.* and *e.r.* estimates in the table below when planning future evaluations and stratifying the sample, where reasonable.

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[22] The impact evaluation period includes project completed between January 1, 2012 and October 31, 2013.
[23] Summer demand savings meet a one tailed relative precision of +10% at 80% confidence.
[24] Winter demand savings meet a one tailed relative precision of +9% at 80% confidence.
[25] While the evaluation team calculated the *c.v.* for the purposes of comparing to the expected values and for future evaluations, the relative precision for the electric savings are calculated based on realization rates by strata which relies on weighted squared errors instead of relative errors. The error ratios are provided here as well.

Table 4-2. Evaluated Coefficients of Variance, Error Ratios, and Confidence/Precision Values

Group	Energy			Summer Demand			Winter Demand		
	c.v.	e.r.	Confidence/ Precision	c.v.	e.r.	Confidence/ Precision	c.v.	e.r.	Confidence/ Precision
Electric - Compressed Air (kWh)	2.18	1.72	90%/18%	1.36	1.7	80%/11%	1.28	1.75	80%/11%
Electric - HVAC (kWh)	1.41	1.15	90%/22%	1.82	1.82	80%/20%	1.62	2.02	80%/36%
Electric – Lighting (kWh)	0.62	0.55	90/20%	0.72	0.62	80%/16%	0.84	0.75	80%/20%
Electric – Process (kWh)	0.69	0.66	90%/25%	2.54	2.21	80%/35%	2.19	2.74	80%/41%
Electric - HPBD/Other (kWh)	0.76	0.67	90%/18%	1.7	0.87	80%/22%	1.7	5.39	80%/29%
Electric Overall	**0.99**	**0.95**	**90%/21%**	**1.62**	**1.40**	**80%/20%**	**1.53**	**1.95**	**80%/25%**
Gas – Boiler (therms)	0.46	0.39	90%/14%	-	-	-	-	-	-
Gas – Other (therms)	0.97	1.03	90%/15%	-	-	-	-	-	-
Gas Overall	**0.71**	**0.82**	**90%15%**	**-**	**-**	-	**-**	**-**	-

The evaluation team found a greater degree of variation across sampled sites than anticipated and thus had lower precision than planned for most of the realization rates. For annual energy savings, it is customary to target ±10% relative precision at the 90% confidence interval in Connecticut energy efficiency program evaluations. The impact evaluation for the 2012-2013 ECB program did not meet this target for gas or electric overall or for any of the individual measure groups as a result of the high variability in site-specific realization rates, which was much higher than anticipated in the sample designs.[26] Table 4-3 shows the weighted average realization rate for each measure group for electric energy savings as well as the standard deviation and maximum and minimum realization rates for the evaluated projects.

Table 4-3. ECB Realization Rate Summary for Electric Energy Savings by Measure Group

Measure Group	Total Sample Reported kWh	Weighted Avg Realization Rate	Min Realization Rate	Max Realization Rate	Std Error	Relative Precision @ 90% Confidence
Compressed Air	11,921,803	49%	0%	1577%	0.11	18%
HVAC	4,070,802	85%	-29%*	871%	0.13	22%
Lighting	6,581,511	102%	0%	277%	0.12	20%
Process	3,742,329	102%	0%	220%	0.15	25%
HPBD/Other	3,394,326	96%	0%	199%	0.11	18%

* Negative savings on project where savings were claimed for multiple, overlapping measures (double-counting savings).

For demand reduction values, sampling must achieve statistical accuracy and precision of no less than 80% confidence at ±10% relative precision (80/10) in order to comply with ISO New England's M-MVDR.[27] As with electric energy savings, high variability in site-specific realization

[26] By the term, "variability," we refer to the degree to which the realization rates were different across projects in the sample. Large variability indicates a wide range of realization rates with high dispersion; small variability indicates a small range of realization rates. Where there were values of 'zero' included in the tracking data and savings were identified, the realization rates were quite high.

[27] ISO New England Inc., ISO New England Manual for Measurement and Verification of Demand Reduction Value from Demand Resources (Manual M-MVDR).

rates prevented the evaluation team from meeting this target for both measure group level and program level summer demand realization rates. One driving factor in this case is several entries of “zero” summer demand savings in the utilities’ tracking databases for some measures that were found to have summer demand savings in the evaluation (four compressed air measures, three process measures, three energy simulation measures, and 10 HVAC measures). Table 4-4 shows the weighted realization rate for each measure group for electric summer demand as well as the standard deviation and maximum and minimum realization rates for the evaluated projects. Similar statistics for winter demand are provided in Table 4-5.

Table 4-4. ECB Realization Rate Summary for Summer Demand by Measure Group

Measure Group	Total Sample Reported Summer kW	Weighted Avg Realization Rate	Min Realization Rate	Max Realization Rate	Std Error	Relative Precision @ 80% Confidence
Compressed Air	1,612	55%	0%	870%	0.08	11%
HVAC	939	66%	0%	1573%	0.16	20%
Lighting	1,304	114%	0%	483%	0.13	16%
Process	541	105%	0%	403%	0.27	35%
HPBD/Other	733	98%	-104%	248%	0.17	22%

Table 4-5. ECB Realization Rate Summary for Winter Demand by Measure Group

Measure Group	Total Sample Reported Winter kW	Weighted Avg Realization Rate	Min Realization Rate	Max Realization Rate	Std Error	Relative Precision @ 80% Confidence
Compressed Air	1,602	58%	0%	1137%	0.08	11%
HVAC	284	108%	0%	1498%	0.28	36%
Lighting	910	112%	-1%	438%	0.15	20%
Process	504	111%	0%	403%	0.32	41%
HPBD/Other	604	45%	0%	49%	0.23	29%

Overall, the electric measure groups having the most significant impact on relative precision, the *c.v.*, and the *e.r.* are Compressed Air and HVAC. Project-specific realization rates for compressed air measures ranged from 0% to 1577% for energy savings and 0% to 870% for summer demand savings. Project-specific realization rates for HVAC measures ranged from -29% to 871% for energy savings and 0% to 1573% for summer demand savings. The variability of realization rates for the other three electric measure groups was also relatively high, with a significant number of measures within each group requiring large positive or negative demand savings adjustments. Due to the high fluctuations in site-specific realization rates, the program-level *e.r.* values were higher than initially assumed. This led to target precision values not being met for either energy or demand savings. In theory, increasing the sample size could have helped us meet our precision target. However, given the extreme variability across site-specific realization rates, the sample needed would likely be cost-prohibitive. The evaluation team calculated the electric measure sample size that would have been required to meet the precision targets given the evaluated *c.v.* values to be 223. This is more than triple the original electric measure sample size. Enhanced up front reviews of *reported* calculations could help to reduce the variability in site-specific realization rates and may be a more cost effective way to ensure that precision targets are met in the future.

Table 4-6. ECB Realization Rate Summary for Gas Energy Savings by Measure Group

Measure Group	Total Sample Reported Therms	Weighted Avg Realization Rate	Min Realization Rate	Max Realization Rate	Std Error	Relative Precision @ 80% Confidence
Boiler	108,141	96%	24%	242%	0.09	14%
Other	422,714	68%	0%	263%	0.09	15%

4.3 Electric Energy Savings & Realization Rates

Table 4-7 shows overall 2012-2013 ECB electric savings based on the evaluation findings. They reflect a wide array of adjustments, which are discussed in more detail below. The **evaluated electric energy realization rate is 84%** with precision of ±21% at the 90% confidence level. The **evaluated summer seasonal electric demand realization rate is 85%** with precision of ±20% at the 80% confidence level. The **evaluated winter seasonal electric demand realization rate is 90%** with a precision of ±25% at the 80% confidence level.

Table 4-7. ECB Overall Electric Program Savings

Savings Adjustment	Energy		Summer Seasonal Demand		Winter Seasonal Demand	
Reported Savings	75,885,185 kWh		14,064 kW		9,768 kW	
Documentation Adjustment	-14,735,383 kWh	-19.4%	-1,697 kW	-12.1%	-1,226 kW	-12.6%
Technology Adjustment	-659,878 kWh	-0.9%	-164 kW	-1.2%	-84 kW	-0.9%
Quantity Adjustment	51,872kWh	0.1%	-271 kW	-1.9%	-209 kW	-2.1%
Operation Adjustment	4,804,705 kWh	6.3%	488 kW	2.6%	573 kW	5.9%
Heating and Cooling Adjustment	-1,368,775 kWh	-1.8%	-445 kW	-3.2%	0 kW	0%
Evaluated Savings	63,977,727 kWh	-15.7%	11,975 kW	-14.9%	8,822 kW	-9.7%
Realization Rate	84%		85.1%		90.3%	
Relative Precision	21%		20%		25%	
Confidence Interval	90%		80%		80%	

As can be seen in Table 4-7, downward documentation adjustments had the most significant impact on the overall electric energy and demand savings realization amongst the population of projects evaluated. Operations adjustments also had a significant impact at the measure category levels, but were off-setting at the program level. Very few quantity adjustments were required, which indicates that the program is performing well when it comes to processing applications and tracking measures in the program database.

Table 4-8, Table 4-9, Table 4-10, Table 4-11, and Table 4-12 summarize the overall 2012-2013 ECB Program electric savings for the Compressed Air, HVAC, HPBD/Other, Lighting, and Process measure groups. A general overview of the most common measures associated with each group accompanies each table.

The **Compressed Air measure group energy realization rate is 49%** with precision of ±18% at the 90% confidence level. The **Compressed Air summer electric demand realization rate is 55%** with precision of ±11% at the 80% confidence level. The **Compressed Air winter electric demand realization rate is 58%** with a precision of ±11% at the 80% confidence level.

Table 4-8. ECB Compressed Air Measure Group Savings

Savings Adjustment	Energy		Summer Seasonal Demand		Winter Seasonal Demand	
Reported Savings	23,216,920 kWh		2,997 kW		2,789 kW	
Documentation Adjustment	-12,072,798 kWh	-52%	-1,708 kW	-57%	-1,618 kW	-58%
Technology Adjustment	-464,338 kWh	-2%	-90 kW	-3%	-84 kW	-3%
Quantity Adjustment	0 kWh	0%	0 kW	0%	0 kW	0%
Operation Adjustment	696,508 kWh	3%	450 kW	15%	530 kW	19%
Heating and Cooling Adjustment	0 kWh	0%	0 kW	0%	0 kW	0%
Evaluated Savings	11,376,291 kWh	-51%	1,648 kW	-45%	1,618 kW	-42%
Realization Rate	49%		55%		58%	
Relative Precision	18%		11%		11%	
Confidence Interval	90%		80%		80%	

The **HVAC measure group energy realization rate is 85%** with precision of ±22% at the 90% confidence level. The **HVAC summer electric demand realization rate is 66%** with precision of ±20% at the 80% confidence level. The **HVAC winter electric demand realization rate is 108%** with a precision of ±36% at the 80% confidence level.

Table 4-9. ECB HVAC Measure Group Savings (Electric)

Savings Adjustment	Energy		Summer Seasonal Demand		Winter Seasonal Demand	
Reported Savings	14,178,645 kWh		4,069 kW		1,229 kW	
Documentation Adjustment	-1,701,437 kWh	-12%	-244 kW	-6%	-111 kW	-9%
Technology Adjustment	0 kWh	0%	0 kW	0%	0 kW	0%
Quantity Adjustment	0 kWh	0%	-81 kW	-2%	0 kW	0%
Operation Adjustment	-425,359 kWh	-3%	-1,058 kW	-26%	209 kW	17%
Heating and Cooling Adjustment	0 kWh	0%	0 kW	0%	0 kW	0%
Evaluated Savings	12,051,848 kWh	-15%	2,685 kW	-34%	1,327 kW	8%
Realization Rate	85%		66%		108%	
Relative Precision	22%		20%		36%	
Confidence Interval	90%		80%		80%	

The **Lighting measure group energy realization rate is 110%** with precision of ±20% at the 90% confidence level. The **Lighting summer electric demand realization rate is 114%** with precision of ±16% at the 80% confidence level. The **Lighting winter electric demand realization rate is 112%** with a precision of ±20% at the 80% confidence level.

Table 4-10. Lighting Measure Group Savings

Savings Adjustment	Energy		Summer Seasonal Demand		Winter Seasonal Demand	
Reported Savings	19,553,930 kWh		3,708 kW		2,661 kW	
Documentation Adjustment	782,157 kWh	4%	445 kW	12%	160 kW	6%
Technology Adjustment	-195,539 kWh	-1%	-74 kW	-2%	0 kW	0%
Quantity Adjustment	195,539kWh	1%	0 kW	0%	-27 kW	-1%
Operation Adjustment	2,542,011 kWh	13%	593 kW	16%	186 kW	7%
Heating and Cooling Adjustment	-1,368,775 kWh	-7%	-445 kW	-12%	0 kW	0%
Evaluated Savings	21,509,323 kWh	10%	4,227 kW	14%	2,980 kW	12%
Realization Rate	110%		114%		112%	
Relative Precision	20%		16%		20%	
Confidence Interval	90%		80%		80%	

The **Process measure group energy realization rate is 102%** with precision of ±25% at the 90% confidence level. The **Process summer electric demand realization rate is 105%** with precision of ±35% at the 80% confidence level. The **Process winter electric demand realization rate is 111%** with a precision of ±41% at the 80% confidence level.

Table 4-11. Process Measure Group Savings (Electric)

Savings Adjustment	Energy		Summer Seasonal Demand		Winter Seasonal Demand	
Reported Savings	14,366,707 kWh		2,707 kW		2,283 kW	
Documentation Adjustment	-1,149,337 kWh	-8%	-189 kW	-7%	342 kW	15%
Technology Adjustment	0 kWh	0%	0 kW	0%	0 kW	0%
Quantity Adjustment	-143,667 kWh	-1%	-189 kW	-7%	-183 kW	-8%
Operation Adjustment	1,580,338 kWh	11%	514 kW	19%	91 kW	4%
Heating and Cooling Adjustment	0 kWh	0%	0 kW	0%	0 kW	0%
Evaluated Savings	14,654,041 kWh	2%	2,842 kW	5%	2,534 kW	11%
Realization Rate	102%		105%		111%	
Relative Precision	25%		35%		41%	
Confidence Interval	90%		80%		80%	

The **HPBD/Other measure group energy realization rate is 96%** with precision of ±18% at the 90% confidence level. The **HPBD/Other summer electric demand realization rate is 98%** with precision of ±22% at the 80% confidence level. The **HPBD/Other winter electric demand realization rate is 45%** with a precision of ±29% at the 80% confidence level.

Table 4-12. HPBD/Other Measure Group Savings (Electric)

Savings Adjustment	Energy		Summer Seasonal Demand		Winter Seasonal Demand	
Reported Savings	4,568,983 kWh		584 kW		805 kW	
Documentation Adjustment	-593,968 kWh	-13%	0 kW	0%	0 kW	0%
Technology Adjustment	0 kWh	0%	0 kW	0%	0 kW	0%
Quantity Adjustment	0 kWh	0%	0 kW	0%	0 kW	0%
Operation Adjustment	411,208 kWh	9%	-12 kW	-2%	-443 kW	-55%
Heating and Cooling Adjustment	0 kWh	0%	0 kW	0%	0 kW	0%
Evaluated Savings	4,386,224 kWh	4%	572 kW	-2%	362kW	-55%
Realization Rate	96%		98%		45%	
Relative Precision	18%		22%		29%	
Confidence Interval	90%		80%		80%	

4.4 Natural Gas Energy Savings & Realization Rates

Table 4-13 shows overall 2012-2013 ECB Program natural gas savings based on the evaluation findings; they reflect a wide array of adjustments. The natural gas energy realization rate is 78% with precision of ±15% at the 90% confidence level.

Table 4-13. ECB Overall Gas Program Savings

Savings Adjustment	Energy	
Reported Savings	978,415 therms	
Documentation Adjustment	-136,747 therms	-14%
Technology Adjustment	0 therms	0%
Quantity Adjustment	31,587 therms	3%
Operation Adjustment	-10,861 therms	-11%
Heating and Cooling Adjustment	0 therms	0%
Evaluated Savings	762,393	
Realization Rate	78%	
Relative Precision	15%	
Confidence Interval	90%	

Table 4-14 and Table 4-15 summarize the overall 2012-2013 ECB Program gas savings for the Gas – (boiler and gas) – and Gas (other) measure groups. The measures included in the Gas–Other group were high efficiency heating equipment, domestic water heaters, and other custom processes.

The **Gas – Boiler energy realization rate is 96%** with precision of ±14% at the 90% confidence level.

Table 4-14. ECB Gas - Boiler Measure Group Savings

Savings Adjustment	Energy	
Reported Savings	346,682 therms	
Documentation Adjustment	-10,400 therms	-3%
Technology Adjustment	0 therms	0%
Quantity Adjustment	0 therms	0%
Operation Adjustment	-3,467 therms	-1%
Heating and Cooling Adjustment	0 therms	0%
Evaluated Savings	332,815 therms	
Realization Rate	96%	
Relative Precision	14%	
Confidence Interval	90%	

The **Gas – Other energy realization rate is 68%** with precision of ±15% at the 90% confidence level.

Table 4-15. ECB Gas - Other Measure Group Savings

Savings Adjustment	Energy	
Reported Savings	631,733 therms	
Documentation Adjustment	-126,347 therms	-20%
Technology Adjustment	0 therms	0%
Quantity Adjustment	31,587 therms	5%
Operation Adjustment	-107,395 therms	-17%
Heating and Cooling Adjustment	0 therms	0%
Evaluated Savings	429,578 therms	
Realization Rate	68%	
Relative Precision	15%	
Confidence Interval	90%	

4.5 Forward-Looking Realization Rates

The forward-looking realization rate is used to determine how the updated 2015 PSD improves the results and realization rates of the sampled 2012-2013 ECB projects that used the 2012-2013 PSD default values for reported estimates. In the forward-looking analysis all stipulated values are updated based upon changes to key assumptions in the PSD, while custom site-specific assumptions from the original reported savings estimates are retained. This approach is used since custom overwrites are permissible regardless of the version of the PSD.

It is also important to note that this forward-looking analysis does not incorporate modifications to baseline assumptions linked to energy code updates. Baseline adjustments, such as code allowable watts per square foot for lighting systems or minimum cooling efficiency for rooftop package units, have not been incorporated as these types of changes compromise the merit of an incented measure. Incentives are paid based upon an assumed amount of savings, which rely upon a certain degree of energy efficiency improvement. The merit and cost-effectiveness of a measure is threatened when baseline efficiency alone is increased.

The adjustments made to the PSD between 2012 and 2015 mostly pertain to changes to effective full load hour (EFLH) assumptions and updates to the interactive effects for lighting measures; namely an increase to the assumed cooling system efficiency. The assumed coefficient of performance (COP) from the 2012 PSD was 2.4 and from the 2013 PSD was 3.5. The 2015 PSD stipulates a COP assumption of 4.5 for all lighting interactive effects (cooling savings/heating penalty) calculations.

The forward-looking electric energy realization rate increased to 86.7%. The forward-looking realization rates for summer and winter demand are 90.5% and 85.9%, respectively. No substantial changes were made to the PSD between 2012 through 2015 with regard to gas measures evaluated. Therefore, the forward-looking gas energy realization rate remains at 78%.

4.6 Accuracy of Vendor Energy Savings Estimates and Recommendations

Crosscutting Themes for Evaluated Compressed Air Measures

The evaluation team identified a number of crosscutting themes among the evaluated compressed air measures. Calculation errors in the reported analyses were the cause of a number of large adjustments to savings estimates. Overall, projects that did not have calculation errors were found to accurately represent the compressed air system energy savings. Unfortunately, calculation errors were discovered in reported savings estimates for three of the largest projects from 2012-2013, which in aggregate resulted in an overall reduction in evaluated electric savings of 8,774,921 kWh. This represents approximately 98% of all savings adjustments made to the compressed air measure category. The remaining 2% of downward savings were distributed amongst the other evaluated compressed air measures.

The weighted overall realization rates for energy and winter and summer demand savings were low compared to the other four electric measure groups (Lighting, HVAC, HPDB/Other, and Process). The weighted average energy savings realization rate for the Compressed Air measure group was approximately 49% and the summer and winter demand realization rates were 55% and 58%, respectively.

Documentation Adjustments

There were generally two types of documentation adjustments made to the compressed air measures reviewed. Many of the measures were adjusted due to the reported analysis (ex-ante) using compressor performance information that was inconsistent with the manufacturers' specifications. Specifically, several measures were adjusted for minor inconsistencies with the compressor full load demand, the full load airflow, or the rated pressure. Additionally, the reported analysis assumed that the part load performance for VFD compressors was proportional to flow. The evaluation revised the VFD performance profile to be consistent with the manufacturer's information and CAGI performance curves or to the Compressed Air Challenges typical performance curves. The adjustments described in this paragraph did not affect sector strata savings significantly in aggregate.

The Compressed Air measure group ended up with a weighted average realization rate of 49% for energy, with the majority of the reduction in savings attributable to a single project selected for the Census stratum. The project involved the installation of four centrifugal air compressors at a manufacturing facility in order to meet a combination of existing and new compressed air demand. The four compressor systems were sized and sequenced to cycle on and off depending on demand. This allows the system to capitalize on part-load system efficiencies. In the reported savings calculations, it was assumed that the manufacturing facility would operate 8,736 hours per year with each air compressor operating for approximately 7,007 hours per year. Based upon a review of daily run-time logs across a 556-day period it became clear that this value was intended to represent the combined run-hours of the compressed air system as a whole. Individual compressors, being sequenced as described above, operate considerably fewer hours per year.

