REPORT

C1630 Largest Savers Evaluation Final Report

Submitted to the Connecticut Energy Efficiency Board in partnership with Warren Energy Engineering

April 25, 2018

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Abstract

This report covers an impact evaluation of the projects with the most energy savings in the CT C&I Energy Conservation Blueprint (ECB) and Energy Opportunities (EO) for program years 2013-2015 and discusses observed trends and their potential impact on future evaluation planning. The study addresses two objectives:

1. Evaluate the energy and peak demand savings impacts for a census of the largest projects supported by the Energize CT initiative.

2. Provide stakeholders with findings that are relevant and useful to potentially reducing future evaluation costs.

The study used a new method, avoided cost of energy, to quantify impacts of electric and gas measures with common units. It then selected the top 35 projects in terms of avoided cost impact over the program period under study. The evaluators provided on site measurement and verification for 34 of the 35 sites using high rigor methods for the largest measure(s) at each site and using low rigor for the remaining measures. The study developed realization rates for the projects to complete Objective 1.

The study recognized that these largest savers were key contributors to program savings, had complex and numerous measures, and were drivers of the realization rates for many commercial programs. The study provides information for future evaluations regarding observed sources of variance between ex ante and ex post savings and suggests strategies to minimize that variance. Also, the study provides information useful to refinements in the PSD and the manner in which computations of savings are developed.

This study found that realization rates (RR), including high and low rigor measures, were as follows:

- ECB electric energy RR: 90%
- ECB summer demand RR: 92%
- ECB gas RR: 92%
- EO electric energy RR: 76%
- ECB summer demand RR: 96%
- ECB gas RR: 76%

Because the sample size is small, inference from the results should be done with caution. The study also found that realization rates and coefficients of variation continue to be strong for lighting measures but show more variance and generally lower RRs for non-lighting measures. The study also found that the relatively high coefficients of variation found in prior studies persists, indicating that reducing sample sizes for C&I Impact Evaluations going forward is not recommended until the programs implement processes to reduce variances and evaluations prove such approaches have the intended result.

1 Executive Summary

1.1 Introduction

The Largest Savers Evaluation was created to provide insight into evaluations that focus only on the largest projects within the Energize CT program portfolio, including energy and peak demand savings, realization rates, and other relevant information for the PSD. The study also provides guidance to future evaluations regarding observed sources of variance between ex ante and ex post savings and suggests strategies to minimize that variance.

1.2 Overview of Objectives

The Largest Savers Evaluation's overall goal was to assess the levels and sources of variance, in order to minimize these in the future. To achieve this goal, the study focused on two primary objectives:

1. Evaluate the energy and peak demand savings impacts for a census of the largest projects supported by the Energize CT initiative.

2. Provide stakeholders with findings that are relevant and useful to potentially reducing future evaluation costs:

    a) Qualitative feedback regarding the quality of savings estimates for large C&I projects.

    b) Investigate trends in key variables that impact evaluation sample size such as coefficients of variation, and provide guidance on trends for use in future evaluation sample design.

    c) Make data from this study available for potential incorporation into future work and initiate a process for other evaluations to do the same moving forward.

1.3 Approach

To achieve the two primary objectives, the evaluation team utilized the following approaches.

1.3.1 Objective 1

The evaluation team used the following steps in performing the impact evaluation of the largest savers:

1. Request savings data for all commercial and industrial (C&I) projects in the Energize CT program portfolio during program years 2013-2015.

2. Equate all savings types to a single unit—avoided cost gross benefits—so each project's overall impact could be compared with the impacts of all other projects, regardless of energy source. The avoided costs used for this analysis are presented in **Table 1-1**.

Table 1-1: Avoided Costs Used to Rank Projects[1]

Savings Type	Unit	Avoided Cost per Unit
Electrical Energy	kWh	$0.07
Summer Electricity Demand	kW	$100
Winter Electricity Demand	kW	$100
Gas Energy	MMBtu	$5.00

3. Rank all projects by total avoided cost gross benefits and select the largest 35 projects for evaluation.

4. Request project files and billing data from the utilities for the selected largest projects. Note: all of the largest projects came from either the Energy Opportunities (EO) or Energy Conscious Blueprint (ECB) programs.

5. Review project files provided by utility and develop site specific measurement and verification plans (SSMVPs).

6. Conduct site visits to verify measure implementation and key operational parameters, interview site staff, and collect measured data.

7. Analyze the collected data to determine ex post savings for each measure reviewed.

8. Aggregate individual measure level savings by measure type and project.

1.3.2 Objective 2

The project level ex ante and ex post savings estimates were used to derive study level results, including: total ex ante savings, total ex post savings, realization rates, and coefficients of variation. Also, measure results were aggregated using different measure parameters, including source program (EO or ECB) and measure type (e.g. lighting, HVAC). Aggregating results by source program and measure type allowed for findings in this study to be compared to findings from the most recent EO and ECB evaluations.

Additionally, the team reviewed the sampling approaches used in prior work, industry best practices, and academic literature on sampling. This review was used to determine whether, based on existing literature and codified best practices, the sampling strategy used in prior program evaluations could be fine-tuned to increase the precision of the realization rate.

1.4 Key Findings

The findings produced as a result of the approaches discussed in the previous section are summarized in this section and are presented by evaluation objective.

1.4.1 Objective 1

Out of the 35 largest projects the evaluation team attempted to evaluate, 34 projects were evaluated, with the evaluation team unable to make contact at one project's site. The overall ex

[1] Avoided cost values from Connecticut General Statues-Section 16-245m(d) 2016-2018 Electric and Natural Gas Conservation and Load Management Plan, 10/1/15.

ante savings, ex post savings, and resulting realization rates are presented in **Table 1-2** below, with separate columns denoting the savings and realization rates for projects originating in the ECB and EO programs.

Table 1-2: Savings by Source Program and Total for Largest Savers Evaluation

		ECB	EO	Total
kWh	Ex Ante	21,673,179	19,995,729	41,668,908
	Ex Post	19,404,802	15,273,681	34,678,483
	Realization Rate	90%	76%	83%
Summer kW	Ex Ante	3,349	2,250	5,599
	Ex Post	3,093	2,166	5,259
	Realization Rate	92%	96%	94%
Winter kW	Ex Ante	2,776	1,799	4,575
	Ex Post	2,431	2,033	4,465
	Realization Rate	88%	113%	98%
Gas CCF	Ex Ante	237,786	1,186,833	1,424,619
	Ex Post	219,316	903,912	1,123,228
	Realization Rate	92%	76%	79%

Table 1-3 and **Table 1-4** present energy and demand savings and corresponding realization rates by measure type. Totals for gas and electric savings are shown, along with the most frequently observed measure types (measure types that represent quantities of 10 individual measures or more in the Largest Savers Evaluation). By far the most prevalent measure type in this evaluation, by both quantity and savings, was lighting. Approximately one quarter of the individual measures evaluated (27 of 105) were lighting and approximately 46% of the evaluated kWh savings came from lighting measures.

Table 1-3: Largest Savers Energy Savings by Measure Type

	kWh			Gas CCF		
Measure Type	Ex Ante	Ex Post	Realization Rate	Ex Ante	Ex Post	Realization Rate
Lighting	16,300,178	15,851,557	97%			
HVAC	5,518,113	4,401,083	80%	179,914	165,749	92%
VFD	3,740,509	2,016,319	54%			
Other[1]	5,966,455	6,537,348	110%	598,716	435,374	73%
Total Electric[2]	41,668,908	34,678,483	83%			
Total Gas[2]				1,424,619	1,123,228	79%

[1] "Other" category was largely comprised of process related measures located in industrial facilities and municipal wastewater treatment plants.

[2] "Total Electric" and "Total Gas" line items contain savings from all measure types, including the measure types listed in this table, as well as those not listed in this table which have very few observations, such as compressed air and refrigeration. Ex ante savings, ex post savings, and realization rates are presented for all measure types in **Table 4-3** and **Table 4-4**.

Table 1-4: Largest Savers Seasonal Peak Demand Savings by Measure Type (electric only)

	Summer kW			Winter kW		
Measure Type	Ex Ante	Ex Post	Realization Rate	Ex Ante	Ex Post	Realization Rate
Lighting	1,981	2,184	110%	1,508	1,811	120%
HVAC	1,201	1,164	97%	323	315	98%
VFD	437	206	47%	561	222	40%
Other[1]	639	1,024	160%	853	1,259	148%
Total Electric[2]	5,599	5,259	94%	4,575	4,465	98%

[1] "Other" category was largely comprised of process related measures located in industrial facilities and municipal wastewater treatment plants.