This error resulted in savings being overestimated by a factor of four and resulted in a downward adjustment to overall project-level savings of 93%. Unfortunately, this was the largest project included in the sample, accounting for 72% of total compressed air savings. The weighted average realization rate for the Compressed Air measure category ended up being 49%, but would have been 91% with this project excluded from the sample.

A number of other compressed air projects were compromised by documentation errors that had large impacts on savings estimates; therefore, this is a cross-cutting theme. In particular, misrepresentation of compressor performance as a function of airflow (performance curves) was notable in several instances.

Technology Adjustments

There were only four technology adjustments made to the 28 compressed air measures evaluated. Two substantive technology adjustments involved modifications to baseline assumptions for air dryers. Technology adjustments accounted for a net energy savings reduction of approximately 4% at the measure group level. Two other relatively minor adjustments resulted from differences between documented and site-verified equipment model numbers.

Quantity Adjustments

There were no quantity adjustments made to the compressed air projects evaluated.

Operation Adjustments

All 28 measures evaluated required operation adjustment. These fell into a number of major categories:

- Differences in evaluated operating hours based on power metering and participant interviews compared to reported (ex-ante) assumptions; both greater and fewer operating hours.
- Measured operating characteristics of the equipment that were different than what was assumed in the reported (ex-ante) calculations (*e.g.* compressor air flow, etc.)
- Installed equipment was found to replace backup equipment.

- Installed equipment was found to not be operating as designed.

Crosscutting Themes for Evaluated HVAC Measures

This section presents the common themes identified for cooling and other HVAC-related measure adjustments. Adjustments for heating, ventilation, and air conditioning (HVAC) measures varied depending upon the technology and affected system type; therefore, findings for the HVAC stratum have been partitioned into several sub-categories: cooling (efficient AC); economizing; chillers; variable frequency drives; and other.

A total of 61 HVAC-related measures were evaluated. HVAC measures included any project that included the installation of high efficiency HVAC equipment or improvements to existing systems and controls that result in savings. Common HVAC measures included:

- Efficient rooftop air conditioning equipment
- Dual enthalpy economizer controls
- Efficient chillers
- Building envelope measures such as cool roofs, exterior wall insulation, and Low-E windows
- Variable frequency drives on hot and chilled water pumps as well as supply, return, and exhaust fans
- Central Energy Management Systems (EMS) controlling base building systems
- Demand control ventilation and CO/CO2 exhaust fan controls

The common themes for each technology category are provided below.

Cooling

Several cross-cutting themes were identified among the cooling measures evaluated. The most significant changes were downward documentation adjustments; however, downward operation adjustments were also substantive. Further detail on common adjustments is described below.

A total of 17 high efficiency cooling equipment measures were evaluated. Eleven of these measures involved the installation of high efficiency air conditioning equipment featuring enthalpy economizing. Savings from the remaining six were exclusively generated by improvements in cooling system efficiency (hereafter referred to as "cooling only measures"). Savings adjustments pertaining to the cooling efficiency component of these projects are addressed in this section. Economizer savings are addressed later. Of the six cooling only measures reviewed, all but one used the prescriptive methodology outlined in the Connecticut PSD.

<u>Documentation Adjustments</u>
The most common documentation adjustment consisted of correcting the facility type assumption, upon determining that the incorrect facility type was used in the reported (ex-ante) calculations. In adjusting the facility type, the hours of operation either increased or decreased depending on the situation. The evaluation team suspects that incorrect facility types used in the program calculator were the result of the program analyst neglecting to edit the facility type

resulting in the use of a default building type. This is suspected based on the fact that several of the calculators were observed with a key input field set to "auto-related."

Documentation adjustments for cooling-only measures amounted to a net reduction in savings of approximately 80.7%. A significant portion of this adjustment is attributed to a very large custom cooling-only project that had an energy savings realization rate of 24%. This project was by far the largest included in the sample - being nearly nine times larger than the next largest cooling project. The program provided no analysis for this project; therefore, the methodology used to determine claimed savings could not be evaluated. It was clear in a project summary file that poor baseline assumptions contributed to the over-estimation of savings.

Technology Adjustments

No cooling projects included technology adjustments.

Quantity Adjustments

Only three cooling measures required quantity adjustments. Adjustments were required upon discovering the cooling capacities used in reported savings calculations were inaccurate.

Operational Adjustments

Operational adjustments for cooling measures were typically the result of differences in operating hours and cooling loads between the assumptions used in reported (ex-ante) calculations and those determined from metering.

Overall, for the cooling measures the savings were adjusted upward slightly, by approximately 7.3%, for the sample. However, the individual projects varied widely, with individual measure realization rates varying from 6% to 148%.

Heating and Cooling Adjustments

No heating and cooling adjustments were made to any cooling measures, since this adjustment only applies to lighting measures.

Economizers

Overall, the savings for dual-enthalpy economizers were significantly lower than estimated for the majority of the evaluated measures. The majority of the savings reductions are attributed to operation adjustments. Common adjustment factors among the measures evaluated are described below.

Documentation Adjustments

Six of the eleven economizer measures evaluated required a documentation adjustment after it was discovered that incorrect, rounded cooling capacities were used in the reported analysis. The evaluated savings estimates used the actual cooling capacities, which resulted in a net reduction in savings of approximately 5%.

Technology Adjustments

Only one economizer measure required a technology adjustment. The rooftop units for project EA12H027 did not feature dual-enthalpy economizers, which contradicts the assumptions used in the reported (ex-ante) analysis.

Quantity Adjustments
Two economizer measures required quantity adjustments.

Operational Adjustments
Current energy codes require that new HVAC units be equipped with air-temperature controlled economizers, effectively eliminating a sizeable portion of claimable savings and resulting in low realization rates on economizer measures. It is possible that the utility programs may not have been updated to reflect these code changes. The incremental savings attributable to enthalpy economizers is relatively low since it only occurs when outdoor air temperatures exceed 70 degrees F and relative humidity is low. **Table 4-16** shows the four primary sets of outdoor air conditions affecting economizer operation.

Table 4-16. Economizer Operation Matrix

Outdoor Air Temperatures	Low Humidity	High Humidity
Temperature <70°F	Air Temp & Enthalpy Economizing	Air Temp Economizing Only
Temperature >70°F	Enthalpy Economizing Only	No Economizing

As shown above, both air temperature and enthalpy economizing will occur when outdoor air temperatures drop below 70 degrees F with low relative humidity. When relative humidity is high in this same temperature band, an enthalpy-controlled economizer will prevent the system from economizing. Alternatively, economizers controlled solely based upon outdoor air temperature will not permit economizing when temperatures rise above 70 degrees F regardless of humidity level; whereas an enthalpy economizer will. During these times, the introduction of extra air has the potential to reduce the cooling load on the coil due to low latent loads, even though the air is warm. However, the primary reason the savings for these types of projects were reduced is simply that there is not sufficient time during the year when these weather conditions occur in this climate zone.

Another common operational adjustment resulted from the discovery that many of the systems do not operate continuously; they are controlled to turn off during at least a portion of the unoccupied periods. Most of these unoccupied hours – at night – will coincide with most opportunities for economizer operation. Therefore, there were between 500 to 1,000 hours during the year where the dual-enthalpy economizer system would operate differently than a temperature-based economizer system.

With 500 operating hours per year, an economizer system would have had to reduce system load by more than 50% during those hours[28] to achieve the reported savings levels estimated. However, most systems are lightly loaded when economizing, due to the economizer periods occurring during moderate outdoor air temperatures. For the systems evaluated, the overall savings per ton for economizing was approximated to be 44 kWh/ton, or 15% of the reported savings values.

[28] Assuming an average cooling efficiency of 1.0 kW/ton

Heating and Cooling Adjustments

No heating and cooling adjustments were made to any cooling measures, since this adjustment only applies to lighting projects.

Efficient Chillers

A total of nine HVAC chiller measures were reviewed. Similar to the economizer measures, the savings for high efficiency chillers were also significantly reduced. The majority of the savings reductions were the result of documentation adjustments. Significant adjustments are described below.

Documentation Adjustments

Of the nine chiller measures reviewed, all but one received a documentation adjustment. The most common adjustments are described below:

1. Incorrect chiller efficiencies used in reported calculations (mostly rounding errors).
2. One measure claimed the savings based on Path A compliance in the PSD, however, the chiller did not meet the full load efficiency requirement for Path A. Therefore, the documentation adjusted savings were recalculated using Path B compliance.
    a. Path A is intended for applications where significant operating time is expected at full load.
    b. Path B is intended for applications where significant operating time is expected at part load.
3. One measure incorrectly used the high efficiency chiller curve to calculate baseline chiller energy consumption. Several measures also did not use the stipulated baseline performance curves specified in the PSD.
4. Two measures used invalid performance curves when calculating claimed savings.

Overall, rounding error corrections amounted to minor adjustments averaging approximately 2%. For instances where an incorrect chiller performance curve was used or the incorrect compliance path was used, savings reductions were far greater. Incorrect chiller performance curves and compliance paths resulted in a net decrease in chiller measure savings of approximately 70.5%.

Technology Adjustments

No chiller measures had technology adjustments.

Quantity Adjustments

Only one measure had a quantity adjustment when it was discovered that two 130-ton chillers were installed instead of a single 310-ton unit, which was outlined in the project description. It should also be noted that the original reported analysis was not provided for this measure, which required the research team to develop a custom load profile resulting in a net reduction in claimed savings of approximately 94%.

Operational Adjustments

Overall, the chiller measures were adjusted significantly upwards with the operational adjustment, resulting in an effective increase of more than 50% from claimed savings after quantity adjustments.

Each chiller project is unique with savings influenced by custom input performance curves, hours of operation, and loading conditions; therefore, no single conclusion could be made from the measures reviewed. Common themes included:

1. Increased hours of operation – Several measures indicated greater hours of operation for occupied periods.
2. Increased loads during unoccupied periods – Chillers were found to operate during overnight hours in cases where the reported analysis conservatively assumed no operation.
3. Reduced loads during occupied periods – Due to the performance improvement for the high efficiency chiller being more pronounced at lower load conditions, reducing the load in many cases increases the savings.

Heating and Cooling Adjustments

No heating and cooling adjustments were made to any cooling measures, since this adjustment only applies to lighting projects.

Variable Frequency Drives

A total of eleven variable frequency drive (VFD) projects were reviewed accounting for a total of 20 measures. Of the eleven VFD projects evaluated, seven of the projects used the prescriptive methodology outlined in the Connecticut PSD to estimate reported savings. The remaining two projects (three measures) were completed as part of a building simulation project. Overall, the savings for HVAC VFDs were predominantly affected by downward documentation adjustments and upward operational adjustments. The individual adjustments are described below.

Documentation Adjustments

Other than Project ID DKar, documentation adjustments were relatively minor for VFD measures, and mostly consisted of rounding corrections and in one instance correcting the facility type. A significant documentation adjustment was assessed on Project ID DKar, which was one of the larger VFD measures evaluated and ended up with an overall realization rate of 0%. It was determined in this project that the drives were installed on backup equipment. Approximately half of the downward savings adjustments from this single-measure project were assessed as a documentation adjustment, which resulted in an overall reduction of VFD measure-level savings of 362,562 kWh.

Technology Adjustments

No VFD measures had technology adjustments.

Quantity Adjustments

Two measures were found to not have installed VFD drives on claimed equipment in the reported analysis. Overall, the connected HP for these VFDs was relatively small and the removal of these measures only reduced the sampled HVAC VFD savings by 2%.

Operational Adjustments

Overall, the VFD measures were adjusted significantly upwards with the operational adjustment, increasing the savings by 50% compared to the claimed savings; however, there were also several measures with off-setting downward adjustments. All but one of the VFD measures evaluated received an operational adjustment. The majority of these adjustments were made based upon differences between stipulated operating characteristics versus metered including:

1. Increased hours of operation – Several measures indicated greater hours of operation for the HVAC fans and pumps.
2. Reduced loads – Several measures showed that the HVAC fans and pumps are operating at lower percent loads than assumed in the PSD. This results in the VFDs operating at lower speeds resulting in increased savings.
3. Baseline controls changed – Several measures used forward curve fans with inlet guide vanes as the baseline fan type and control method. These fans were found to be in new construction and subject to current energy code, which only requires outlet dampers for the fan sizes associated with the evaluated projects. Outlet dampers are less efficient than inlet guide vanes.
4. Controls not functioning – Two measures were found to have non-functioning drives resulting in zero energy savings. These two measures accounted for a combined 13% reduction in the sampled claimed savings among the evaluated VFD measures.

Heating and Cooling Adjustments

No heating and cooling adjustments were made to any cooling measures, since this adjustment only applies to lighting measures.

Crosscutting Themes for Evaluated Lighting Measures

Overall, the evaluated estimate of savings for lighting measures was found to be close to claimed savings, for both energy and demand. Several cross-cutting themes were identified among the lighting measures evaluated for this study. These themes illustrate common characteristics of the results of this evaluation resulting in differences between *reported* and *evaluated* savings, and the common documentation, technology, quantity, and operation adjustments made in our analyses.

Documentation Adjustments

Documentation adjustments were primarily a result of *reported* calculation errors or poor assumptions on the part of program vendors in three areas:

- Incorrect PSD factors used (particularly in demand calculations) – A very large portion of the measures used energy interactive factors to calculate demand savings. Additionally, even for facilities with constant demand, coincidence factors were still applied in reported estimates. In 48% of these cases, the factor applied was incorrect or inappropriate.
- Calculation errors – A minor error in the program calculator where rounded lighting power density values were used to estimate savings. This was found on 6 of the 21 lighting measures evaluated.

- Hours of operation being inconsistent with PSD specified values for building types (8 of 34 lighting measures evaluated).
- Incorrect building type classification – The building type for one project was incorrectly specified as a hospital. The hospital building type has significantly more operating hours than the office building type, which was more consistent with the building operation.
- Change from the whole building method to space-by-space method when sufficient information was available.
- Several incorrect space area (ft2) calculations of various types were identified in the supplied project documentation.

Technology Adjustments

Only one lighting measure required a technology adjustment that was relatively minor and site-specific.

Quantity Adjustments

Quantity adjustments were made when there were discrepancies in equipment quantities observed by the field team, versus those recorded in the reported calculations. Seven measures required a quantity adjustment.

For these measures, it appeared that the original analysis was not based on the final lighting design. In many instances, the specific quantities of light fixtures may not have been appropriately modified as changes were made during the design phase. The evaluation team also encountered instances where the combined fixture count was correct, but the documented breakdown by fixture type did not match installed quantities.

Two measures had incorrect building space type associated with the installed lighting that were not identified in the provided documentation. Since the baseline wattage was a function of the associated space type and the lighting power density for that type, the change to the building space type was considered a quantity adjustment.

Operational Adjustments

The most significant cause of operational adjustments for lighting measures were those that operated greater or fewer hours than assumed in the reported analysis. For the measures evaluated, approximately 55% of them required operating hours to be increased, compared to 45% that had the hours decreased. In aggregate, the net changes in hours of operation increased the total energy savings for lighting measures by approximately 6.5%.

It should be noted that one measure has a significant effect on the operational adjustment for the lighting category. Project WE12S044 is the largest lighting project included in the sample. This project includes the installation of a large number of production lights for a television studio. The original analysis assumed that all of the lighting systems operate during the customer provided production schedule. However, based on the data collected, some of the studios have multiple production areas with only one of which is operating at any given time. Therefore, the actual total operating power during production is substantially lower than what was used in reported savings estimates. This operation adjustment resulted in measure energy savings being decreased by more than 50%. Aside from this project, the combined operation adjustment among the remaining projects was a net increase of 25%.

A small number of measures had operational adjustments due to fixture wattage ratings being different than specified in the reported analysis. However, these adjustments were typically minor compared to the hours of operation adjustments.

Heating and Cooling Adjustments

The primary reasons for heating and cooling adjustments to lighting savings were facilities with cooling systems that were more efficient than the PSD assumption, or were not cooled. Specifically, of the 34 lighting measures evaluated, 19 claimed cooling interactive effect savings. Of these 19 projects, two measures were found to have lighting installed within spaces without cooling. For the remaining projects, the average cooling system COP was found to be 3.8, including lighting installed in refrigerated spaces. This COP is significantly higher than the default cooling system COP of 2.4 from the 2012 Connecticut Program Savings Document. However, this value is lower than the 2015 Connecticut Program Savings Document default cooling system COP of 4.5.

It should be noted that for the measures reviewed, minimal changes were made to the fraction of heat removed by the cooling system ("F" factor in the PSD). According to the PSD, for cooling systems equipped with economizers, approximately 35% of the energy from lighting must be removed by mechanical cooling. Based on the evaluation analysis, this factor was found to be approximately 34%. This minor adjustment reduced the overall lighting project savings by approximately 0.2%.

Crosscutting Themes for Evaluated Process Measures

Process measures covered a wide range of technologies but were dominated by measures involving refrigeration systems, VFDs on process equipment, and other efficient process equipment. The evaluation team identified a number of crosscutting themes among the evaluated process measures, which are described below.

The most significant savings adjustments occurred in the documentation adjustments; however, the combined upward and downward adjustments at the portfolio level ended up offsetting one another. The evaluation team evaluated seven process projects comprising 17 separate measures.

Documentation Adjustments

Documentation adjustments were primarily a result of reported calculation errors and inappropriate assumptions. The calculation errors observed by the evaluation team were not consistent and only occurred in seven of the 17 measures. The majority of these resulted in a downward adjustment to savings. A brief summary of the downward adjustments is provided below:

1. In two commercial refrigerated case measures, the cooling load reduction was calculated and converted to energy savings without using the refrigeration system efficiency. This reduced the savings by an approximate factor of 2.0 for freezers and 2.7 for coolers.
2. One project included two measures for upgrading an existing refrigeration condenser and a new efficient condenser. The new efficient condenser calculations also included the savings for the upgraded existing condenser, resulting in the savings being claimed twice.

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3. One measure for an externally mounted conveyor motor for a blast freezer was reduced due to the provided calculations assuming the motor would be 100% loaded. Conveyor motors are typically significantly oversized to allow the motors to start a conveyor that is fully loaded. In addition, the analysis included twice as many motors as were installed on the blast freezer, cutting the savings in half.
4. The reported analysis for a process chiller measure inappropriately incorporated a chilled water pump, which did not include a load factor. A typical loading factor of 80% was applied to the chilled water pump, which led to a discount of savings.
5. The only measure that received an upward adjustment was for an evaporator project, where the horsepower (HP) assumption in the reported analysis was lower than the actual verified HP.

Technology Adjustments

No process measures included technology adjustments.

Quantity Adjustments

Quantity adjustments were only made for two measures. In each case, the adjustment was made to account for discrepancies between the equipment described in the reported calculations and the equipment observed on site by the evaluation team. One measure was found to have larger motors installed than originally claimed.

Operation Adjustments

Operation adjustments affected all but two measures. Overall, these adjustments varied largely from measure to measure, but the total of all sampled process measures resulted in only minor adjustment overall for the sector stratum. The adjustments made included:

1. Two commercial refrigerated case measures had their savings increased due to the reduced lighting thermal load, which had not been incorporated into the refrigeration savings.
2. Many of the measures had differences in observed operating hours as compared to reported assumptions; both greater and fewer operating hours.
3. Many of the measures found that the equipment operated at either higher or lower operating loads as compared to the reported assumptions.

Heating and Cooling Adjustment

No process measures included heating and cooling adjustments.

Crosscutting Themes for Evaluated High Performance Building Design/Other Measures

Five of the sampled projects (nine total measures) were comprehensive, multi-measure projects completed through the use of building energy simulation software as part of a new construction or major renovation project. These comprehensive projects were assigned to the High Performance Building Design (HPBD) measure group. All reported savings for these projects were determined from calibrated building simulation models.

Evaluating the five HPBD projects was difficult as final building simulation files were excluded from the documentation provided for review. Incomplete energy simulation files were provided for two of the sampled projects, but in one instance, the documentation only included the "Pre" version of the building simulation and not the "Post" version with the energy efficiency measures incorporated.

In the absence of having the final simulation model for each site, the research team was forced to develop its own building energy simulation using project documentation, conservative assumptions and engineering judgment. The evaluation team also used information obtained from a few customers and/or architectural and engineering (A&E) firms involved on the projects. Due to inevitable differences in model assumptions between the reported and evaluated models, the savings for each project were adjusted. The majority of the adjustments made to the sampled HPBD project savings occurred under the operational adjustment; however, one project was also assessed a significant documentation adjustment (-552,952 kWh) that resulted from a calculation error in the claimed (ex-ante) savings estimate. The error was traced back to an incorrect cell reference in the spreadsheet calculation used to determine baseline RTU fan energy consumption. A value from the pump energy use calculations was referenced rather than the horsepower of the RTU fans (Project ID CE12S136).

Overall, the energy savings for the five evaluated HPBD projects were adjusted upward by approximately 5%. The effects of adjustments made to summer seasonal demand savings were insignificant and the winter seasonal demand savings were adjusted downward by approximately 53%. Due to a lack of transparency with regard to how reported savings were determined, the evaluation team is unable to provide meaningful conclusions as to the primary causes for saving adjustments.

Crosscutting Themes for Evaluated Gas-Boiler Measures

This section presents the common themes identified for natural gas boiler replacement measure adjustments. Adjustments for boiler measures included several factors. The most significant changes were downward documentation adjustments and offsetting upward and downward operations adjustments. A total of 18 boiler measures were evaluated. The total savings for the evaluated boiler measures was reduced by approximately 4%. The individual adjustments are described below.

Documentation Adjustments

Documentation adjustments were primarily a result of reported calculation errors on the part of program vendors. Of the eighteen boiler measures evaluated, four required a documentation adjustment. Three of the measures were adjusted after correcting the baseline efficiency assumption. All three of the measures used a baseline boiler efficiency of 75%; however, the 2012 PSD specifies baseline system efficiency of 80%. For the fourth measure (CE13G046), where documentation adjustment occurred, no analysis was provided; therefore, the documentation adjustment was determined as the difference between the tracking system savings and savings calculated using the PSD method. The combined effect of documentation adjustments was a net reduction in reported savings of 3%.

Technology Adjustments

No boiler measures included technology adjustments.

Quantity Adjustments

No boiler measures included quantity adjustments.

Operational Adjustments

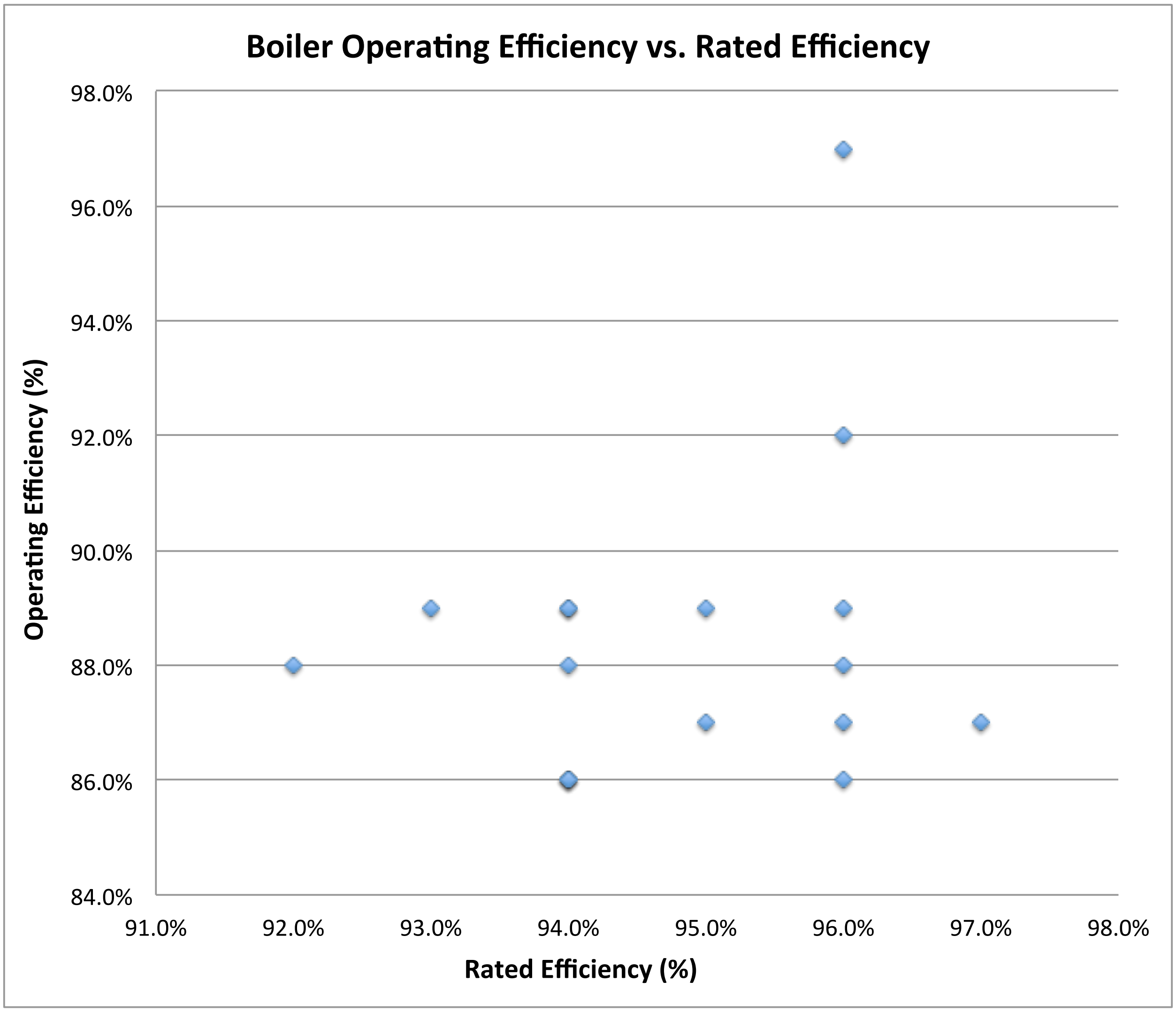
Operational adjustments for the evaluated boiler measures primarily consisted of downward adjustments to boiler system operating efficiency and offsetting upward adjustments in annual equivalent full load hours (EFLH). The combined effect of the operation adjustments was a net reduction in reported savings of approximately 1%; however, the significance and magnitude of these adjustments is significantly masked by the fact that they are offsetting.

First, with regard to the operating efficiency adjustments, a total of 74 boilers were evaluated within the 18 sampled projects. For each of these boiler systems, the operating efficiency used in the reported savings calculations was based on the rated nominal efficiency from the manufacturer and was then de-rated by 3% in accordance with the ECB Program savings methodology for gas-fired boilers. The boiler systems evaluated had an average nominal efficiency of 95.1% and therefore a “de-rated” average of 92.1%.

In the evaluated analysis, boiler efficiency was determined from manufacturer performance curves or typical performance curves, the boiler load conditions, and the boiler return water temperatures. The evaluation team found that the boilers evaluated were operating at a significantly lower efficiency level than the de-rated nominal efficiency. The majority of the boilers were observed to be operating at high return water temperatures, often operating between 140° and 180°F, depending on the individual settings and reset schedules. The average operating return water temperature was estimated to be 145°F. At these return water temperatures, condensing boilers are considered to be operating outside the “condensing region” which decreased energy performance substantially.

Based on manufacturer performance curves and the observed return water temperatures, the resulting average operating efficiency of the boiler systems evaluated was approximately 88.3%. This represents a 30% reduction in assumed energy efficiency improvement when compared to a baseline efficiency of 80%. Table 4-17 (seen several pages below) provides further details with regard to the verified EFLH for each boiler measure evaluated, as well as the rated heating capacity and average return water temperature. Figure 4-1 below shows a comparison of the de-rated efficiency used in reported calculations versus the efficiencies used in evaluated energy savings estimates.

Figure 4-1: Operating Efficiency vs. Rated Efficiency of Boilers



As mentioned above, the operating efficiency adjustments were nearly offset by the upward adjustment of EFLH used to calculate annual consumption. The EFLH values used in the reported savings estimates are stipulated based on facility type; however, the number of facility types provided in the PSD are relatively limited. In contrast to the reported approach, the evaluated savings estimates used EFLH values determined from sub-metering feed water pumps and burner blower fans. Sub-metering revealed that the boilers operated an average of 1,628 EFLH on an annual basis. This is 46% greater than the average EFLH value of 1,111 from the reported analyses. The actual measure-specific EFLH values varied substantially from measure-to-measure, ranging from 127 EFLH per year to a maximum of 2,342 EFLH per year.

Heating and Cooling Adjustments

No heating and cooling adjustments were made to any boiler measures, since this adjustment only applies to lighting projects.

Crosscutting Themes for Evaluated Gas-Other Measures

Gas measures other than boiler systems were classified as Gas–Other projects. Measures included in this stratum include:

1. HVAC equipment such as furnaces, rooftop package units, and infrared heaters (IR)
2. HVAC controls
3. Commercial laundry equipment
4. Commercial kitchen equipment
5. Custom process equipment
6. Domestic water heaters

A total of 25 Gas–Other measures were evaluated. For these projects, the sample savings were reduced by approximately 32%. Nearly 59% of the total downward savings adjustments occurred due to documentation adjustments. The remaining 41% of total downward adjustments occurred due to operational adjustments. Two projects received upward savings adjustments due to quantity adjustments. The individual causes for adjustments are described below. For reporting purposes, the evaluation team has separated these measures into two major categories: HVAC measures and Other measures.

Gas–Other: HVAC

Overall, savings for the Gas-Other: HVAC measures were adjusted downward slightly, by approximately 17% for the sample. There was wide variability among measures, with individual measures that increased by as much as 163% or decreased as much as 100%; however, most of the measures were adjusted by less than 50%. Two measures were credited with zero savings based on as found conditions. On one project the installation of infrared heaters did not result in energy savings due to the fact that space temperature setpoints had not been reduced, per Program requirements, and it was discovered that the spaces could also be heated by conventional rooftop equipment in addition to the IR heaters. On the second, it was determined that a heat recovery system was not generating any quantifiable savings.

<u>Documentation Adjustments</u>

Thirteen Gas-Other: HVAC (furnaces, infrared heaters, and HVAC controls) measures were reviewed and 9 of them had documentation adjustments. Due to the variety of technologies covered under this measure group, no clear patterns or trends could be developed; however, the majority of the documentation adjustments made were for calculation errors or incorrect building types used in the reported analysis.

Three of the unit heater measures evaluated had documentation adjustments due to the original analysis calculating savings using the approach specified in the PSD, but using a building type inconsistent with the actual building type. Two of the measures interchanged the office and warehouse building types, which may have been due to simple input errors; however, the third measure involved the installation of heaters within a greenhouse, which is not a facility type conducive to the PSD prescriptive measure. A custom approach using site-specific hours of operation would likely have resulted in a more accurate reported savings estimate.

Technology Adjustments

Only one technology adjustment was made for the reviewed Gas-Other: HVAC measures. As noted above, the measure involved the installation of CO2 controls and energy recovery on two rooftop units; however, on-site verification revealed that neither of the installed units included energy recovery. This eliminated the original savings for the project, as well as causing the increase given to the measures in the documentation adjustment.

Quantity Adjustments

Only two quantity adjustments were made to the evaluated Gas-Other: HVAC measures. The first measure (CE12G112) involved the installation of 82 infrared heaters in a warehouse. Two fewer units were found to be installed than claimed in the reported analysis. The remaining two units were found on-site in storage, but are not installed. This slightly reduced the savings for the measure.

The other measure (CE12G065) with quantity adjustment involved the installation of four direct-fired make-up air units. Four units were verified during an on-site inspection. However, the installed units were found to have more than twice the rated heating output capacity than was claimed in the original reported analysis. Based on the customer interview, it is evident that the project scope had changed and the reported analysis had not been appropriately updated. Increasing the heater size to the installed units more than doubled the measure savings.

Operational Adjustments

Operational adjustments are based on the difference in the calculated savings, based on the collected metered data for each site and the claimed savings, after the adjustments listed above. Therefore, the operations adjustments are effectively the difference in the assumed hours of operation and loading conditions and the ‘as found’ conditions.

Heating and Cooling Adjustments

No heating and cooling adjustments were made to any Gas-Other: HVAC measures, since this adjustment only applies to lighting projects.

Gas-Other: Miscellaneous (Laundry, Cooking Equipment, and Process)

Twelve Gas-Other: Miscellaneous measures were evaluated. For these measures, the sample savings were reduced by approximately 65%. Unlike the Gas-Other: HVAC measures, approximately 65% of the adjustments were due to operational changes and the remaining were documentation adjustments. The majority of the operational adjustments were assessed on a single project where the amount of available process cooling was overestimated. Excluding this measure, nearly 80% of the savings reductions were due to documentation adjustments. The individual causes for adjustments are described below.

Documentation Adjustments

Similar to the Gas-Other: HVAC measures, the majority of adjustments occurred in the documentation adjustment. Of the twelve projects evaluated, seven had documentation adjustments, as summarized below:

- A vendor used an incorrect baseline water heater gas usage value (E_b from the PSD) on all three of the domestic hot water measures evaluated. The values used were from the 2011 PSD rather than the 2012 PSD, which were updated for new federal baseline standards. Two of the hot water heater measures also included changes to building type classifications, which affects annual consumption in gallons and thereby savings.
- One of the hot water heater measures also required a second documentation adjustment in order to correct for an error in the reported savings estimate, which used the square of the building area (ft^4 instead of ft2) to estimate hot water demand. This resulted in hot water usage being overestimated by a factor of 2,700%; however, this was partially offset by the use of an incorrect facility type bringing the adjusted savings down to 185% of the reported estimate.
- One measure included the installation of a high efficiency griddle. The savings for this measure was based on a study that compared the installed equipment to old installed equipment at a different location. The savings were revised to compare the installed unit to a new unit meeting current federal standards. This reduced the savings for the measure by 83%.
- Two laundry measures included calculation errors that resulted in different amounts of laundry being washed and dried in the baseline and efficient cases. Correcting this error resulted in a 30% reduction of savings for these two measures.
- One laundry measure assumed nearly 11,000 hours of operation per year, which is impossible.
- One measure included the installation of a magnetic water conditioning system. Based on a literature review, insufficient evidence was found to support the savings claimed and they were set to zero.

Technology Adjustments

No other non-HVAC gas savings measures had technology adjustments.

Quantity Adjustments

No other non-HVAC gas savings measures had quantity adjustments.

Operational Adjustments

The most significant downward operational adjustment was assessed on a heat recovery measure where it was determined that the amount of heat available for recovery was substantially lower than anticipated. The reported analysis estimated that cooling loads could be reduced by approximately 300-tons by removing heat from process water; however, based on six months of field measurement data, the actual average reduction in cooling load for the process, and the heat available for recovery, amounted to less than 50-tons, on average.

For the remaining measures, the operational adjustments were much less significant and only accounted for 20% of total adjustments made to project savings. The majority of the operational adjustments corrected for overestimated loads on installed equipment. This included all of the laundry equipment measures and a commercial kitchen equipment measure.

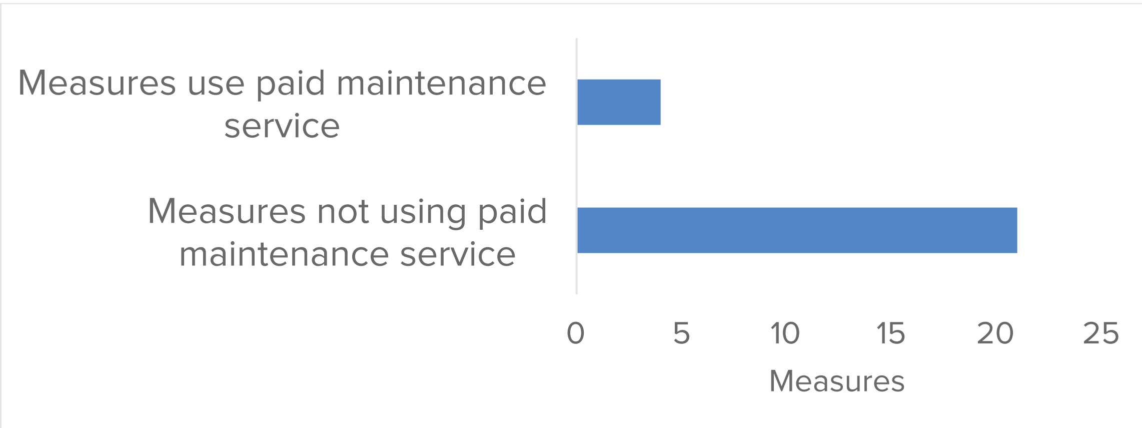
Heating and Cooling Adjustments

No heating and cooling adjustments were made to any other gas measures.

4.7 Non Energy Impacts

As shown in Figure 4-2: four lighting measures (16%) used a paid maintenance service for regular maintenance. No respondents indicated that maintenance service expenditures changed as a result of the program. However, one respondent that did not use a paid maintenance service indicated that the number of hours needed to maintain lighting measures decreased, although the individual was unsure of the extent to which the hours were reduced.

Figure 4-2: Respondents indicated that 16% of lighting measures use a paid maintenance service



For non-lighting measures, respondents were asked whether the program resulted in a reduction of hours needed for operation and maintenance for a variety of measures. As shown in Figure 4-3, about 20% of measures resulted in a change of hours. When asked how the hours changed, respondents indicated that a majority of measures needed fewer hours for maintenance as a result of the program (see Figure 4-4). Most respondents did not know or did not share the actual hours reduced as a result of the program.

Figure 4-3. Respondents reported that hours required for maintenance changed as a result of the program for about a fifth of measures, however most indicated no change or did not know

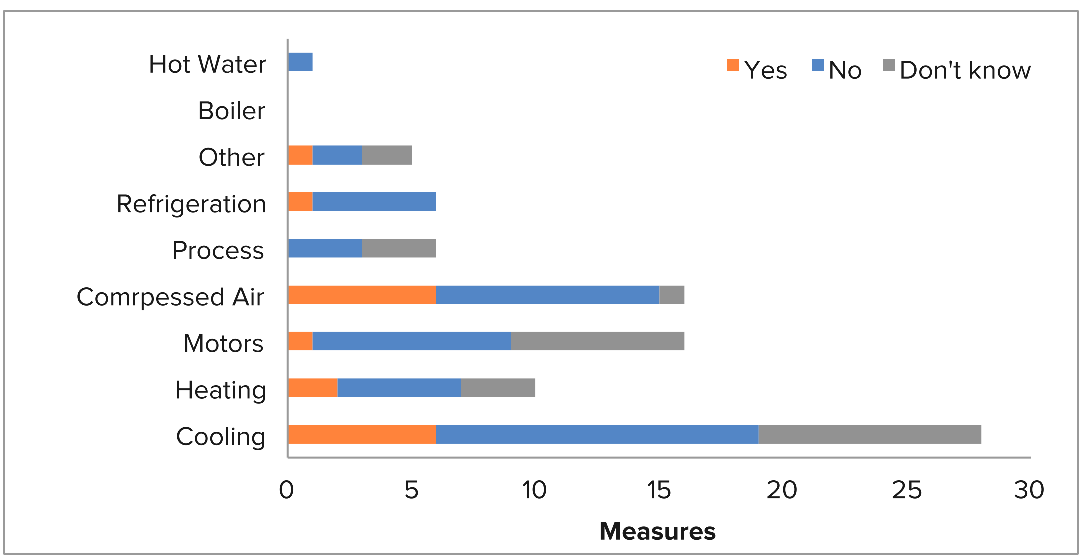
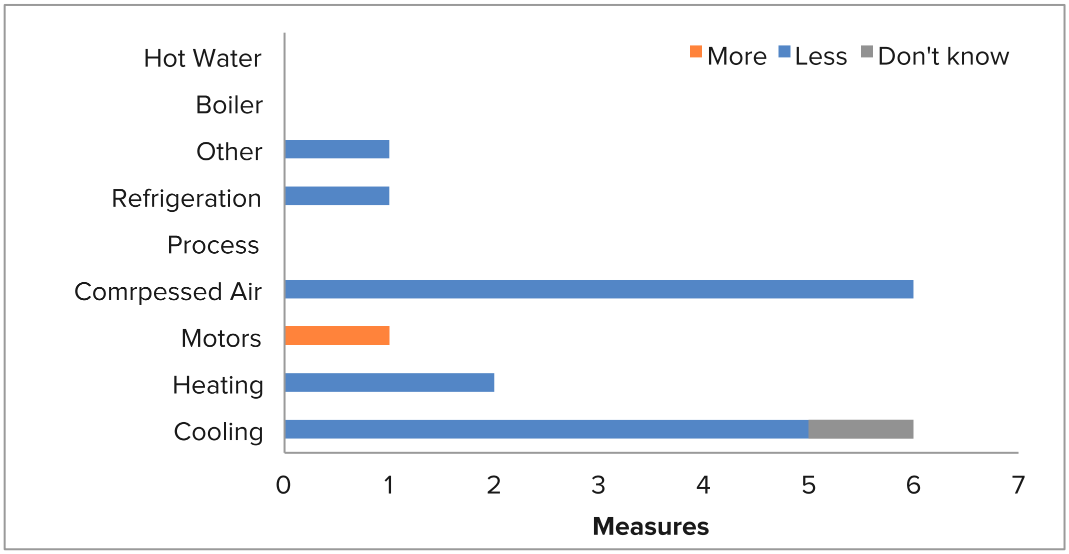


Figure 4-4. Respondents indicated that the program has resulted less hours for maintenance for most measures.



Respondents were also asked about changes in throughput (defined as a measure of output per unit of labor input) as a result of the program. Respondents indicated that 5 measures (across multiple measures) were associated with increase in throughput, while 71 measures resulted in no change in throughput. Four of these 5 measures resulted in a change to the respondents' firm revenues. When asked about how revenues changed, only one response was recorded, indicating that revenues were increased by about 20%.

4.8 Recommended Changes to PSD

Revise the adjustment factor used to de-rate operating efficiency assumption used in the savings algorithm currently being used for condensing boiler replacement measure in the Connecticut PSD. For the majority of the condensing boiler projects evaluated, the rated boiler efficiency used in the claimed savings estimates was higher than the verified operating efficiency used in evaluated calculations. Adjustments in the savings calculations were required whenever return water temperatures were found to be greater than the rated return water temperature. In general, the operating efficiency of a condensing boiler decreases whenever return water temperatures exceed 130°F. Figure 4-5 from the 2008 ASHRAE Handbook Chapter 31 on boilers shows the effect of inlet water temperature on boiler efficiency, dew point, and the condensing range.

As the return water temperature to a boiler decreases, boiler efficiency increases and vice versa. The target return water temperature for a condensing boiler should be below 130°F, as anything above that temperature will cause the system to operate in non-condensing mode, which is less efficient. As shown in Figure 4-5, with a system return water temperature of 130°F, this particular condensing boiler will operate at 87% efficiency, but is capable of operating at 98% efficiency when the return water temperature drops down to 60°F.