[2] "Total Electric" includes all measure types, including the measure types listed in this table as well as those not listed in this table which have very few observations, such as compressed air and refrigeration. Ex ante savings, ex post savings, and realization rates are presented for all measure types in **Table 4-3** and **Table 4-4**.

1.4.2 Objective 2

The end uses shown in the tables in this section align with end uses listed in the most recent EO and ECB Evaluation reports to allow for comparison. It is important to bear in mind that the quantity of individual measures evaluated by each measure type are relatively small compared to full program evaluations, and therefore, the reader is cautioned against drawing absolute conclusions from this data. However, the realization rate and coefficient of variation (c.v.) values may still inform future evaluations in Connecticut as it is still beneficial to compare these findings against the most recent EO and ECB Evaluation findings.

Table 1-5 and **Table 1-6** on the following pages display realization rates by program and end use. **Table 1-5** shows that both the ECB and overall Largest Savers Evaluations found HVAC measure realization rates generally below 100% for electric energy and demand. Also, the HVAC kWh realization rates of the overall Largest Savers Evaluation and the ECB Evaluation were found to be close to one another at 85% and 80%, respectively.

kWh realization rates for lighting measures across the previous EO and ECB Evaluations and the Largest Savers Evaluation generally did not vary much, with realization rates of 102%, 89%, and 97% for the ECB Evaluation, EO Evaluation, and overall Largest Savers Evaluation, respectively. Similarly, summer and winter kW demand savings for lighting measures were consistent across three evaluations, in that they all were above 100%, ranging from 110% to 144%.

The Largest Savers gas measure realization rates generally agreed with each of the previous program evaluation findings. Comparing the ECB Evaluation results to the overall Largest Savers Evaluation results, the realization rates for both the Boiler and Other (gas) measure categories were different by 4% and 6%, respectively. Similarly, when comparing the EO Evaluation results to the Largest Savers evaluation results, the Gas measure category realization rates varied by 5%.

Table 1-5: Realization Rates for Measure Groups Listed In Most Recent ECB Evaluation Report

		Measure Quantity, n[1]	kWh	Summer KW	Winter kW	Gas CCF
		Most Recent ECB Evaluation				
Electric	Compressed Air	26	49%	55%	58%	
	HVAC	57	85%	66%	108%	
	Lighting	32	102%	114%	112%	
	Process	21	102%	105%	111%	
	HPBD/Other	10	96%	98%	45%	
Gas	Boiler	17				96%
	Other	26				68%
		Largest Savers - ECB Projects Only				
Electric	Compressed Air					
	HVAC	9	77%	99%	72%	
	Lighting	11	111%	111%	132%	
	Process[2]					
	HPBD/Other[3]	15	69%	68%	64%	
Gas	Boiler	3				88%
	Other	6				94%
		Largest Savers - Overall				
Electric	Compressed Air	1	39%	48%	48%	
	HVAC	19	80%	97%	98%	
	Lighting	27	97%	110%	120%	
	Process[2]					
	HPBD/Other[3]	46	73%	79%	85%	
Gas	Boiler	7				92%
	Other	19				74%

[1] Where applicable, Largest Savers measures were considered as two observations, one for electric, and one for gas.
[2] The Largest Savers Evaluation did not use a direct equivalent measure type to the "Process" category listed in the ECB evaluation report.
[3] The "HPBD/Other" category used in the ECB program evaluation is considered equivalent to the sum of all other electric measure types not listed above in this table from the Largest Savers Evaluation.