The average rated efficiency among the condensing boiler measures evaluated was approximately 95.1% and the verified operating efficiency based upon on-site observations was approximately 88.3%. A summary of the rated boiler efficiencies vs. the evaluated efficiencies for all evaluated measures is provided in Table 4-17. The table also shows average return water temperatures, facility types, the PSD EFLH assumptions, and the evaluated EFLH values.

Figure 4-5: Example Inlet Water Temperature (°F) vs. Boiler Efficiency (%) Curve for Typical Condensing Boiler

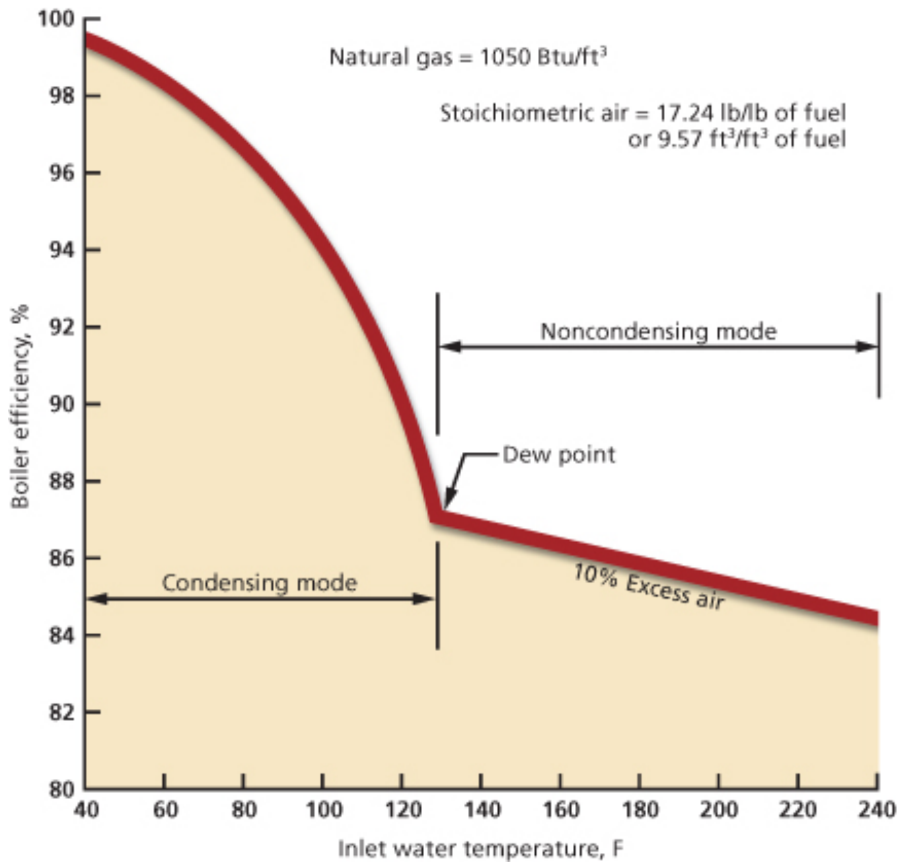


Table 4-17. Summary of Rated and Evaluated Condensing Boiler Efficiencies and EFLH Values

Rated Boiler Capacity (MBH)	Measures Evaluated	Rated Eff%	Evaluated Eff%	Avg Return Water Temp (°F)	Facility Type	PSD EFLH	Evaluated EFLH
105	1	95.0%	89.0%	147	Other	1,169	1,956
285	28	96.0%	89.0%	147	Other	1,169	1,956
290	3	92.0%	88.0%	138°F	Rubber/ Plastics	1,007	2,342
400	2	93.0%	89.0%	157°F	Library	905	1,839
550	4	94.0%	86.0%	148°F	Apartment	1,169	1,443
700	2	94.0%	88.0%	130°F	School	905	1,141
700	3	96.0%	86.0%	157°F	Rubber/ Plastics	1,169	2,260
750	2	96.0%	87.0%	144°F	School	905	1,538
750	4	94.0%	86.0%	154°F	Other	1,169	1,258
750	2	94.0%	89.0%	146°F	Apparel	900	1,024

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Rated Boiler Capacity (MBH)	Measures Evaluated	Rated Eff%	Evaluated Eff%	Avg Return Water Temp (°F)	Facility Type	PSD EFLH	Evaluated EFLH
750	8	94.0%	86.0%	148°F	Apartment	1,169	1,443
800	1	94.0%	89.0%	131°F	Misc. Manufacturing	991	1,700
1,400	2	95.0%	87.0%	160°F	Government	1,169	1,072
1,800	1	97.0%	87.0%	130°F	Education	1,023	456
1,999	5	96.0%	97.0%	81°F	Wholesale	900	1,185
3,000	2	96.0%	92.0%	111°F	School	905	1,538
3,000	4	96.0%	88.0%	160°F	Other	1,259	1,593
Weighed Averages		**95.2%**	**88.6%**	**142°F**		**1,109**	**1,671**

The savings algorithm used in the Connecticut PSD for gas-fired condensing boiler measures incorporates an adjustment factor of 0.97 to account for periods of non-condensing operation.\ However, based on the findings from this evaluation a more conservative assumption might be 0.93 to 0.95, which would be expected to produce more accurate reported savings estimates.

4.9 Evaluation Recommendations

The evaluation team recommends using *e.r.* values found in this study for future ECB evaluations. The evaluation team found that the realization rates for projects in this program were highly variable. The evaluated *e.r.* values for the Compressed Air, HVAC, HPBD/Other, and Process measure groups were much higher than the a priori estimates of 0.5. The evaluation team recommends adjusting these *e.r.* values to those found in this evaluation for future studies. Such an adjustment will result in a greater emphasis on non-lighting project sites, which have higher variability.

4.10 Baseline Pilot Study Findings from the General Vendor Baseline Survey

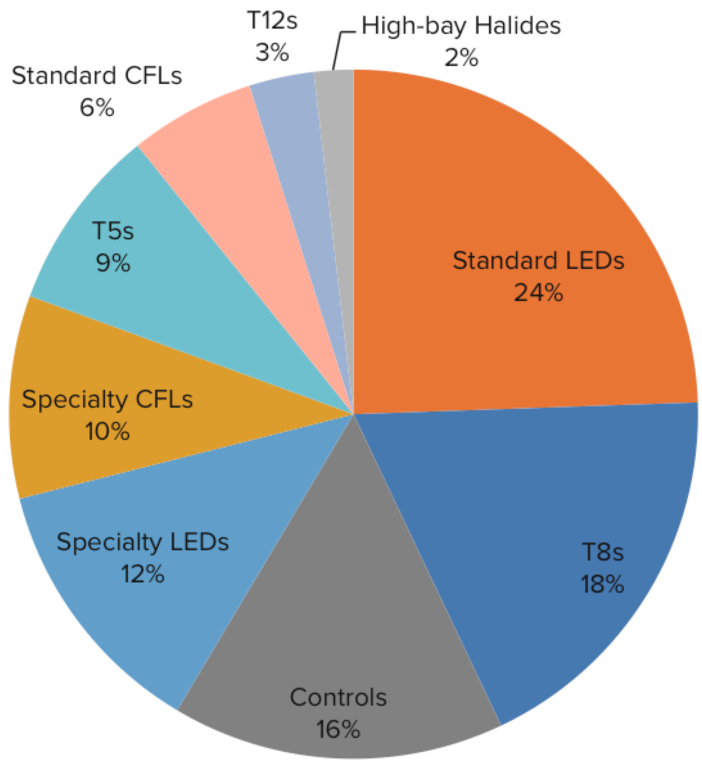
In this section, we report the findings from the lighting and HVAC general vendor baseline surveys. The lighting results section presents the market share of different lighting products and LED market growth. The HVAC results section presents the efficiency and market share of HVAC products by category and size.

During telephone recruitment, 220 vendors agreed to complete our online survey. However, only 50% of these vendors followed through. In total, there were 63 online responses from lighting vendors and 46 online responses from HVAC vendors. All surveys were conducted between March 2015 and May 2015.

Lighting Market Share and Efficiency

Lighting vendors reported that the most common type of lighting product sold was standard LEDs (24% by quantity). Other categories with large market share include T8s (18%); controls (16%); specialty LEDs (12%); specialty CFLs (10%); and T5s (9%). Recessed, surface, and linear LEDs were the most common LEDs, and occupancy sensors were the most common control. **Figure 4-6** shows the market share of lighting technologies based on the number of reported products sold.

Figure 4-6. Lighting Technology Market Share by Number of Products Sold, 2015



When comparing the market share results to a previous study from 2010,[29] it is clear that the lighting market has changed dramatically in recent years. Linear fluorescents accounted for 80% of the market share in 2010, and LEDs were only included in an "Other" category that accounted for 2% of the market. CFLs have also increased (up from 10%) market share in recent years. We note that the 2010 study measured commercial lighting inventory and that our results include lighting controls and exclude incandescent and halogen light bulbs. These factors cause some discrepancies when comparing the studies, but the overall trends are still clear.

Nearly all lighting vendors (95%) encourage energy efficiency in their projects at least some of the time. On average, these vendors specify or recommend energy efficient lighting options for 78% of their projects. Some vendors reported specific steps to encouraging efficiency, including:

1. Promoting LEDs (n = 14)
2. Explaining cost savings over time (n = 9)
3. Promoting rebates (n = 5)
4. Promoting lighting controls (n = 4)

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[29] Rosenberg, Mitchell. "Moving Targets and Moving Markets in Commercial Lighting", Table 2. 2012 ACEEE Summer Study on Energy Efficiency in Buildings. p. 317

More than half of vendors (53%) install equally efficient equipment in new construction projects as compared to retrofit projects. However, 34% of vendors install more efficient equipment in new construction and only 13% install less efficient equipment.

Lighting vendors expect sustained growth for LEDs in the next five years. Vendors estimated that LEDs increased from 15% to 39% of floor space in the past two years for retrofit projects, and 20% to 46% of floor space for new constructions projects. This LED growth was faster than expected for 36% of the vendors, compared to 18% that thought it was slower than expected. In the next five years, vendors expect LED floor space to increase to 61% of floor space for retrofits and 71% for new construction. Figure 4-7 shows the estimated and expected growth of the LED market by floor space percentage. Error bands represent the average estimated floor space with 90% confidence.

Figure 4-7: Estimate of LED Floor Space by Project Type

HVAC Vendor Survey Results

HVAC vendors reported on the efficiency and size of their sales within multiple product categories. For each category, HVAC vendors selected how many of their sales were within prescribed efficiency ranges. A full analysis by category can be seen in Appendix D: Additional Vendor Survey Analysis. The number of vendors with sales in each product category is shown in Table 4-18.

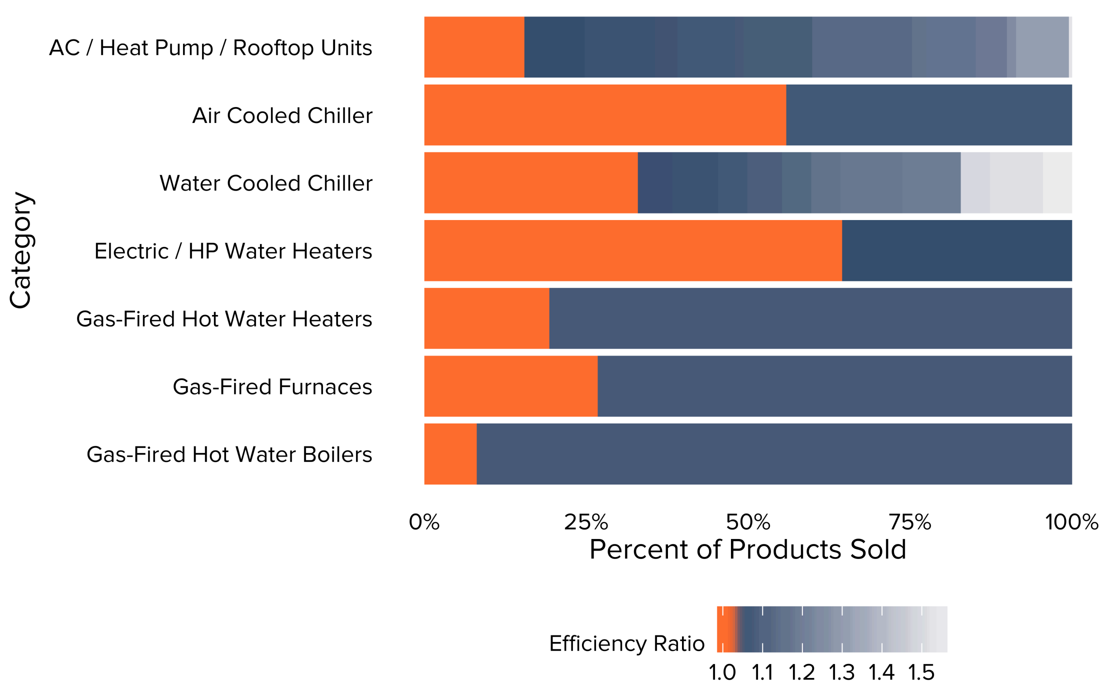
Table 4-18. HVAC Vendors with Sales by Product Category

HVAC Product Category	Number of Companies (n = 46)	Percent of Companies
Commercial AC / Packaged Heat Pump / rooftop units	35	76.1%
Commercial Gas-Fired Hot Water Boilers	31	67.4%

Commercial Gas-Fired Hot Water Heaters	30	65.2%
Commercial Gas-Fired Furnaces	30	65.2%
Commercial Boiler Tune-ups	22	47.8%
Commercial Electric / Heat Pump Water Heaters	17	37.0%
Air cooled chillers (with condenser)	13	28.3%
Water cooled chillers	13	28.3%

Vendors reported that most of their sales were above the code minimum. Electric water heaters had the largest number of sales at code (64%), followed by air-cooled chillers (56%); gas-fired hot water boilers had the fewest sales at code (8%). Seventeen percent (17%) of water-cooled chillers sold were high efficiency (had a ratio of product efficiency to code minimum efficiency greater than 1.25) and 9% of AC / heat pump units sold were high efficiency (had a ratio of product efficiency to code minimum efficiency greater than 1.25). Figure 4-8 shows the efficiency at or above code for all product types. AC / heat pumps and water-cooled chillers have more granularity due to the number of questions asked of vendors (the codes in these categories vary by unit size). Heat pump water heaters are considered above code but do not have a numeric percentage above code.

Figure 4-8: Efficiency at Code or above Code for all HVAC Products Sold by Product Category



Nearly all HVAC vendors (98%) encourage energy efficiency in their projects at least some of the time. Some vendors reported specific steps to encouraging efficiency, including:

1. Promoting rebates or incentives (n = 9)
2. Estimating cost savings over time (n = 7)
3. Explaining the benefits of efficient equipment (n = 7)

Almost half of vendors (44%) install equally efficient equipment in new construction projects as compared to retrofit projects. However, 40% of vendors install more efficient equipment in new construction and only 11% install less efficient equipment (5% did not know).

Additional General Vendor Survey Results

All vendors were asked whether they were aware of the Energy Conscious Blueprint Program or the Energy Opportunities Program. One third (30%) of HVAC vendors and 30% of lighting vendors were aware of the Energy Conscious Blueprint Program, while 37% of HVAC vendors and 32% of lighting vendors were aware of the Energy Opportunities Program. The majority (89%) of vendors that were aware of the programs had previously participated in at least one program.

All respondents reported some firmographic information including their firm type, types of customers, and the types of sales. The majority of HVAC vendors (83%) and lighting vendors (87%) were self-identified as contractors. Most vendors' customers (59% for HVAC and 56% for lighting) were building owners or managers; general contractors (28% for HVAC and 24% for lighting) were also common customers. The most common sales types for HVAC vendors are replacement on failure (32%), new construction (27%), and remodeling or build-out (20%). The most common sales types for lighting vendors are early replacement (31%), new construction (26%), and remodeling or build-out (21%).

5. FINDINGS AND RECOMMENDATIONS

The impact evaluation recommendations are split between those that are for the ECB program and those that apply to future evaluation efforts. A number of these recommendations also address the evaluators' assessment of the accuracy of methods used by vendors in estimating savings for complex "custom" projects, recommending changes to some program procedures in order to increase project savings realization. Table 5-1 shows the evaluated *c.v., e.r.*, and confidence/precision values.

Table 5-1. Evaluated Coefficients of Variance, Error Ratios, and Confidence/Precision Values

Group	Energy			Summer Demand			Winter Demand		
	c.v.	e.r.	Confidence/ Precision	c.v.	e.r.	Confidence/ Precision	c.v.	e.r.	Confidence/ Precision
Electric - Compressed Air (kWh)	2.18	1.72	90%/18%	1.36	1.7	80%/11%	1.28	1.75	80%/11%
Electric - HVAC (kWh)	1.41	1.15	90%/22%	1.82	1.82	80%/20%	1.62	2.02	80%/36%
Electric – Lighting (kWh)	0.62	0.55	90/20%	0.72	0.62	80%/16%	0.84	0.75	80%/20%
Electric - HPBD/Other (kWh)	0.69	0.66	90%/25%	2.54	2.21	80%/35%	2.19	2.74	80%/41%
Electric – Process (kWh)	0.76	0.67	90%/18%	1.7	0.87	80%/22%	1.7	5.39	80%/29%
Electric Overall	**0.99**	**0.95**	**90%/21%**	**1.62**	**1.40**	**80%/20%**	**1.53**	**1.95**	**80%/25%**
Gas – Boiler (therms)	0.46	0.39	90%/14%	-	-	-	-	-	-
Gas – Other (therms)	0.97	1.03	90%/15%	-	-	-	-	-	-
Gas Overall	**0.71**	**0.82**	**90%/15%**	**-**	**-**	-	**-**	**-**	-

ECB Program Recommendations

Require sufficient project documentation from vendors as a condition of payment. A significant number of the projects reviewed for this evaluation had insufficient project documentation for the evaluators to check whether the reported savings reported could be justified using standard calculations or engineering analysis practices. Some had no documentation. In order to streamline project qualification for Program Administrators and to facilitate ongoing evaluations, as a condition for incentive payment. Program participants should be required to submit program documentation in electronic form. Participants should also be required to provide copies of all calculations in forms readily checked using computer-based tools without manual transcription.

Improve the program administrator engineering review process in order minimize calculation errors in claimed savings estimates. Several correctable and preventable calculation errors were found in the claimed savings estimates reviewed. These errors ranged from simple math errors to failure to use prescriptive methodologies and assumptions from the Connecticut PSD. Corrections to calculation errors are assessed as documentation adjustments. Documentation adjustments accounted for approximately 62.8% of all downward electric energy savings adjustments made. Documentation adjustments also accounted for approximately 50.6% of all downward electric demand savings adjustments and 39% of all downward gas energy savings adjustments. The combined effects of all downward documentation adjustments resulted in gross[30] savings reductions of 10,590,853 kWh and 216,022 therms.

Given the magnitude of these adjustments, it is recommended that the internal project review process be evaluated and refined in order to achieve greater consistency in claimed savings estimates. The evaluation team recommends implementing the following:

1. All large projects reporting savings over a threshold of 300,000 kWh or 10,000 therms undergo a complete QA/QC review prior to incentive payment in addition to the standard internal review process. Typically, a QA/QC process reviews engineering calculations, verifies inputs, checks payback period and incentive payments for reasonableness, and ensures compliance with program requirements and the relevant version of the CT PSD. In order to align with the above recommendation regarding program management and implementation, the research team recommends that the ECB Program determine and document the specific requirements and steps in the QA/QC process to ensure accountability.
2. The ECB Program should consider performing three- to six-month post-installation random inspections for controls-based measures in order to confirm measure persistence and to identify opportunities to improve performance. Savings for these types of measures are reliant upon the use of designed setpoints and operations.

Set clear guidance on when vendors should use the PSD and what inquiries and assumptions should be used in different circumstances.[31] The use of deemed measure values provides valuable program streamlining and greatly simplifies the application process for both customers and efficient product vendors; as such it removes market barriers and encourages wider adoption of efficient products. However, when misapplied, deemed values can result in erroneous savings estimates. It is important to set clear guidelines and examples to help vendors understand when and how deemed values may be applied in standardized savings calculations, and when a 'custom' engineering calculation is required to justify an incentive payment.

Require participants to provide final building simulation files as a condition of payment for all HPBD projects/measures. The evaluation team evaluated a total of seven HPBD projects and none of them included a final version of the building simulation file in the documentation provided for review. Building simulation projects are complicated and therefore require an enhanced level of rigor and documentation. It is recommended that the following information be requested on all participant projects:

1. Project description — All projects should include a project description to ensure that the project, including the baseline and the energy efficiency improvement, are clearly defined. This is especially critical for comprehensive whole building projects that often include multiple interconnected energy efficiency improvements.
2. Building simulations or calculations – These are critical for the reviewer and the evaluator to understand the reasonableness and accuracy of the savings estimates.

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[30] Net reduction in savings from upward and downward documentation adjustments for electric energy was approximately -9,916,727 kWh.

[31] A long-term goal for the evaluation effort is to help make program estimates more accurate by updating the PSD to include some assumptions to be used depending upon broad categories of building use or customer type or delineate when and how to use customer interview data with the PSD to create more accurate project-specific reported savings estimates.

3. Equipment specifications – The equipment specifications are important for all projects to ensure that any improvement meets program requirements and calculations are accurate.
4. Building plans – The building plans are important to ensure that modeled energy efficiency improvements are consistent with the as-built conditions.
5. Equipment sequences of operation – Similar to building plans, these will help to ensure that the modeled building condition is consistent with the as-built condition.
6. Any other information to characterize or justify the project and/or modeled conditions – This can include metered data collected, customer descriptions of operation, email correspondence of changes not reflected in the plans, etc.

Recommend modifying the program calculator used for high efficiency cooling equipment measures to disallow the use of a default facility types. The most common documentation adjustment made to cooling projects consisted of correcting the facility type assumption upon determining that the incorrect facility type was used in the reported calculations. The evaluation team suspects that incorrect facility types used in the program calculator were the result of the program analyst neglecting to edit the facility type and thus resulting in the use of a default building type. This is suspected based on the fact that several of the calculators were observed with a key input field set to "auto-related." It is recommended that all auto-selection or default functionality be disabled and require that the user enter the appropriate project-specific information.

Reconsider the cost-effectiveness of incentivizing enthalpy economizers. Current energy code requires that new HVAC equipment be equipped with an air-temperature controlled economizer, which effectively eliminates a sizeable portion of the claimable savings. Enthalpy economizers are designed to take advantage of conditions when outdoor air temperatures are high, but relative humidity is low allowing economizing to occur beyond a simple high limit setpoint temperature. Unfortunately, there are not many hours during the year in this climate zone when these conditions occur. For this reason, the overall realization rate for dual-enthalpy economizer measures was approximately 62% (un-weighted).

Require that vendors use Compressed Air and Gas Institute (CAGI) performance curves when developing load profiles and energy savings on high efficiency air compressor projects. There were several high efficiency air compressor measures included in the sample in which an incorrect or inappropriate part-load performance curve was used to approximate post-installation energy consumption. It is recommended that the program require that participants use CAGI performance curves for the specific equipment being installed or standard performance curves made available by the Compressed Air Challenge.

Establish a protocol requiring that all baseline boiler thermal efficiency assumptions used in reported calculations be based upon the minimum requirements of ASHRAE 90.1-2007 and the known input capacity of the equipment being replaced. Documentation adjustments were required on several of the condensing boiler projects evaluated. There were several projects with reported savings calculations based upon a baseline efficiency of less than 80%. According to the 2012 PSD, the baseline efficiency to be used in the savings calculation is the minimum efficiency specified by ASHRAE 90.1 – 2007.

Incorporate a data field into the condensing boiler application form requesting that the customer provide estimated supply and return water temperatures. This information coupled with product specifications could be used by the Program to develop an anticipated operating efficiency of the boiler system, which would improve the overall accuracy of claimed savings estimates.

Consider undertaking a study to develop State of Connecticut-specific EFLH values for boiler replacement measures. This is recommended for two reasons:

1. The EFLH value was adjusted in the evaluated savings calculations for a majority of the boiler measures evaluated. This is demonstrated in Table 3-17 within Section 3.7 of this Report where a comparison can be made between the PSD stipulated EFLH values used in the claimed savings estimates for each measure and the evaluated EFLH determined from metering.
2. Based on the fact that there are no cited sources in the Connecticut PSD for the EFLH values currently being used by the program to estimate savings. Table 5-2 shows the five EFLH values that are currently being used in savings estimates.

Table 5-2. Current EFLH Assumptions Used to Estimate Savings for Boiler Replacement Measures

Occupancy Category	Equivalent Full-Load Heating Hours
Residential, Hospitals, Police, & Fire Stations (24/7 Operation)	1,519
Manufacturing	1,140
Retail Sales/Restaurants	1,170
Offices	1,306
Schools	1,176

Resolve issue of vendors repeatedly using the cooling energy interactive savings factor (Sc) to estimate summer peak demand savings instead of the algorithm for Summer Seasonal Peak Demand Savings (SKW). A common error was encountered in reported savings calculations for lighting measures. Vendors frequently used a PSD-stipulated cooling savings factor (Sc) to determine summer peak demand savings; however, this approach is inconsistent with the methodology outlined in the PSD. The following equation should be used when accounting for interactive effect savings for summer peak demand:

$$SKW = \left(CF_{OS} \times \frac{\sum_{n=1}^{N} O_n W_n}{1000}\right) \times \left(1 + \frac{G}{COP}\right)$$

where:

SKW = summer seasonal peak demand savings
CF_{OS} = occupancy sensor coincidence factor, from Appendix 1 of the PSD
O_n = number of occupancy sensors
W_n = controlled wattage per occupancy sensor
G = estimated summer lighting heat to space = 0.73
COP = coefficient of performance of cooling system (4.5 unless otherwise specified)

In this equation the estimated lighting heat to space (variable G) is used to calculate the demand savings for lighting measures. Using the algorithm above, instead of the cooling savings factor will result in increased claimed savings.

APPENDIX A: IMPACT METHODS DETAIL

This appendix provides more details on the approach used for the impact evaluation. First, the method to calculate the final relative precision is presented followed by specific approaches to data collection and analysis used by the evaluation team at the measure level.

A.1 Relative Precision

After collecting data, the evaluation team calculated the coefficient of variation (*c.v.*) and the relative precision of sampling studies based on the measured realization rates using the following equation:

$$r.p. = \sqrt{1-\frac{n}{N}}\,\frac{z \times c.v.}{\sqrt{n}}$$

where:
x = sample mean
s = standard deviation
n = number of samples in a finite population
N = total number of units in the population
z = the appropriate z-value for the confidence level
$c.v. = \frac{s}{\bar{x}}$

Note that the equation includes the finite adjustment factor of $\sqrt{1-\frac{n}{N}}$.

The evaluation team determined the sampling precision using stratified ratio estimation. Stratified ratio estimation combines a stratified sample design with a ratio estimator; in this case, the ratio estimator, *B*, is realization rate, or the percent of observed savings relative to reported tracking savings. The ratio for any given site, b_i, is determined as $e_i = y_i - bx_i$; where *y* is the evaluated savings and *x* is the tracking savings. Case weights, w_i, are used to weight each project. The standard error of the sample ratio, *b*, is calculated as:

$$se(b) = \frac{\sqrt{\sum_{i=1}^{n} w_i(w_i - 1)e_i^2}}{\sum_{i=1}^{n} w_i x_i}$$

The relative precision is then determined by the following equation:

$$r.p. = \frac{se(b) * z}{b}$$

The error ratio for use in future sample designs was calculated as shown, assuming γ =0.8.

$$\hat{e}r = \frac{\sqrt{(\sum_{i=1}^{n} w_i\, e_i^2 / x_i^{\gamma})(\sum_{i=1}^{n} w_i x_i^{\gamma})}}{\sum_{i=1}^{n} w_i y_i}$$

A.2 Lighting Data Collection and Analysis

The primary method to verify savings estimates for lighting projects in this evaluation is International Performance Measurement and Verification Protocol (IPMVP) Option A, Partially Measured Retrofit Isolation. Data were collected during site visits and then analyzed for direct and interactive effects.

Lighting Data Collection

For lighting data collection, a site visit was performed for each sample project. Each site visit included four steps:) customer interview; 2) installed measure verification; 3) metering; and 4) HVAC system inspection. Each of these steps is described below.

Customer Interview

The customer was interviewed during the site visit to provide additional information regarding the use of the lighting, the hours of facility operation, and the HVAC system. Specific data gathered through interviews are identified along with that activity.

Installed Measure Verification

The project measures were verified for installation and inspected to ensure consistency with the project documentation, including lamps, ballasts, etc., as well as lighting controls. This included occupancy sensors, time clocks, photocells, and daylighting controls where the project included them or they are relevant to lighting operation. In addition to verifying that the project measures were installed, the verification inspections were used to collect power consumption information. Lamp and ballast information for the installed lighting, as well as the removed lighting, was collected to the extent available. The lamp and ballast information was then used to stipulate fixture power consumption, using manufacturer literature. If the lamp and ballast information was not available, and it was possible to take spot measurements of fixture demand for the installed fixtures, spot checks of demand were taken using a NIST-calibrated Fluke 1735 power analyzer. This information was used to provide base-case and post-case power consumption information for the fixtures included in this project.

Metering

In order to determine the hours of use for the fixtures, meters capable of logging lighting On/Off state, lumens, and/or power were installed during the site visit depending on what data were required for the evaluation. For each site, the number of loggers necessary to accurately determine the hours of use of the lighting involved in the project was based on circuit configuration and the predicted variability of the lighting operation, as determined by the field engineer through the onsite interview process. Specific metering equipment used in this evaluation, along with their purpose, included:

- HOBO® UX90-002 Light On/Off loggers – to monitor the operational status (on/off) of the lights.

- HOBO U12-012 lumen level loggers – to monitor the operational status (on/off) of the lights.
- HOBO U12-012 external channel loggers with split-core current transducers of appropriate sizes – to monitor the current supplied to the lights where all or a significant portion of the lights are powered by dedicated and independent circuits (no other equipment or outlets on the circuit).

For sites that involved the installation of occupancy sensors, the customer was asked if there were any lights in the facility that operated in the same manner as the occupancy sensor controlled lighting did prior to the installation of the occupancy sensors. If so, loggers were also installed to monitor these lights, providing proxy base-case operating data for the lighting controlled by the installed occupancy sensors. If no lighting in the facility was operated similarly to the controlled lighting prior to the completion of the project, the customer was interviewed to determine the base case operation of the lights.

All loggers installed were launched from a computer with a UTC-calibrated clock, and were deployed with a sampling interval no greater than 5 minutes, for a minimum of 3 weeks. Special care was taken to identify emergency or security fixtures that operate 8,760 hours per year or an alternate schedule.

The customer was also interviewed to verify the facility hours of operation. Specifically, the customer was interviewed to determine if the operation of the lighting during the metering period was "typical" or if there were variations to the expected operation that were not captured. These variations could include seasonal variations, shut-downs due to maintenance, power outages, or any other variations to operation that should be considered. This information was used to remove any atypical operation from the metered data, as well as to assist in the extrapolation of the metered data to the expected annual operation.

HVAC System Inspection

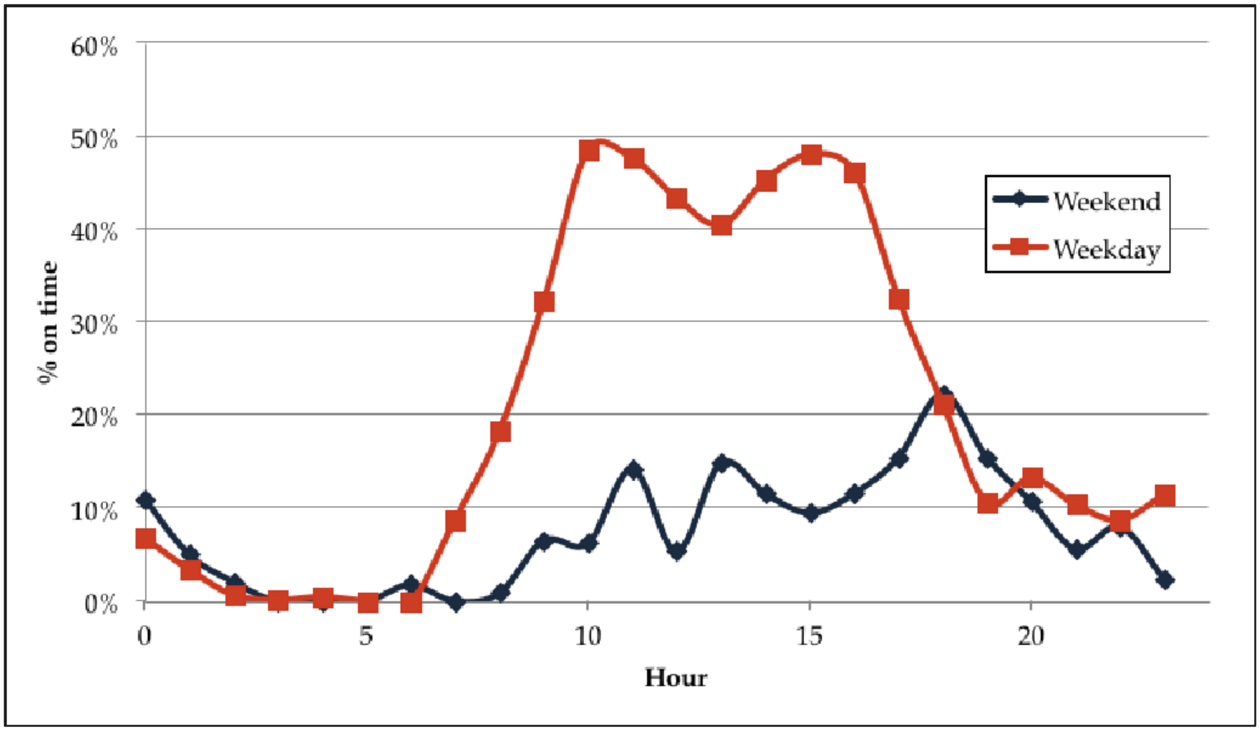
In order to verify interactive effects on energy use between lighting and heating and cooling systems, whenever possible the make and model numbers for the heating and cooling equipment were recorded. The make and model numbers were used to verify operational efficiency data, such as EER, COP for heating or cooling, or kW/ton, as well as the presence of an economizer. The customer was interviewed to determine the operational parameters for the heating and cooling equipment as well, such as temperature setpoints for both occupied and unoccupied periods, economizer operation and controls, and daily and weekly operating schedules. These parameters also included the expected annual heating and cooling operation, either through the collection of annual schedules for the dates that cooling plants are typically started and stopped, or temperatures above which cooling equipment is expected to operate.

Lighting Savings Analysis

The data collected from metering was used to create average weekly operating profiles (one for each logger). An example profile is provided in Figure A-1. The weekly hourly operating profiles are applied to an entire year with due consideration of weekday, weekend and holiday operations, resulting in an hourly profile of equipment operation for both the pre/base case and the post-installation case for an entire year. The resulting profile is called an "8760 model." The

8760 model is used to estimate *ex post* savings, which are the sum of savings resulting directly from the lighting measures and also indirectly through interactive HVAC effects.

Figure A-1: Example Lighting Profile



Direct Lighting Savings Analysis

The annual energy savings for each project's measures were determined by combining the 8760 model of lighting fixture hours of use with the fixture demand change from the pre- to post-case. The peak demand savings were estimated as the expected demand reduction during the peak and seasonal peak hours, which are a function of both time of day and outdoor air temperature. Additional details on peak definitions are given in Appendix E: Peak Period.

Interactive Effects Analysis

The interactive effects were calculated using the 8760 model, where the cooling energy effects are accounted for in each hour of the year. Specifically, the cooling effects are calculated using the demand formula from the PSD, where the cooling interactive effects factor is calculated as:

$$F_d = 1 + \frac{G}{COP}$$

where:
F_d is the cooling interactive effects factor;
G = 0.73 and is the percent of the energy of the lighting that results in heat rejected to the space, as defined by the PSD; and
COP = the efficiency of the cooling system as determined based on observations and/or PSD assumptions

Interactive savings were calculated separately for the occupied and unoccupied period as defined for each project. Interactive savings only occur if the lights are operating during the specific hour and the outside air temperature is above the selected balance point for either the occupied or unoccupied hours. These criteria and calculations are intrinsic to the 8760 model The balance point for each period is selected for each project based on the specific site conditions, dependent upon space setpoint temperature, internal gains, and economizer operation and included in the model.

A.3 Non-Lighting Data Collection and Analysis

For the non-lighting projects, the specific approach taken to evaluate each project was determined based on the following: type of technology, *reported* calculation methodology, available information, and the expected magnitude of the savings. Therefore, this section outlines the overall approach taken toward non-lighting projects, rather than the specific approaches taken for individual projects.

Non-Lighting Data Collection

Non-lighting data collection varied by project. For each project, the evaluation team reviewed project documentation, developed a site-specific measurement and verification plan (SSMVP), and conducted site visits. Each of these steps is described in this section.

Project Documentation Review

The first step in the evaluation process for each project was the desk review of *reported* project documentation. The desk review first allowed the analyst to become familiar with the project calculations and descriptions to ensure that the calculations were consistent with the described project and the claimed savings in the tracking system. The analyst was also able to review the calculations and identify areas of uncertainty that would then be addressed through the measurement and verification efforts.

Second, the desk review was used to review the calculations. Prescriptive project documents were reviewed to ensure consistency with program prescriptive measure specifications, and that the method from the PSD was followed for calculating savings correctly. Non-prescriptive – or custom – savings calculations were reviewed for calculation errors and to ensure that they were completed using accepted engineering practices, appropriate assumptions, and equipment characteristics consistent with the supplied documentation.

In some cases, the revisions to the savings estimates involved simply substituting verified parameters into the original calculation. In other cases, where the underlying calculation methods were flawed or inappropriately applied, an independent calculation of energy savings was developed based on engineering fundamentals, accepted energy efficiency practices and judgment.

Finally, the desk review supported the development of an SSMVP to inspect and monitor key data to confirm project savings.

Site Specific Measurement and Verification

Prior to performing an onsite inspection, an SSMVP was written for each site. The SSMVP included the results of the *reported* project review as well as a description of the measures involved in the project, the method used to calculate savings in the original analysis, and any comments regarding the analysis or adjustments made to the analysis as a result of the desk review.
The SSMVP also included a description of the various parameters used to determine the savings, and described the data collection efforts and the measurement and verification plan to be undertaken to verify the project savings. Specifically, the SSMVP addressed the following areas:

1. Verify that the equipment included in the project is installed as expected and operates as described in the project documentation
2. Verify make/model number of affected equipment
3. Verify operational parameters such as hours of operation, motor load factors, heating and cooling efficiencies, etc.
4. Verify baseline system operation
5. Collection of instantaneous measurements
6. Installation of data loggers for short or long-term metering

Special care was taken to ensure that the data collection efforts focused on factors of uncertainty that would have significant impacts on the actual energy savings. Additionally, the SSMVP described the IPMVP approach(es) to be utilized for each project. The four IPMVP approaches are described in Figure A-2 below.

Figure A-2: Summary of International Performance Measurement & Verification Protocol (IPMVP) Evaluation Methods

IPMVP Option	Used for	Examples
A. Retrofit Isolation with Key Parameter Measurement	Calibrating energy models where metering all points is cost-prohibitive for the amount of savings, or not possible.	Spot check on lighting power plus logging hours of usage; using an on/off logger to estimate packaged air conditioning unit load.
B. Retrofit Isolation with All Parameter Measurement	Determining loading and duty cycle for measures that have significant savings and where all significant parameters can be metered.	Determining the duty cycle of a variable frequency drive; measuring the duty cycle and output of a large chiller.
C. Whole Facility	Projects that are expected to save at least 10% of facility / meter consumption.	Multiple measure / comprehensive facility projects such as retrocommissioning, new control systems, or major system replacements or upgrades.
D. Calibrated Simulation	New construction primarily, or major retrofit projects and complex projects that are expected to save less than 10% of the facility / meter consumption.	New construction and retrocommissioning projects where the quantity of affected equipment and systems results in prohibitively expensive alternative M&V methods.

The specific approach taken was determined based on the project type as well as the expected savings levels. For example, retrofit isolation with parameter measurement (Option A) may be used for a specific measure; however, if the impacts are significant enough such that results should be apparent on billing data, analysis on billing data (Option C) would also be conducted as a cross-check. Similarly, if Option C is the primary means of M&V, Option A or B could be used to verify savings from specific measures with a significant impact on the total billed savings. A more comprehensive list of examples for applying IPMVP methods is included in the table below.

Measure Category	IPMVP Option A	B	C	D	Comments
High-efficiency lighting equipment	✓				Lighting hours key unknown
Lighting controls (occupancy sensors)	✓				Lighting hours key unknown
Lighting controls (daylighting)	✓				Lighting hours key unknown
High-efficiency HVAC equipment	✓	✓			Packaged / residential may use hours to calibrate. Direct measurement of power and output for large equipment like chillers.
HVAC Diagnostics	✓	✓			Typically spot check input power and output and calibrate model for run time.
HVAC Quality Installation	✓	✓			Data sets such as outputs from diagnostic tools may be used as analysis inputs.
High-efficiency motors	✓	✓			Need loading and run time for steady state or continuous loading for varying loads.
Variable-speed drives		✓			Duty cycle required. Needs continuous direct monitoring for calibration.
Building envelope measures			✓	✓	Too complex for custom calculations. Calibrated simulations or billing regression needed.
Weatherization			✓		Measure effectiveness (infiltration) is very difficult to measure.
New construction whole building performance				✓	Comprehensive sets of measures require simulation. Few components with little interaction could use Options A/B.
Refrigeration measures	✓	✓	✓	✓	Measures vary significantly. Method depends on measure.
Process measures	✓	✓	✓		Measures vary significantly. Method depends on measure.
Appliances	✓	✓			Direct measurement for quantification of use needed.
Water heater and hot water measures	✓	✓			Flow rates measured directly. Use measured with temperature measurements. For larger facilities water heating may be metered separately.
Retrocommissioning	✓	✓	✓	✓	Measures and total impacts vary tremendously.

A. Retrofit Isolation with Key Parameter Measurement
B. Retrofit Isolation with All Parameter Measurement
C. Whole Facility
D. Calibrated Simulation

Non-Lighting Site Visits

Similar to lighting site visits, each site visit included the physical inspection of measures and a customer interview to gather information about the completed project for verification purposes.

For projects that operate mainly at a steady state, spot measurements of critical parameters such as amps, kW, temperatures and flow rates were taken. Examples of these projects may include constant speed fans and pumps, or process heating or cooling systems that serve a constant load. Such projects were analyzed primarily using IPMVP Option A or Option B.

For projects that operate with significant fluctuations, power data logging was completed for a period of at least two weeks. Additional data was collected, as appropriate, to normalize or extrapolate the data to the expected annual operation. These data could include outdoor air temperatures, production levels, facility schedules, or other factors as required. Examples of such projects would include most compressed air systems improvements, variable frequency drives, and controls projects. These projects are primarily analyzed using IPMVP Option A or Option B.