Table 1-6: Realization Rates for Measure Groups Listed In Most Recent EO Evaluation Report

	Measure Quantity, n[1]	kWh	Summer KW	Winter kW	Gas CCF
	Most Recent EO Evaluation				
Lighting	67	89%	115%	144%	
Non-Lighting Electric	44	112%	168%	228%	
Overall Electric	111	98%	127%	172%	
Gas	33				84%
	Largest Savers - EO Projects Only				
Lighting	16	75%	108%	100%	
Non-Lighting Electric	41	77%	92%	119%	
Overall Electric	57	76%	96%	113%	
Gas	18				76%
	Largest Savers - Overall				
Lighting	27	97%	110%	120%	
Non-Lighting Electric	65	74%	85%	87%	
Overall Electric	92	83%	94%	98%	
Gas	26				79%

[1] Where applicable, Largest Savers measures were considered as two observations, one for electric, and one for gas.

Coefficient of variation (c.v.) is a way to express the amount of variance in a given dataset and is defined as the standard deviation divided by the mean. In **Table 1-7** and **Table 1-8** on the following pages is a comparison between c.v. values found in the Largest Savers Evaluation and those reported from the most recent ECB and EO program evaluations, respectively. The EO and ECB Evaluations reported c.v. values using different measure groupings. Results from the Largest Savers Evaluation were aggregated two different ways to best align with each program's grouping methodology, and allow for a more direct comparison of each program.

Lighting c.v. values across all savings types generally were consistent between this evaluation and previous EO and ECB evaluations, with kWh and summer kW c.v. values varying by 0.11 or less across the two recent program evaluations and the overall Largest Saver Evaluation results. Winter kW had the largest c.v. for lighting in all three evaluations. While the basis for deriving each measure's savings (i.e. PSD or custom) was not specifically tracked throughout this evaluation, it was generally noted that lighting measures tended to rely on PSD default input parameters and assumptions more often than non-lighting measures, conceivably contributing to the relatively consistent and relatively low lighting c.v. values observed across the evaluations.

The Overall Electric measure group's kWh c.v. values varied little across the three evaluations, with the Largest Savers value of 0.98 being almost identical to the 0.99 value reported for the most recent ECB program evaluation and 0.12 greater than the 0.86 value reported for the most recent EO program evaluation. The corresponding summer kW and winter kW c.v. values across the three evaluations each varied considerably, with both summer and winter demand c.v. values ranging approximately 1.1 to 1.7.

The 0.95 and 0.71 Overall Gas c.v. values found in the most recent EO and ECB program evaluations were slightly higher than the 0.58 value found in the Largest Savers Evaluation.

Table 1-7: Coefficients of Variation for Measure Groups Listed In Most Recent ECB Evaluation Report

		Measure Qty, n[1]	kWh	Summer KW	Winter kW	Gas CCF
		Most Recent ECB Evaluation				
Electric	Compressed Air	26	2.18	1.36	1.28	
	HVAC	57	1.41	1.82	1.62	
	Lighting	32	0.62	0.72	0.84	
	Process	21	0.69	2.54	2.19	
	HPBD/Other	10	0.76	1.7	1.7	
	Electric Overall	146	0.99	1.62	1.53	
Gas	Boiler	17				0.46
	Other	26				0.97
	Overall	43				0.71
		Largest Savers - ECB Projects Only				
Electric	Compressed Air[2]					
	HVAC	9	0.43	0.38	0.42	
	Lighting	11	0.38	0.65	0.92	
	Process[3]					
	HPBD/Other[4]	15	0.56	1.04	0.27	
	Electric Overall	35	0.82	0.93	1.17	
Gas	Boiler	3				0.03
	Other	6				0.28
	Overall[5]	9				0.28
		Largest Savers - Overall				
Electric	Compressed Air[2]					
	HVAC	19	0.44	0.41	0.66	
	Lighting	27	0.67	0.77	1.15	
	Process[3]					
	HPBD/Other[4]	48	1.01	1.49	1.86	
	Electric Overall	94	0.98	1.11	1.68	
Gas	Boiler	7				0.66
	Other	22				0.52
	Overall[5]	29				0.58

[1] Where applicable, Largest Savers measures were considered as two observations, one for electric, and one for gas.
[2] There was only one compressed air measure in the Largest Savers Evaluation, and it came from the EO program.
[3] The Largest Savers study did not use a direct equivalent measure type to the "Process" category listed in the ECB evaluation report.
[4] The "HPBD/Other" category used in the ECB program evaluation is considered equivalent to the sum of all measures that were not lighting or HVAC.
[5] For the purposes of calculating c.v. values, lighting measures with a gas penalty were removed