There is a compelling case to use IPMVP Option C; (whole building billing analysis), in combination with Option A, (partially measured retrofit isolation), for energy management system (EMS) projects. The rationale for using Option C is that the EMS typically has direct impact on (is controlling or interactive with) the entire facility, including all new measures and preexisting energy systems, and because the savings claimed as a percent of pre-implementation energy consumption are typically quite high for such projects. In addition, it is usually impossible to determine what the baseline HVAC operating sequences or system conditions and functionality was prior to implementation in these projects. Therefore, unless the *reported* savings estimates are very low as a percentage of pre-implementation energy consumption, Option C is typically the most suitable. The use of Option A in combination with Option C serves to:

1. Confirm savings are due to properly functioning energy management systems operating in accordance with project documentation where Option C results are reasonably close to reported estimates;
2. Where Option C results diverge from reported estimates, determine why this is the case (i.e. identify which measures or systems under EMS control are not operating as expected); and
3. Isolate and remove any effects due to minor changes in facility operation/equipment or other energy efficiency projects that were completed around or near the time of the project completion but not as part of the project scope.

Option C provides the best estimate of savings for EMS measures at a reasonable resource use, while Option A either corroborates that savings are due to effective energy management system deployment, or it helps explain why savings are not reasonably consistent with the *reported* estimates.

Instantaneous measurements of demand were taken using a NIST-calibrated three-phase RMS power meter. Short- and long-term metering was completed using equipment consistent with the relevant sections of the M-MVDR.

Non-Lighting Savings Analysis

Non-lighting site-specific analysis is conducted in the same general way as for lighting. The data collected through measurement are used to develop hourly operating and/or power use profiles for each measure by day-type (e.g., weekday, weekend, holiday, as well as any customer-specific day-types, and/or in relation to incidence of outside temperature [so-called 'bin methods']) for the post-implementation case, to whatever degree of resolution is needed and practical. The evaluation team also developed an estimated pre-implementation operation case for each day-type based on the post-implementation metered data, equipment specification data, and any customer interviews. The day-types were then applied to each day of the year to develop an hourly profile (8760 model) of equipment operation for both the pre/base case and the post-installation case for an entire year. Using the 8760 model, the evaluation team calculated both energy and peak demand *ex post* savings values based on the difference between pre- and post-implementation condition (e.g., the operational and coincident adjustment). This was done for both electric and gas projects, producing overall energy impacts and peak demand results. Although peak gas demand is not specifically required in the evaluation, it is a valuable by-product of this analysis strategy.

The construction of the profile is different for non-weather sensitive and weather sensitive measures; each is described in this section.

Non-Weather Sensitive Measures

For non-weather sensitive measures, the short-term data collected was used to relate the operating characteristics, such as kW, of the affected equipment to other parameters. These parameters included time of day, day-type, production levels, operating schedules, and other factors specific to the project, as determined through examination of the original calculations as well as through on-site interviews. Typically, multiple relationships were required to sufficiently account for annual expected operating patterns and variations. The relationships were then annualized based on the expected annual patterns in production, day-type relationships, and other factors, to determine the savings for each hour of the year in the 8760 model.

Weather Sensitive Measures

For weather sensitive measures using IPMVP Option A and Option B, the short-term metered data collected was used to relate the operating characteristics (such as kW) of the affected equipment to outdoor air temperature and humidity levels, as applicable. Typically, multiple regression analyses were required for each individual piece of equipment to account for variations in operation for occupied versus unoccupied periods, day-types, as well as any other factor determined to be significant.

The results of the regression analysis were then used to calculate the expected usages and savings for each hour of the year, including the peak period for peak demand, using TMY3 data in the 8760 model.

Evaluating energy management system measures with Option C involves a somewhat different approach. Project documentation is reviewed to best determine when the energy management system was installed and became functional. In addition, site staff were interviewed to determine if any changes to the facility (building, occupancy, fuel change, etc.), not directly related to the project being evaluated, occurred during the energy bill sampling period being used as the basis for Option C analysis. This is done to ensure that changes unrelated to the measure(s) under study (exogenous) can be eliminated from the analysis. This was performed using interviews, verification reports, calculation dates, and invoicing information from the project file. Three to four years of electric and/or natural gas billing data was used for these evaluations. For most projects, there was a year to a year and a half of data available before and after energy management system deployment. This provided a representative sample of data to assess performance before and after implementation.

Billing data were weather normalized using actual weather data from the nearest weather station, over the billing periods according to the utility meter read dates. Energy use per degree day (heating or cooling as appropriate) was developed using regression techniques, to determine the functional relationship between energy consumption and degree days for the evaluated billing period both pre and post project implementation. The difference represents savings as a function of degree-days. Savings for a “typical meteorological year” (TMY) were then applied to this function to determine savings under normal conditions.

For the Option A and/or Option B portion of an analysis of an energy management system, parameters from the program-provided documentation were verified on site. Some of these were fixed parameters such as building shell features. Other parameters varied included outdoor air percentage, building temperature setback (heating), and building temperature set-forward (cooling). These parameters were targeted for inspection, metering, and/or data logging as appropriate.

To determine peak demand impacts for energy management systems using primarily billing data, the projects were first evaluated for energy savings year-round, using the combination of IPMVP options described above. Once savings were verified or adjusted as appropriate and related to a specific degree-day function, peak weather conditions were found in the TMY records and were applied to these energy models to determine the demand impacts under these conditions.

APPENDIX B: METERING EQUIPMENT USED

Hobo UX90 Light On/Off Logger

The Hobo UX90 light on/off logger is a state logger that records the time and determines light state (on/off) when a change in state is determined, based on observed light level. When installed, the Hobo UX90 must be launched from a computer that has the clock synchronized to a NIST time source and programmed with a logging interval of no less than once every 15 minutes. For this evaluation, all loggers installed were launched from a computer with a UTC-calibrated clock, and were deployed with a sampling interval no greater than 5 minutes, for a minimum of 3 weeks. Per the manufacturer specifications, the UX90 loggers have a rated time accuracy of ±1 min/month. This meets the requirements of the M-MVDR.

Hobo U12-012 Lumen Level Loggers

The Hobo U12-012 Temp/%RH/1 external channel/ lumen level logger is a status logger that records the dry bulb temperature, % relative humidity, information made available by 1 external device, and lumen level at a preset time interval. When installed, the Hobo U12-012 must be launched from a computer that has the clock synchronized to a NIST time source and programmed with a logging interval of no less than once every 15 minutes. For this evaluation, all loggers installed were launched from a computer with a UTC-calibrated clock, and were deployed with a sampling interval no greater than 5 minutes, for a minimum of 3 weeks. Per the manufacturer specifications, the U12-012 loggers have a rated time accuracy of ±1 min/month. This meets the requirements of the M-MVDR. Because the Temp/%RH/lumen level is not used to correlate to demand, but instead is used as a "threshold" variable indicating light status, the lumen level accuracy requirement is not subject to the M-MVDR requirements and is not addressed.

Hobo U12-013 External Channel Status Loggers

The Hobo U12-012 Temp/%RH/2 external channel logger is a status logger that records the dry bulb temperature, % relative humidity, and information made available by up to 2 external devices at a preset time interval. When installed, the Hobo U12-012 must be launched from a computer that has the clock synchronized to a NIST time source and programmed with a logging interval of no less than once every 15 minutes. For this evaluation, all loggers installed were launched from a computer with a UTC-calibrated clock, and were deployed with a sampling interval no greater than 5 minutes, for a minimum of 3 weeks. Per the manufacturer specifications, the U12-012 loggers have a rated time accuracy of ±1 min/month. This meets the requirements of the M-MVDR. Because the Temp/%RH are not used to directly calculate demand, they are not required to meet the ±2% accuracy set forth by the M-MVDR for proxy variables.

Dent ElitePro Energy Logger

The Dent ElitePro kW logger is a status logger that records the average kW over a predetermined time interval by measuring the total kWh for the stated time interval. When installed, the Dent ElitePro logger must be launched from a computer that has the clock synchronized to a NIST time source and programmed with a logging interval of no less than once every 15 minutes. Per the manufacturer specifications, the Dent ElitePro loggers have a rated time accuracy of ±5 sec/week. The Dent ElitePro combined with SCT Amp Current Transformers has a combined rated accuracy of ±1.5% within 10% to 130% of SCT Amp Current Transformer rated current. This meets the requirements of the M-MVDR for both ±2 min/month time accuracy and ±2% kW accuracy.

APPENDIX C: GENERAL VENDOR SURVEY INSTRUMENTS

General Vendor Telephone Survey

Per the 2012 Conservation and Load Management Plan, the objective of the ECB program is “to maximize electric and natural gas energy savings for ‘lost opportunity’ projects, at the time of initial construction/major renovation, or when equipment needs to be replaced or added.” This survey is targeting the general vendor population in Connecticut in order to estimate the baseline equipment efficiencies and to determine if efficiency differences exist between measures installed in new construction and retrofit projects.

Sample Variables

Table C-1: Summary of Sample Variables

Code	Description
<&CONTACT>	First and last name of respondent
<&APPOINT>	Date and time you arrange with respondent to call back if they are busy at time of first call
<INTERVIEWER NAME>	Name of interviewer
<SURVEY COMPANY>	Name of survey company
<&COMPANY TYPE>	Type of company (lighting or HVAC)
<&ACTUAL COMPANY TYPE>	Type of company (lighting, HVAC, or both) as identified by respondent
<&COMPANY>	Name of respondent’s company
<&ADDRESS>	Respondent’s address
<&CITY>	Respondent’s city

Fielding Instructions

This section details fielding instructions:

- Attempt each record six times on different days of the week and at different times.
- Leave messages on the first and fourth attempt.
- Experienced interviewers should attempt to convert "soft" refusals (e.g., "I'm not interested", immediate hang-ups) at least once.
- After completing 10 interviews, hold calling and output a preliminary SPSS dataset and recordings of the pretest interviews. Resume calling after EMI Consulting checks the data (usually with 1-2 working days).
- Monitor at least 10 percent of the interviews to ensure proper interview protocols (e.g., reading questions verbatim, proper probing, accurate data entry).
- Calling hours are 9 AM to 5 PM EST.

Interview Instructions

Respondents to this survey are electric or mechanical contractors, equipment distributors and suppliers, and equipment retailers providing energy-efficient equipment and services. The Energy Conscious Blueprint Program provides rebates (incentives) for energy-efficient equipment in new construction or major renovation projects or in projects where the existing equipment is at the end of its usable life.

Survey

Section I: Introduction

Hello, this is <INTERVIEWER NAME> calling from <SURVEY COMPANY> on behalf of Eversource and United Illuminating. This is not a sales call, but a study on the commercial HVAC and lighting markets. Please be assured that your company name will not be identified in the study report.

I1. I'm looking to speak to the person in your firm that is most knowledgeable about your company's sales of different <&COMPANY TYPE> products. Could you point me to such a person in your firm?

1. No, I am not available right now.
2. Unable to refer someone who can help [TERMINATE]
3. Yes, that would be me [SKIP TO COMMENT 2]
4. Yes, let me transfer you to _______________ [SKIP TO I7]

-8. DON'T KNOW [SKIP TO 14]
-9. REFUSED [TERMINATE]

IF NECESSARY: Connecticut's electric and gas utilities are interested in getting input from <&COMPANY TYPE> vendors serving businesses in Connecticut regarding market share for different <&COMPANY TYPE> products and services. We are collecting the information through an online survey and will provide a $50 Amazon gift card in appreciation of your time.

I2. [IF I1=1] When would be a good day and time for us to call back?

1. Record day of the week, time of day, and date to call, as <&APPOINT>

-8. DON'T KNOW [SKIP TO COMMENT 1]
-9. REFUSED [SKIP TO COMMENT 1]

I3. [IF I1=1] Is there a phone extension or phone number you recommend we use when we call back?

1. Record extension or phone number, as <&PHONE> [TERMINATE]

-8. DON'T KNOW [TERMINATE]
-9. REFUSED [TERMINATE]

I4. [IF I1=-8] If it would make you more comfortable, I can offer you the contact information for the utilities we are working with so that you can verify the legitimacy of this study. Would that help?

1. Yes
2. No [SKIP TO I6]

I5. [IF I4=1] The contact for United Illuminating is Roy Haller. His number is 203.499.2025 and his email address is roy.haller@uinet.com. The contact for Eversource is Joe Swift. His number is 860.665.5692 and his email is joseph.swift@nu.com. When would be a good day and time for us to call back?

1. Record day of the week, time of day, and date to call, as <&APPOINT>
-8. DON'T KNOW [SKIP TO COMMENT 1]
-9. REFUSED [SKIP TO COMMENT 1]

I6. [IF I4=2] Is there someone else I could speak with?

1. Yes, let me transfer you to ________________
-8. DON'T KNOW [READ COMMENT 1]
-9. REFUSED [READ COMMENT 1]

COMMENT 1. Thank you for your time. Those are all of the questions I have for you today. [**TERMINATE**]

I7. [**READ IF TRANSFERRED**]
Hello, this is <INTERVIEWER NAME> calling from <SURVEY COMPANY> on behalf of Connecticut Light & Power, Yankee Gas, and United Illuminating. We are interested in speaking with the person most knowledgeable about your company's sales of different <&COMPANY TYPE> products. I was told that would be you. Is this correct?

COMMENT 2. [READ FOR ALL RESPONDENTS]
Connecticut's electric and gas utilities are interested in getting input from <&COMPANY TYPE> vendors serving businesses in Connecticut regarding market share for different commercial <&COMPANY TYPE> products and services. To determine whether your company primarily serves the commercial market, can you tell me…

I8. Is your company…

1. A lighting company [RECORD lighting AS <&ACTUAL COMPANY TYPE>]
2. An HVAC company [RECORD HVAC AS <&ACTUAL COMPANY TYPE>]
3. Both [RECORD lighting & HVAC AS <&ACTUAL COMPANY TYPE>]
4. [DO NOT READ] Neither
-8. [DO NOT READ] DON'T KNOW
-9. [DO NOT READ] REFUSED

[IF I8 =4 or I8=-8 or I8=-9, Thank and Terminate. Those are all the questions I have. Thank you for your time.]

I9. About what percentage of your company's Connecticut <&ACTUAL COMPANY TYPE> equipment sales or installations are to business and institutional rather than residential customers? Would you say:

1. Less than 25%
2. 25-50%
3. 50-100%

-8. DON'T KNOW
-9. REFUSED

[IF I8 =1 or I8=-8 or I8=-9, Thank and Terminate. Thanks for your time. We are focused on vendors who do most of their Connecticut work serving businesses.]

I10a. [IF <&ACTUAL COMPANY TYPE> = lighting or HVAC] Does your company also work with [IF <&ACTUAL COMPANY TYPE> = lighting, HVAC or compressed air] / [IF <&ACTUAL COMPANY TYPE> = HVAC, lighting or compressed air] / [IF <&ACTUAL COMPANY TYPE> = lighting & HVAC, compressed air? [DO NOT READ]

1. Yes, lighting
2. Yes, HVAC
3. Yes, compressed air
4. Yes, both.
5. No, neither.
6. Other [RECORD VERBATIM]

-8. DON'T KNOW
-9. REFUSED

I10b. [IF <&ACTUAL COMPANY TYPE> = lighting & HVAC] Does your company also work with compressed air? [DO NOT READ]

1. Yes
2. No
3. Other [RECORD VERBATIM]

-8. DON'T KNOW
-9. REFUSED

I11. [IF I8 =3 or I10a=1, 2 or 4] Would you say that lighting or HVAC is a larger share of business?

1. Lighting
2. HVAC
3. Both
4. Other [RECORD VERBATIM]

-8. DON'T KNOW
-9. REFUSED

COMMENT 3. [READ FOR ALL RESPONDENTS]
We are collecting information on the breakdown of commercial equipment sales through online surveys and will provide a $50 Amazon gift card in appreciation of your time. All data will be kept confidential and only reported in aggregate with all other results.

EMI CONSULTING

I12. Are you willing to participate in the study?

1. Yes
2. No [TERMINATE]
-8. DON'T KNOW [SKIP TO I6]
-9. REFUSED [TERMINATE]

I13. [IF I8 =3 or I10a=1, 2 or 4] There are separate online surveys for lighting and HVAC. We will provide two $50 Amazon gift cards if you complete both. Are you willing to complete both?

1. Yes
2. No
-8. DON'T KNOW

Can you please tell me the e-mail address(es) you would like us to send the online portion of the survey to?

[RECORD EMAIL ADDRESS(ES)]
-8. Don't know (GO TO CLOSE 2)
-9. Refused (GO TO CLOSE 2)

I14. Thank you. We have a few introductory questions and will then send you the online survey(s), which you can complete on your own time.

Section F: Firmographics

F1. First, what is your position or job title? [DO NOT READ]

1. Technician, installer, maintenance person
2. General sales
3. HVAC sales
4. Lighting sales
5. Plumbing sales
6. Inside sales/quotes
7. Manager
8. President/Owner
9. Other [RECORD VERBATIM]
-9. REFUSED

F2. [IF I8=2 or 3 or I10a=1, 2 or 4] Which activities are a major part of your company's HVAC work? Installation? Distribution? Retail? Repair? Design? [ALLOW MULTIPLE RESPONSES]

1. Install
2. Distribute
3. Retail
4. Repair

5. Design
6. Other [RECORD VERBATIM]
-8. DON'T KNOW
-9. REFUSED

F3. [IF I8=1 or 3 or I10a=1, 2 or 4] Which activities are a major part of your company's lighting work? Installation? Distribution? Retail? Repair? Lighting Design? Daylighting Design? [ALLOW MULTIPLE RESPONSES]

1. Install
2. Distribute
3. Retail
4. Repair
5. Lighting Design
6. Daylighting Design
7. Other [RECORD VERBATIM]
-8. DON'T KNOW
-9. REFUSED

F4. Which of the following would you use to describe your company? [READ LIST; ALLOW MULTIPLE RESPONSES]

FOR <&ACTUAL COMPANY TYPE> = HVAC, no involvement with lighting:

1. HVAC contractor
2. Plumbing contractor
3. Boiler maintenance contractor
4. Mechanical contractor
5. Controls contractor
6. Mechanical engineer/designer
7. Energy Services company
8. Distributor or wholesaler
9. Retailer
10. Other [RECORD VERBATIM]
-8. DON'T KNOW
-9. REFUSED

FOR <&ACTUAL COMPANY TYPE> = LIGHTING, no involvement with HVAC:

1. Lighting contractor
2. Electrical contractor
3. Electrical engineer/designer
4. Energy services company
5. Distributor or wholesaler
6. Retailer
7. Other
-8. DON'T KNOW
-9. REFUSED

FOR companies involved in both HVAC and lighting:

1. HVAC contractor
2. Plumbing contractor
3. Boiler maintenance contractor
4. Mechanical contractor
5. Controls contractor
6. Mechanical engineer/designer
7. Lighting contractor
8. Electrical contractor
9. Electrical engineer/designer
10. Energy services company
11. Distributor or wholesaler
12. Retailer
13. Other [RECORD VERBATIM]

-8. DON'T KNOW
-9. REFUSED

Section C: CT Rebates

C1. Approximately what percent of your company's sales are to customers in Connecticut?
[0–100]

C2. [IF I8=2 or 3 or I10a=1, 2 or 4] Next I would like to ask about the number of HVAC **jobs** that your firm has worked on recently, including multiple projects for a single customer. About how many commercial HVAC **jobs** has this location of your firm worked on in Connecticut in the past year?

C3. [IF I8=2 or 3 or I10a=1, 2 or 4] About what percentage, if any, of those jobs received rebates from a Connecticut Utility? Would you say:

1. Less than 5%
2. 5-10%
3. 11-25%
4. 26-50%
5. More than 50%

-8. DON'T KNOW
-9. REFUSED

C4. [IF I8=1 or 3 or I10a=1, 2 or 4] Next I would like to ask about the number of lighting **jobs** that your firm has worked on recently, including multiple projects for a single customer. About how many commercial lighting **jobs** has this location of your firm worked on in Connecticut in the past year?

C5. [IF I8=1 or 3 or I10a=1, 2 or 4] About what percentage, if any, of those jobs received rebates from a Connecticut Utility? Would you say:

1. Less than 5%
2. 5-10%
3. 11-25%

4. 26-50%
5. More than 50%
-8. DON'T KNOW
-9. REFUSED

Section A: Awareness

A1. Before this survey, had you or your company ever heard of the Energy Conscious Blueprint program?

1. Yes
2. No
-8. DON'T KNOW
-9. REFUSED

A2. Before this survey, had you or your company ever heard of the Energy Opportunities program?

1. Yes
2. No
-8. DON'T KNOW
-9. REFUSED

[**CONTINUE WITH THIS SECTION IF A1 = 1, YES OR A2 = 1, YES; OTHERWISE SKIP TO CLOSING**]

A3. To your knowledge, has your firm ever completed a project that received a rebate through the [IF A1 = 1 AND A2 NOT EQUAL TO 1: *Energy Conscious Blueprint program*, IF A1 NOT EQUAL TO 1 AND A2 = 1: *Energy Opportunities program*; IF A1 = 1 AND A2 = 1: Connecticut energy efficiency programs]?

1. Yes
2. No
-8. DON'T KNOW
-9. REFUSED

CLOSE. Thank you again for your agreeing to participate in our study. You will receive an invitation to the online portion of the survey within a few days. Please complete the survey(s) to get your $50 Amazon gift(s) card as a token of our appreciation. Have a good day!

[**TERMINATE**]

Section O: Online Section

Online Survey – To be coded in Qualtrics and delivered to the email address provided in the introduction.

Connecticut Light & Power, Yankee Gas, and United Illuminating thank you for participating in our study of the HVAC market. You will be provided with a $50 gift card once you complete this survey.

[See Online Questions below]

Lighting Vendor Online Survey

START Eversource and United Illuminating thank you for participating in our study of the lighting market. Please be assured that your company name will not be identified in the study report. We estimate this survey will take about 12-15 minutes. Please answer as many questions as you can. You will be provided with a $50 gift card if you complete this survey. It will be emailed to you within two weeks of completing the survey.

Section A: Firmographics and General Efficiency

Q1a What is the approximate average dollar value of your nonresidential lighting jobs in Connecticut (average revenue per job)? If dollar value available, enter here.

(ENTER VERBATIM RESPONSE)

Q1b Otherwise, would you say the average was: (check one)

Less than $2,000
$2,000 - $5,000
$5,000 - $10,000
$10,000 - $25,000
$25,000 - $50,000
More than $50,0000
Don't Know

Q2 What percent of your company's nonresidential lighting projects in Connecticut, by value, were made to the following kinds of customers? Please enter percentages so that they total 100%.

_______ Direct for building owners/managers
_______ General contractors
_______ Lighting or electrical contractors
_______ Retail stores
_______ Other

Q3 What percentage of your company's nonresidential lighting sales would you characterize as … * Early replacement is defined as replacement of equipment that is working and is not at the end of its expected useful life.

_______ New Construction or expansion
_______ Remodeling/build-out
_______ Early replacement* without significant remodeling
_______ Replacement on failure without significant remodeling
_______ Other

Q4 Is the equipment your company installs in a new construction project generally different than the equipment your company installs in an equipment replacement or retrofit project?

New Construction is more energy efficient
New Construction is less energy efficient
New Construction is equally energy efficient

Q5a In the course of bidding, proposing or marketing nonresidential lighting projects, does your company take steps to encourage your customers to select options that are more energy efficient than the standard equipment available or required by code?

Yes
No
Sometimes
Don't Know

[**If Q5a** = **Yes**]
Q5b Can you give an example of the kinds of steps your company takes?

(ENTER VERBATIM RESPONSE)

[**If Q5a** = **No**]
Q5c What are the main reasons your company does not take steps to promote equipment that is more energy efficient than required by code?

(ENTER VERBATIM RESPONSE)

Q5d Are there certain kinds of projects or circumstances in which your company is more likely to promote lighting equipment that is more energy efficient than code to a nonresidential customer or contractor?

Yes
No
Don't Know

[**If Q5d** = **Yes**]
Q5e Could you describe those for me? (For example, type of owner, type of building, type of equipment, availability of rebates)

(ENTER VERBATIM RESPONSE)

Q5f When your company attempts to sell or specify energy efficient lighting equipment, what factors or equipment features do you discuss with the customer?

(ENTER VERBATIM RESPONSE)

Q5g On what percentage of nonresidential lighting projects does your company specify or recommend energy efficient lighting options?

(ENTER VERBATIM RESPONSE)

Section E: Baseline Efficiency

E1 Which of the following types of lighting products has your company sold to nonresidential customers in Connecticut in the last 12 months? (Select all that apply)

Super or high performance T8 lamps (both linear and u-bend)
Standard T8 lamps (both linear and u-bend)
T12 lamps, including Energy savers (both linear and u-bend)
T5 lamps
LED linear retrofit
LED linear (set, lamp & ballast, all new)
Standard screw-in CFL bulbs
Specialty CFL bulbs - dimmable
Specialty CFL bulbs - candelabra
Specialty CFL bulbs - reflector
Hardwired CFL Fixtures
High-bay metal halides
T1, LED, or electro-luminescent Exit Signs
Other LED lighting - Recessed, surface, and pendant-mounted down luminaires
Other LED lighting - Under-cabinet, shelf-mounted task luminaires
Other LED lighting - Wall wash luminaires
Other LED lighting - Omni-directional
Other LED lighting - Decorative
Other LED lighting - Directional
Other LED lighting - Other 1 ______________________
Other LED lighting - Other 2 ______________________
Daylighting controls
Occupancy sensors

E2 For the following types of lighting products, please indicate about how many of each your company sold to nonresidential customers in Connecticut in the last 12 months. Please consider the number of bulbs rather than the number of fixtures or projects, unless the number of fixtures or jobs is specified.

0
1 – 100
101 – 1000
1,001 - 5,000
5,001 - 10,000
10,000 +

[If E1 - T8 lamps (both linear and u-bend) Is Selected]

E3 When you attempt to recommend or specify high performance T8 lamps, what concerns, if any, do customers and/or contractors express?

[If E1 - T5 lamps Is Selected]

E4 When you attempt to recommend or specify T5 lamps, what concerns, if any, do customers and/or contractors express?

[If E1 - Standard screw-in CFL bulbs Is Selected]

E5 What concerns, if any, do customers and/or contractors express about CFL bulbs?

[If E1 - Specialty CFL bulbs - dimmable Or Specialty CFL bulbs - candelabra Or Specialty CFL bulbs - reflector Is Selected]

E6 When you attempt to recommend or specify specialty CFL bulbs, what concerns, if any, do customers and/or contractors express?

[If E1 - Specialty CFL bulbs - dimmable Or Specialty CFL bulbs - candelabra Or Specialty CFL bulbs - reflector Is Selected]

E7 What availability issues, if any, have you encountered with specialty CFLs?

[If E1 - Hardwired CFL Fixtures Is Selected]

E8 What concerns, if any, do customers and/or contractors express about hardwired CFL fixtures?

[If E1 - Hardwired CFL Fixtures Is Selected]

E9 What availability issues, if any, have you encountered with hardwired CFL fixtures?

[If E1 - T1, LED, or electro-luminescent Exit Signs Is Selected]

E10 When you attempt to recommend or specify T1, LED, or electro-luminescent Exit Signs, what concerns, if any, do customers and/or contractors express?

[If E1 - T1, LED, or electro-luminescent Exit Signs Is Selected]

E11 What availability issues, if any, have you encountered with T1, LED, or electro-luminescent Exit Signs?

[If E1 - Other LED lighting (Recessed, surface, and pendant-mounted down luminaires; Under-cabinet, shelf-mounted task luminaires; Wall wash luminaires; Omni-directional; Decorative; Directional; Other) Is Selected]

E12 When you attempt to recommend or specify other types of LED lighting, what concerns, if any, do customers and/or contractors express?

[If E1 - Other LED lighting (Recessed, surface, and pendant-mounted down luminaires; Under-cabinet, shelf-mounted task luminaires; Wall wash luminaires; Omni-directional; Decorative; Directional; Other) Is Selected]

E13 What availability issues, if any, have you encountered with other types of LED lighting?

[If E1 - Daylighting controls Is Selected]

E14 What concerns, if any, do customers and/or contractors express about daylighting controls?

[If E1 - Occupancy sensors Is Selected]

E15 What concerns, if any, do customers and/or contractors express about occupancy sensors?

Section L: LED Market Growth

L1 Based on your experience, what percentage of nonresidential building floor space has any type of LED lighting installed as a part of a … Your best estimate is fine.

_______ Retrofit or equipment replacement
_______ New construction

L2 Two years ago, what percentage of nonresidential building floor space had any type of LED lighting installed as a part of a … Your best estimate is fine.

_______ Retrofit or equipment replacement
_______ New construction

L3 Has the growth of LED usage in the following building types over the last 2 years been faster, slower or as you expected?

	Slower	As expected	Faster	Don't Know
Existing Buildings				
New Construction				

L4 What % of lighting in the following building types will be LEDs five years from now? Your best estimate is fine.

_______ Existing Buildings
_______ New construction

Section B: Closing

Q34 Thank you for completing the survey! Please enter your name and email below if you would like us to send you your $50 Amazon gift card. Name:

Q35 Please enter your company name: (This information is for internal purposes only and will not be shared or made public in any way.)

Q36 Email:

Q37 Make sure you click the "next" button to ensure all your responses are recorded.

HVAC Vendor Online Survey

START Eversource and United Illuminating thank you for participating in our study of the HVAC market. Please be assured that your company name will not be identified in the study report. We estimate this survey will take about 12-15 minutes. Please answer as many questions as you can. You will be provided with a $50 gift card if you complete this survey. The gift card will be sent within two to three weeks of survey completion.

Section A: Firmographics and General Efficiency

S1 Is your company a contractor, distributor, or something else? Your response will not impact the type of questions that you are asked.

Contractor
Distributor
Other

Q1a What is the approximate average dollar value of your nonresidential HVAC jobs in Connecticut (average revenue per job)? If dollar value available, enter here:

(ENTER VERBATIM RESPONSE)

Q1b Otherwise, would you say the average was:

Less than $10,000
$10,000 - $25,000
$25,000 - $50,000
$50,000 - $100,000
More than $100,000

Q2 What percent of your company's nonresidential HVAC projects in Connecticut, by value, are undertaken for the following kinds of customers? Please enter percentages so that they total 100%.

_______ Direct for building owners/managers
_______ General contractors
_______ Other mechanical contractors
_______ Other

Q3 What percentage of your nonresidential HVAC projects would you characterize as … (Early replacement is defined as replacement of equipment that is working and is not at the end of its expected useful life.)

_______ New Construction or expansion
_______ Remodeling/build-out
_______ Early replacement* without significant remodeling
_______ Replacement on failure without significant remodeling
_______ Other

Q4 Is the equipment your company installs in a new construction project generally different than the equipment your company installs in an equipment replacement or retrofit project?

New Construction is more energy efficient
New Construction is less energy efficient
New Construction is equally energy efficient
Don't Know

Q5a In the course of bidding, proposing or marketing nonresidential HVAC projects, does your company take steps to encourage your customers to select options that are more energy efficient than the standard equipment available or required by code?

Yes
No
Sometimes
Don't Know

[**IF Q5a** = **Yes**]
Q5b Can you give an example of the kinds of steps your company takes?

(ENTER VERBATIM RESPONSE)

[**IF Q5a** = **No**]
Q5c What are the main reasons your company does not take steps to promote equipment that is more energy efficient than required by code?

(ENTER VERBATIM RESPONSE)

Q5d Are there certain kinds of projects or circumstances in which your company is more likely to promote HVAC equipment that is more energy efficient than code to a business customer or contractor?

Yes
No
Don't Know

[IF Q5d = Yes]

Q5e Could you describe those for me? (For example, type of owner, type of building, type of equipment, availability of rebates)

Q5f When your company attempts to sell or specify energy efficient HVAC equipment, what factors or equipment features do you discuss?

(ENTER VERBATIM RESPONSE)

Section E: Baseline Efficiency and Market Share

E1 Which of the following types of heating and cooling products has your company sold to nonresidential customers in Connecticut in the last 12 months?

(A) Commercial AC/Packaged Heat Pump/rooftop units
(B) Air cooled chillers (with condenser)
(C) Water cooled chillers
(D) Commercial Gas-Fired Hot Water Heaters
(E) Commercial Electric / Heat Pump Water Heaters
(F) Commercial Gas-Fired Furnaces
(G) Commercial Gas-Fired Hot Water Boilers
(H) Commercial Boiler Tune-ups

[Ask questions EA1 through EH1 if the corresponding choice from question E1 is selected. Ex. Ask EA1 if choice (A) Commercial AC/Packaged Heat Pump/rooftop units is selected.]

EA1 For the following types and sizes of AC/Heat Pump/Rooftop units, please indicate about how many units your company sold to nonresidential customers in Connecticut in the last 12 months. Please consider the number of units rather than the number of jobs or projects.

	0	1 - 5	6 - 20	21 - 50	50 +
13 SEER or below					
13.1 SEER - 13.9 SEER					
14 SEER - 15 SEER					
15.1 SEER - 19 SEER					
19.1 SEER or greater					
11.2 EER or below					
11.3 EER - 11.5 EER					
11.5 EER - 12 EER					
12.1 EER or greater					

EA2 For the following types and sizes of AC/Heat Pump/Rooftop units, please indicate about how many units your company sold to nonresidential customers in Connecticut in the last 12 months. Please consider the number of units rather than the number of jobs or projects.

	0	1 - 5	6 - 20	21 - 50	50 +
10 EER or below					
10.1 EER - 10.7 EER					
10.8 EER - 11.5 EER					
11.6 EER or greater					
10 EER or below					
10.1 EER - 10.4 EER					
10.5 EER - 10.8 EER					
10.9 EER or greater					
9.7 EER or below					
9.7 EER - 10.2 EER					
10.3 EER or greater					

EA3 What concerns, if any, do customers and/or contractors express about higher efficiency units?

EB1 For the following types and sizes of Air Cooled Chiller units with a condenser, please indicate about how many units your company sold to nonresidential customers in Connecticut in the last 12 months. Please consider the number of units rather than the number of jobs or projects.

	0	1 - 5	6 - 20	21 - 50	50 +
IPLV rating of 12.5 EER or less					
IPLV rating of 12.6 EER or greater					
IPLV rating of 12.75 EER or less					
IPLV rating of 12.76 or greater					

EB2 What concerns, if any, do customers and/or contractors express about higher efficiency units?

EC1 For the following types and sizes of Water cooled chiller units, please indicate about how many units your company sold to nonresidential customers in Connecticut in the last 12 months. Please consider the number of units rather than the number of jobs or projects.

	0	1 - 5	6 - 20	21 - 50	50 +
IPLV rating of 0.539 kW/ton or greater					
IPLV rating between 0.539 and 0.4 kW/ton					
IPLV rating of 0.4 kW/ton or less					
IPLV rating of 0.549 kW/ton or greater					
IPLV rating between 0.4 and 0.549 kW/ton					
IPLV rating of 0.4 kW/ton or less					
IPLV rating of 0.596 kW/ton or greater					
IPLV rating between 0.596 and 0.45 kW/ton					
IPLV rating of 0.45 kW/ton or less					

EC2 For the following types and sizes of Water cooled chiller units, please indicate about how many units your company sold to nonresidential customers in Connecticut in the last 12 months. Please consider the number of units rather than the number of jobs or projects.

	0	1 - 5	6 - 20	21 - 50	50 +
IPLV rating of 0.54 kW/ton or greater					
IPLV rating between 0.54 and 0.49 kW/ton					
IPLV rating of 0.49 kW/ton or less					
IPLV rating of 0.58 kW/ton or greater					
IPLV rating between 0.58 and 0.54 kW/ton					
IPLV rating of 0.54 kW/ton or less					
IPLV rating of 0.615 kW/ton or greater					
IPLV rating between 0.615 and 0.586 kW/ton					
IPLV rating of 0.586 kW/ton or less					
IPLV rating of 0.63 kW/ton or greater					
IPLV rating between 0.63 and 0.6 kW/ton					
IPLV rating of 0.6 kW/ton or less					

EC3 What concerns, if any, do customers and/or contractors express about higher efficiency units?

ED1 For the following types and sizes of Commercial Gas-Fired Hot Water Heaters, please indicate about how many units your company sold to nonresidential customers in Connecticut in the last 12 months. Please consider the number of units rather than the number of jobs or projects. EF = Energy Factor

	0	1 - 5	6 - 20	21 - 50	50 +
At or below 63% EF					
64% EF and higher					
At or below 80% efficiency					
81% efficiency and higher					
Small (					
Large (>75,000 Btu/h)					

ED2 What concerns, if any, do customers and/or contractors express about higher efficiency units?

EE1 For the following types and sizes of Commercial Electric / HP Water Heaters, please indicate about how many units your company sold to nonresidential customers in Connecticut in the last 12 months. Please consider the number of units rather than the number of jobs or projects.

	0	1 - 5	6 - 20	21 - 50	50 +
Standard water heater					
Heat pump water heater					
Standard water heater					
Heat pump water heater					

EE2 What concerns, if any, do customers and/or contractors express about higher efficiency units?

EF1 For the following types of Commercial Gas-Fired Furnaces, please indicate about how many units your company sold to nonresidential customers in Connecticut in the last 12 months. Please consider the number of units rather than the number of jobs or projects.

	0	1 - 5	6 - 20	21 - 50	50 +
At or below 80% efficiency					
81% efficiency and higher					

EF2 What concerns, if any, do customers and/or contractors express about higher efficiency units?

EG1 For the following types of Commercial Gas-Fired Hot Water Boilers, please indicate about how many units your company sold to nonresidential customers in Connecticut in the last 12 months. Please consider the number of units rather than the number of jobs or projects.

	0	1 - 5	6 - 20	21 - 50	50 +
At or below 80% efficiency					
81% efficiency or greater, non-condensing					
81% efficiency or greater, condensing					

EG2 What concerns, if any, do customers and/or contractors express about higher efficiency units?

EH1 Please indicate about how many Commercial Boiler Tune-ups your company completed for nonresidential customers in Connecticut in the last 12 months. Please consider the number of units rather than the number of jobs or projects.

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Section B: Closing

Q35 Thank you for completing the survey! Please enter your name and email below if you would like us to send you your $50 Amazon gift card. Name:

Q36 Please enter your company name: (This information is for internal purposes only and will not be shared or made public in any way.)

Q37 Email:

Q38 Make sure you click the "next" button to ensure all your responses are recorded.

APPENDIX D: ADDITIONAL VENDOR SURVEY ANALYSIS

HVAC Efficiency Summary Tables

The following tables show the efficiency and size of HVAC sales within multiple product categories. For each category, HVAC vendors selected how many of their sales were within prescribed efficiency ranges and size ranges. The tables highlight the most common efficiency range for each size range and the market share by size category.

Table D-1. Average Efficiencies, Sizes, and Market Shares of Commercial AC / Heat Pump / Rooftop Units

Size	Average Efficiency	Standard Error in Efficiency	Most Common Efficiency Category	Efficiency Category Percentage	Total Units	Market Share
AC / Heat Pump / Rooftop Units						
Less than 5.4 Tons	14.85	0.33	14 SEER - 15 SEER	40.5%	682	28.9%
5.4 to 11.3 Tons	11.83	0.13	11.3 EER - 11.5 EER	32.3%	690	29.2%
11.3 to 20 Tons	11.70	0.16	11.5 EER - 12 EER	35.0%	523	22.2%
20 to 30 Tons	10.99	0.14	10.8 EER - 11.5 EER	40.5%	227	9.6%
30 to 63.3 Tons	10.79	0.25	10.9 EER or greater	43.8%	128	5.4%
63.3 Tons or greater	10.54	0.21	10.3 EER or greater	63.1%	111	4.7%

Table D-2. Average Efficiencies, Sizes, and Market Shares of Commercial Chillers

Size	Average Efficiency	Standard Error in Efficiency	Most Common Efficiency Category	Efficiency Category Percentage	Total Units	Market Share
Air Cooled Chiller						
< 150 Tons	12.42	0.16	IPLV rating of 12.5 EER or less	61.8%	55	11.80%
>= 150 Tons	12.75	0.28	IPLV rating of 12.75 EER or less	50%	56	12.02%
Water Cooled Chiller						
Centrifugal Chiller >= 600 Tons	0.53	0.04	IPLV rating of 0.539 kW/ton or greater	58%	50	10.73%
Centrifugal Chiller 300 - 600 Tons	0.48	0.04	IPLV rating between 0.4 and 0.549 kW/ton	50%	64	13.73%
Centrifugal Chiller <= 300 Tons	0.56	0.04	IPLV rating between 0.596 and 0.45 kW/ton	50.0%	44	9.44%
Screw chiller >=300 Tons	0.52	0.02	IPLV rating of 0.54 kW/ton or greater	33.3%	48	10.30%
Screw Chiller 150 - 300 Tons	0.55	0.02	IPLV rating of 0.54 kW/ton or less	54.3%	70	15.02%
Screw Chiller 75 - 150 Tons	0.60	0.01	IPLV rating between 0.615 and 0.586 kW/ton	37.3%	51	10.94%
Screw Chiller < 75 Tons	0.60	0.01	IPLV rating of 0.6 kW/ton or less	57.1%	28	6.01%

Table D-3. Average Efficiencies, Sizes, and Market Shares of Commercial Water Heaters

Size	Average Efficiency	Standard Error in Efficiency	Most Common Efficiency Category	Efficiency Category Percentage	Total Units	Market Share
Gas-Fired Hot Water Heaters						
Small Storage (<=75,000 Btu/h)	66.16	0.42	64% EF and higher	88%	334	21.8%
Large Storage (>75,000 Btu/h)	82.56	1.02	81% efficiency and higher	72.9%	314	20.5%
Instant/Tankless	-	-	Large (>75,000 Btu/h)	65.5%	521	33.9%
Electric / HP Water Heaters						
<=100 MBH	-	-	Standard water heater	69.1%	204	13.3%
>100 MBH	-	-	Standard water heater	58.6%	162	10.6%

Table D-4. Average Efficiencies, Sizes, and Market Shares of Commercial Furnaces

Category	Average Efficiency	Standard Error in Efficiency	Most Common Efficiency Category	Efficiency Category Percentage	Total Units
Gas-Fired Furnaces	82.70	0.86	81% efficiency and higher	74.4%	497.00

Table D-5. Average Efficiencies, Sizes, and Market Shares of Commercial Water Boilers

Category	Average Efficiency	Standard Error in Efficiency	Most Common Efficiency Category	Efficiency Category Percentage	Total Units
Gas-Fired Hot Water Boilers	84.22	0.32	81% efficiency or greater, condensing	62.8%	589.00

HVAC vendors also completed 2610 boiler tune-ups. This measure did not include any efficiency or size information.

APPENDIX E: PEAK PERIOD

There are several values for demand impacts. This section first presents definitions of the demand values and then presents the methods for estimating demand impacts.