Table 1-8: Coefficients of Variation for Measure Groups Listed In Most Recent EO Evaluation Report

	Measure Qty, n[1]	kWh	Summer KW	Winter kW	Gas CCF
	Most Recent EO Evaluation				
Lighting	67	0.59	0.66	1.17	
Non-Lighting Electric	44	1.37	1.74	0.91	
Overall Electric	111	0.86	1.23	1.09	
Gas	33				0.95
	Largest Savers - EO Projects Only				
Lighting	16	0.43	0.77	0.86	
Non-Lighting Electric	43	1.19	1.54	2.58	
Overall Electric	59	1.00	1.35	2.28	
Gas[2]	20				0.61
	Largest Savers - Overall				
Lighting	27	0.67	0.77	1.15	
Non-Lighting Electric	67	0.92	1.20	1.84	
Overall Electric	94	0.98	1.11	1.68	
Gas[2]	29				0.58

[1] Where applicable, Largest Savers measures were considered as two observations, one for electric, and one for gas.

[2] For the purposes of calculating c.v. values, lighting measures with a gas penalty were removed

1.5 Recommendations

Presented in this section are the key observations made by the evaluation team during this evaluation, as well as corresponding recommendations for the consideration of all conservation and load management (C&LM) program stakeholders. The observations and recommendations are divided into program implementation and program evaluation categories; however, the observations/recommendations may apply to both implementation and evaluation stakeholders.

1.5.1 Program Implementation

- **Observation:** The definition of hours that are to be used to estimate peak demand savings for C&LM programs (Seasonal Peak Hours) creates a different set of peak hours each year, which adds complexity to calculating and tracking demand savings. Variance between ex ante and ex post savings measures, which have deemed peak demand savings or coincidence factors listed in the PSD, were found to be generally minimal, provided the appropriate PSD version was referenced and followed by both ex ante and ex post savings estimates. However, for measures without deemed peak demand savings or coincidence factors in the PSD, determining a new set of peak hours each year could lead to variance between ex ante and ex post savings estimates if the same procedure is not closely followed and appropriately tracked over the course of a multi-year program cycle.

  Recommendation: C&LM programs should consider using a definition that references a standard time/day window each year. This approach would eliminate any potential variance stemming from different peak period definitions used by implementers and evaluators and changing peak period definitions over the course of a multi-year program cycle. A standard peak timeframe would also be more conducive to generating and periodically updating prescribed coincidence factors in the Program Savings Document (PSD) using consistent assumptions.

After reviewing this recommendation, both Eversource and United Illuminating (UI) each noted two advantages in favor of maintaining the current peak hours definition:

1. Previous analysis found that the current definition more closely aligns with the actual ISO-NE system peak.
2. Changing definitions would involve costly changes to the companies' tracking systems and processes for calculating savings and bidding them into the ISO-NE Forward Capacity Market, which may not prove cost effective to implement.

Without a full review of the data and underlying assumptions that support these claimed advantages, Nexant is not able to provide additional detail to the recommendation noted above. In a similar vein as the utilities' comments, Nexant stresses that C&LM program stakeholders understand that changing the peak demand definition brings with it broad and complex cost and policy implications, which would require further review and discussion.

- **Observation:** Savings calculators largely appeared to be custom-built for each project, including common measure types (e.g. lighting or VFDs).

  Recommendation: The CT EEB should consider creating standardized savings workbooks for common measures, which would be used by program implementers and evaluators across the utilities. The primary function of the workbooks would be to automate the PSD for common measures, which would ensure the PSD is consistently applied, reduce time per measure needed to calculate energy and demand savings, minimize calculation errors, and allow for faster review by utility staff and evaluators.