E.1 Peak Demand Definitions

Per the requirements of this evaluation, four values for electric demand reductions and two values for gas demand reductions are presented for each project. The six demand values are:

1. Summer Peak — This is the average demand reduction during the summer 1:00-5:00 PM period during non-holiday weekdays in June, July, and August.
2. Winter Peak — This is the average demand reduction during the winter 5:00-7:00 PM period during non-holiday weekdays in December and January.
3. Summer Seasonal Peak — This is the average demand reduction during the summer hours that the ISO New England Real-time System Hourly Load is equal to or greater than 90% of the most recent “50/50” System Peak Load Forecast for the Summer Season, including June, July, and August.
4. Winter Seasonal Peak — This is the average demand reduction during the winter hours that the ISO New England Real-time System Hourly Load is equal to or greater than 90% of the most recent “50/50” System Peak Load Forecast for the Winter Season, including December and January.
5. Peak Day — This is the daily CCF reduction for the average coldest day per year for the past 30 years.
6. Extreme Peak Day — This is the daily CCF reduction for the coldest day in the past 30 years.

E.2 Peak Demand Estimation Methods

For the purposes of this evaluation, all peak demand reductions were calculated using an 8760 hour modeling approach, with the expected demand reductions being calculated for each hour of the year. Using this approach, the summer and winter peak demand reductions can be determined by averaging the non-holiday weekday peak hours as defined previously.

However, the determination of the seasonal peak is determined on the hourly system load, and if that system load is greater than or equal to 90% of the expected 50/50 peak load forecast. Therefore, the times and dates for this condition cannot be so easily defined. It has been shown that system load is found to be related to both the time of day and weather conditions.

Seasonal Peaks

This section provides greater detail on the seasonal peaks: summer seasonal peak and winter seasonal peak.

Summer Seasonal Peak

The Total Heat Index (THI) and Weighted Heat Index (WHI) are forecast variables used by ISO New England to relate system load and weather conditions. Both attempt to account for temperature and humidity levels. In addition, WHI includes a “history” component to account for weather conditions in the previous two days. THI and WHI are calculated as:

THI = 0.5 x DBT + 0.3 x DPT +15,

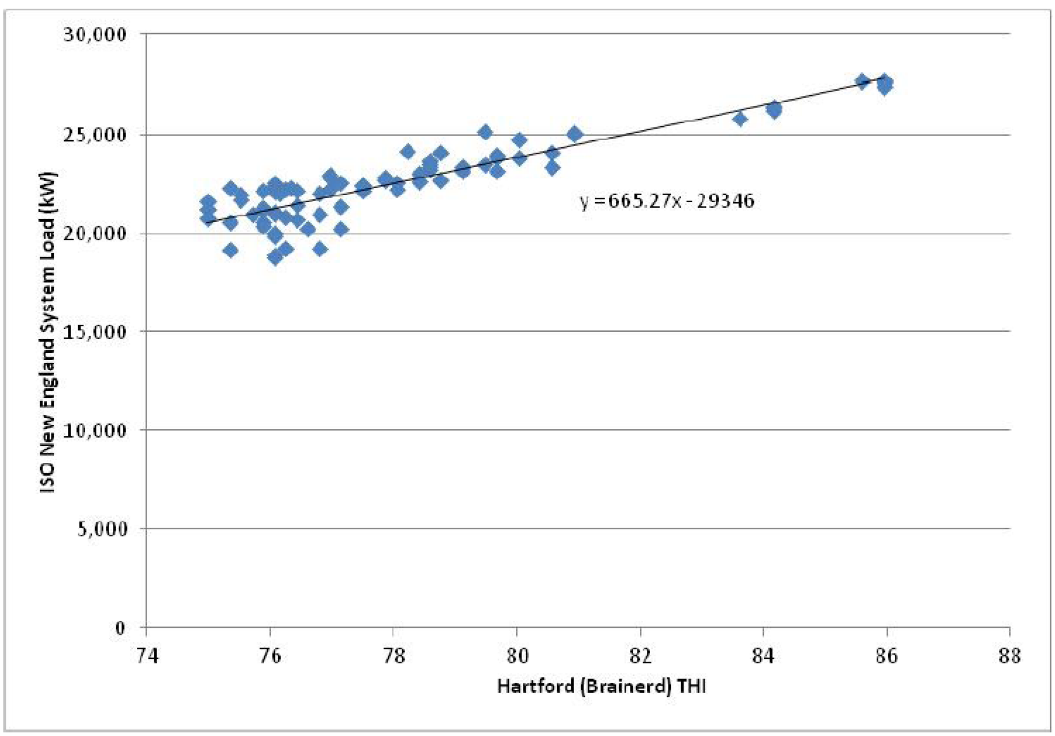
where
THI = Total Heat Index
DBT = Dry Bulb Temperature (°F)
DPT = Dew Point Temperature (°F)

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

where
WHI = Weighted Heat Index
THI_{di-hi} = Total Heat Index for current day and hour
$THI_{d(i-1)-hi}$ = Total Heat Index for previous day at the same hour
$THI_{d(i-2)-hi}$ = Total Heat Index for two days prior at the same hour

For this evaluation, in order to determine the summer seasonal peak hours, the non-holiday weekday hourly system load profile from the ISO New England Hourly Zonal (SMD) report, was correlated to both THI and WHI, where the THI and WHI were based on Hartford (Brainerd), CT weather conditions. The resulting relationship, showing only temperatures 75°F and above, is given in **Error! Not a valid bookmark self-reference.** below.

Figure E-1. System Load as a function of THI



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Based on the 2011-2020 Forecast Report of Capacity, Energy, Loads, and Transmission report, the expected 50/50 system peak load for the summer condition was expected to be 27,550 kW.[32]

Therefore, 90% of the 50/50 system peak load for the summer condition is met when the system load was 24,975 kW or greater. Based on the WHI relationship developed above, this is expected to be met when the THI conditions are 81.6°F or greater. Therefore, hours used to determine the peak for the purposes of this evaluation were the hours when the THI was at or greater than 81.6°F for Hartford (Brainerd) for the TMY3 file utilized.

A similar approach was taken to correlate to WHI; however, the WHI correlation did not affect the hours selected, and therefore was not included.

Winter Seasonal Peak

To determine the winter seasonal peak demand reductions, a similar approach was taken as given above. However, several changes were made to the analysis. First, based on the 2011-2020 Forecast Report of Capacity, Energy, Loads, and Transmission report, the expected 50/50 system peak load for the winter condition was expected to be 22,085 kW.[33] Therefore, 90% of the 50/50 system peak load for the winter load condition is met when the system load was 19,877 kW or greater. Second, for the winter condition, humidity is not expected to significantly affect the system load; therefore, the system load is correlated to dry bulb temperature. Finally, based on a review of the data, the system load varied significantly based on the time of day. Therefore, the decision was made to produce separate correlations for each hour considered. Based on this analysis, the peak load condition is expected to be met when the temperature is at or below the temperatures given for each hour listed in Table E-1 below.

Table E-1. Winter Peak Temperature Conditions

Hour	Starting Time	Ending Time	Dry Bulb Temperature
16	5:00	6:00	20.4 °F
17	6:00	7:00	17.7 °F
18	7:00	8:00	5.0 °F

[32] ISO New England. (2011). 2011-2020 Forecast Report of Capacity, Energy, Loads, and Transmission. Retrieved from: http://www.iso-ne.com/trans/celt/report/2011/2011_celt_rprt.pdf
[33] ibid

Figure E-2. System Load as a function of Dry Bulb Temperature for Hour 18

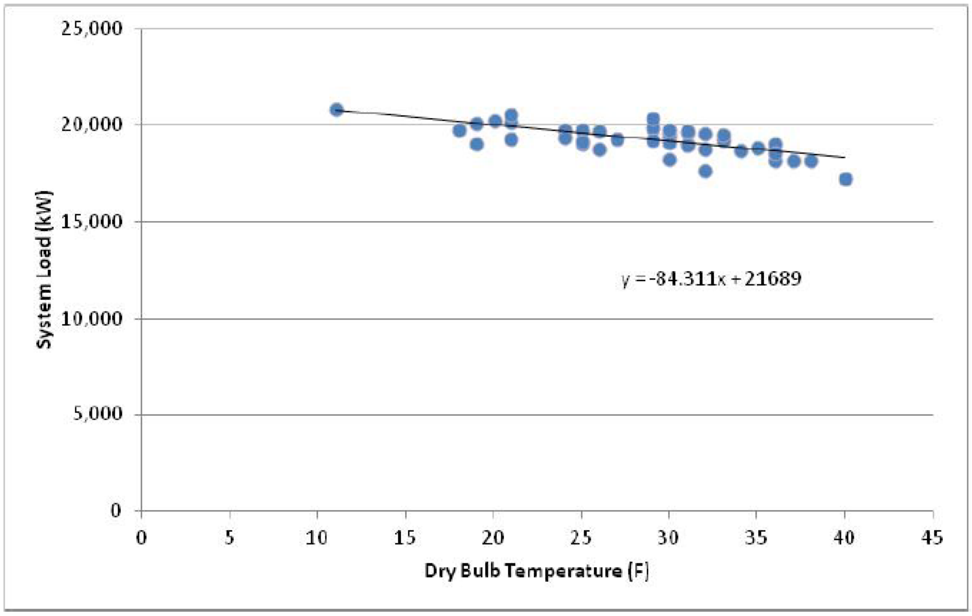


Figure E-3. System Load as a function of Dry Bulb Temperature for Hour 19

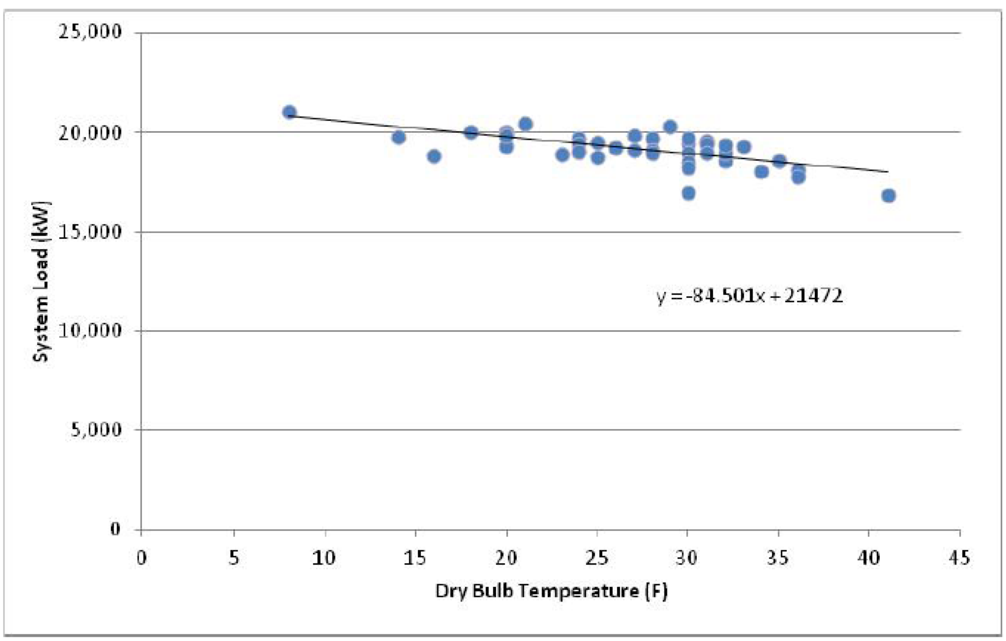
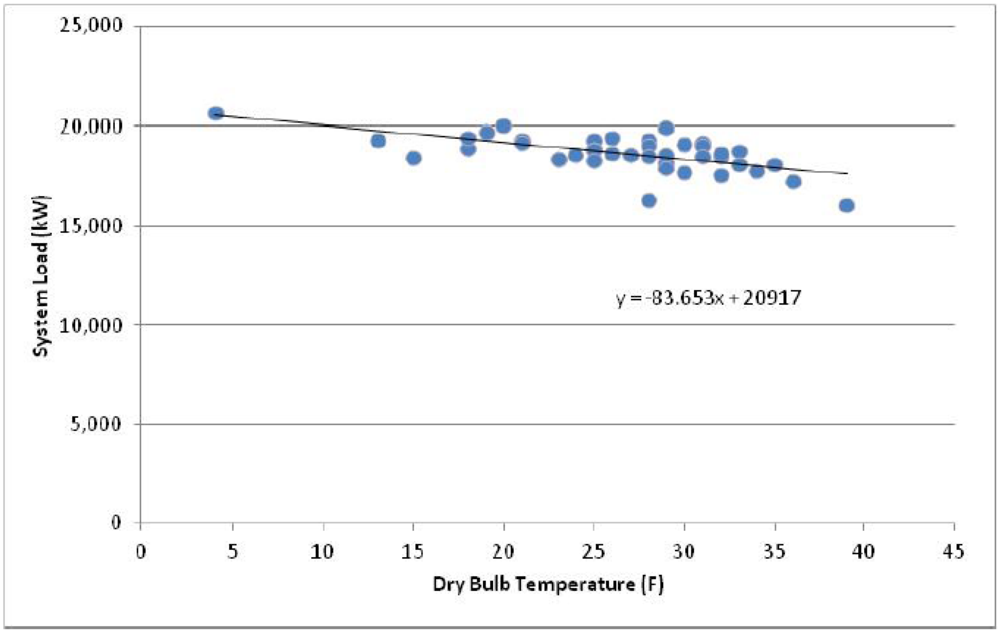


Figure E-4. System Load as a function of Dry Bulb Temperature for Hour 20



APPENDIX F: ON-SITE M&V RECRUITMENT SCRIPT

INTRO: Hello, this is __________ from Michaels Energy calling on behalf of [UTILITY]. I am calling regarding your [PROJECT] project that you completed and received an incentive from [UTILITY] back in [YEAR/MONTH]. We are conducting a follow-up to review how the project has gone and to verify the energy savings. [UTILITY] is required to verify a sample of the energy savings achieved through their programs and to identify things that work well and what things require improvement. This follow-up will not affect your incentive in anyway and is only used to provide feedback to future program planning and design. I would like to schedule a visit to interview you or a member of your staff that you designate about the project. During the visit we may also install some data loggers to monitor the operation of the installed equipment to better understand how your equipment operates. These data loggers will not interfere with any of your equipment.

Q1: We are planning to be in your area the week of [WEEK]. Would it work to schedule a time to meet now?

Yes (SCHEDULE TIME)
No—Not able to schedule at this time (Ask when a better time to schedule would be)
No—That week does not work (Ask what weeks would work better for them)
No—Not willing to participate (offer incentive, if still no THANK YOU and TERMINATE)

[IF Q1=1 ASK Q2]
Q2: I would like to verify your facilities address.

Yes, that is correct
No, (RECORD CORRECT INFORMATION)

[AFTER Q2=1 ASK Q3]
Q3: What is the best way to contact you in the future? (Direct Line, Email, Cell Phone)

(RECORD CORRECT INFORMATION)

[AFTER Q3 ASK Q4]

Q4: Are there any safety requirements or equipment that I should be aware of to visit your facility?

(RECORD CORRECT INFORMATION)

[AFTER Q4 ASK Q5]

Q5: Ask any additional questions about the project that arose during project review.

(RECORD CORRECT INFORMATION)

IF THEY HAVE ANY QUESTION ABOUT THE LEGITIMACY OF THIS STUDY HAVE THEM CONTACT OR AQUIRE THEIR EMAIL ADDRESS AND SEND THE LETTER OF ASSOCIATION (LOA)

APPENDIX G: IMPLICATIONS OF NEGATIVE AND ZERO REPORTED SAVINGS

In our sample, there were measures that had negative or zero reported demand savings that were found to have evaluated demand savings. To be specific, 17 measures had zero (15) or negative (2) reported summer demand savings, and 52 measures had zero (50) or negative (2) reported winter demand savings. In order to include the evaluated savings as part of the program realized savings, the reported savings had to be replaced by a positive value. As the realization rate is a ratio of evaluated savings to reported savings, negative reported savings result in negative realization rates, which do not meaningfully translate into typical projects with positive reported savings. Also, reported savings of zero result in a mathematical error (zero cannot be a denominator).

The selection of a small positive value is not trivial. In this case, we selected a small positive value of 1.000001. This has implications in the resulting realization rates. For example, one measure with reported summer demand savings of zero was found to have 46.93 kW summer seasonal demand savings. Without replacement, this measure's realization rate is not a number and is not able to roll up into the calculations. However, with replacement at 1.00001, the realization rate is 46.93 (4693%). Neither of these solutions is ideal. Selecting a reported savings equal to the evaluated savings would indicate more accurate program predictions than observed. The considerations here are summarized in Table G-1.

Table G-1. Implications of Treatment of Zero and Negative Reported Savings

Reported Savings Value in Realization Rate Calculation when Evaluated Savings Value is Positive	Implications
Zero	The realization rate cannot be calculated. The number of measures included in the final result is lower, with negative impacts on precision and realized savings.
Negative	The realization rate is negative and has an inaccurate relationship to typical positive reported savings, with negative impacts on precision and realized savings.
Set to small positive value (i.e. 1.00001)	The realization rate may be calculated extraordinarily high, on the order of thousands of percent, with negative impacts on precision, but accurate realized savings.
Set equal to evaluated	The realization rate is artificially equal to 1 for the measure. This has positive impacts on precision, overstating program prediction accuracy, but accurate realized savings.

We opted to report savings using the findings with substitution of zero and negative reported demand savings with a small positive value in order to ensure that the final realized savings would be accurate and the program prediction accuracy would not be overstated. Table G-2 shows the overall findings if we were to instead drop the measures that had zero or negative reported savings.

Table G-2. Realization Rates with and without Removing Measures with Negative and Zero Reported Savings

Category	Reported Realization Rates (All Measures Included)	Realization Rates with Negative and Zero Savings Measures Removed	Evaluated Demand Savings with Negative and Zero Measures Removed
Electric Summer Demand	83%	76%	11.0 MW
Electric Winter Demand	90%	73%	7.0 MW

The coefficients of variation and error ratios show that the realization rates are generally more tightly grouped when the zero and negative results are removed. For summer demand, the comparison is shown in Table G-3; here, we can see that the process measure group is especially affected.

Table G-3. Summer Demand Coefficients of Variation and Error Ratio, by Treatment of Zero and Negative Reported Values

Measure Group	Negative and Zero Values Replaced (Report)		Negative and Zero Values Dropped	
	c.v.	e.r.	c.v.	e.r.
Compressed Air	1.36	1.7	1.34	1.7
HVAC	1.87	1.87	2.05	1.81
Other	1.7	0.87	1.4	0.85
Light	0.72	0.62	0.72	0.62
Process	2.54	2.21	1.09	1.18
Electric Overall	**1.62**	**1.40**	**1.22**	**1.14**

For winter demand, the comparison is shown in Table G-4.

Table G-4. Winter Demand Coefficients of Variation and Error Ratio, by Treatment of Zero and Negative Reported Values

Measure Group	Negative and Zero Values Replaced (Report)		Negative and Zero Values Dropped	
	c.v.	e.r.	c.v.	e.r.
Compressed Air	1.28	1.75	1.34	1.77
HVAC	1.62	2.03	1.94	2.16
Other	1.7	5.39	0.73	3.19
Light	0.84	0.75	0.84	0.75
Process	2.19	2.74	1.1	1.32
Electric Overall	**1.53**	**1.95**	**1.08**	**1.32**

APPENDIX H: RESULTS BASED ON ORIGINAL SAMPLE DESIGN

The original sample design was at the project level, organized into measure groups by the measure with the maximum annual energy savings for the project. The evaluation plan included a strategy of reporting by measure instead of project, to avoid counting savings and realization rates for smaller measures of a different group within the maximum measure group. As an example, a lighting project could have been originally sampled for the lighting measure group, but the scope of the project may have also involved the replacement of smaller HVAC units and an air compressor that generated less savings than the lighting measures. Without post-stratification, all measures affiliated with the sampled project ID would have contributed to the 'Lighting' measure group realization rate, which may have less meaning when considering program improvements.

This appendix reports the findings using the original sample organization for those who are interested in the comparison to the measure level findings reported in the main body. Realization rates and relative precision at the program level are given in Table H-1.

Table H-1. Overall Realization Rate and Precision, Original Design

Category	Realization Rate	Evaluated Savings	Units	Precision *
Electric Energy	81%	61,316	MWh	± 22%
Electric Summer Demand	77%	11	MW	± 21%
Electric Winter Demand	90%	9	MW	± 34%
Gas	76%	747,909	therms	± 18%
* Precision reported at 90% confidence for Energy and 80% confidence for Demand				

The coefficients of variation and error ratios are given in Table H-2 and Table H-3.

Table H-2. Coefficients of Variation and Error Ratios, Electric, Original Design

Max Measure Group	Energy		Summer Demand		Winter Demand	
	c.v.	e.r.	c.v.	e.r.	c.v.	e.r.
Compressed Air	0.49	0.49	1.36	0.95	1.47	0.98
Cool	0.83	1.13	0.66	1.09	0.87	1.33
Light	0.63	0.6	0.46	0.56	0.68	0.79
Other	0.64	0.67	1.29	0.86	2.19	4.19
Process	1.07	1.56	1.41	2.21	1.29	2.5
Electric Overall	**0.71**	**0.97**	**1.07**	**1.26**	**1.31**	**2.40**

Table H-3. Coefficients of Variation and Error Ratios, Gas, Original Design

Max Measure Group	Energy	
	c.v.	e.r.
Boiler	0.53	0.36
Other	0.92	1.02