1.5.2 Program Evaluation

- **Observation:** Coefficient of variation values found in this evaluation generally agree with those found in the previous EO and ECB evaluations, indicating a much larger amount of variance than originally assumed by ISO New England, particularly for summer and winter electric demand savings. ISO New England's Measurement and Verification of Demand Reduction Value from Demand Resources (M-MVDR) specifies that, in the absence of more specific data relevant to the sampled population, the assumed c.v. should be 0.5 for homogeneous populations and 1.0 for heterogeneous populations.[2]

  Recommendation: In order to reduce c.v. values, and thus sample size and evaluation cost, program administrators should seek opportunities to create better alignment of ex ante and ex post savings values using the observations and recommendations provided in this report and previous evaluation reports. For example, program administrators may

[2] ISO New England Manual for Measurement and Verification of Demand Reduction Value from Demand Resources, Manual M-MVDR, Revision 6, effective June 1, 2014.

choose to conduct more pre-installation metering on retrofit measures and commissioning on new construction measures. If actions are not taken to reduce future c.v. values, future program evaluations in Connecticut should base sample sizes on the larger observed c.v. values, referencing the c.v. values determined in this evaluation and the previous EO and ECB Evaluations, in lieu of using the default M-MVDR values, in order to ensure confidence and precision targets are met.

- **Observation:** Using realization rates at the stratum level from prior evaluations directly in the sample design process will improve the precision.

  Recommendation: Collect the raw evaluation data from the prior program evaluations so that future evaluators can use this information in selecting the best possible strata selection technique as well as the strata themselves. Store data in a central repository.

2 Overview

The Largest Savers Evaluation was designed to provide evaluation results for the set of largest program savers, projects that are key contributors to savings, have complex and numerous measures, and are the drivers for realization rates for multiple commercial programs in the Energize CT program portfolio. This study provides guidance to future evaluations regarding observed sources of variance between ex ante and ex post savings and suggests strategies to minimize that variance.

Objectives

The Largest Savers Evaluation's overall goal was to assess the levels and sources of variance, in order to minimize these in the future. To achieve this goal, the study focused on two primary objectives:

1. Evaluate the energy and peak demand savings impacts for a census of the largest projects supported by the Energize CT initiative.

2. Provide stakeholders with findings that are relevant and useful to potentially reducing future evaluation costs:

    a) Qualitative feedback regarding the quality of savings estimates for large C&I projects.

    b) Investigate trends in key variables that impact evaluation sample size, such as coefficients of variation, and provide guidance on trends for use in future evaluation sample design.

    c) Make data from this study available for potential incorporation into future work and initiate a process for other evaluations to do the same moving forward.

3 Methodology

The Largest Savers Evaluation's methodology is broken down into four high level steps in the following sections. The first three, **Project Selection**, **Data Collection**, and **Project Analyses** were all conducted as part of Objective 1, while the fourth section, **Aggregate Analysis**, was conducted to fulfill Objective 2.

3.1 Project Selection

In order to select the largest projects, the term "project" first was defined. For this study, the following parameters were used in determining what was considered a project:

- Measures were implemented during 2013, 2014, or 2015.
- All measures were implemented at a single street address. Projects spanning multiple street addresses were not included in the study. Examples of removed projects include: measures across campuses, street lighting, measures across multiple municipal facilities, and multiple chain retailer locations combined into one project.
- All measures must be implemented on equipment/facilities served by the same utility meter.
- Projects listed as upstream lighting were not included in the study.

With the project definition set, the first of three data requests was sent to United Illuminating (UI) and Eversource asking for their tracking data of all commercial and industrial (C&I) projects implemented during program years 2013, 2014, and 2015. The data request specifically asked for project-level savings so that the projects could be ranked by size. However, Energize CT programs incentivize multiple savings types (i.e. kW, kWh, and CCF) which are not able to be directly added together. Therefore, each savings type was equated based on its avoided cost gross benefits by referencing values listed in the state's C&LM Plan[3]. The avoided cost values used for the purposes of this study are shown below in **Table 3-1**.

Table 3-1: Avoided Costs Used to Rank Projects

Savings Type	Unit	Avoided Cost per Unit
Electrical Energy	kWh	$0.07
Summer Electricity Demand	kW	$100
Winter Electricity Demand	kW	$100
Gas Energy	MMBtu	$5.00

[3] Avoided cost values from Connecticut General Statues-Section16Section 16-245m(d) 2016-2018 Electric and Natural Gas Conservation and Load Management Plan, 10/1/15.

Once the total avoided cost gross benefits were estimated for each project's savings, all projects could then be ranked from largest to smallest. The Evaluation Administrator directed Nexant to focus on the largest 30 projects. This quantity of projects was considered adequate enough to provide robust findings while balancing the cost of performing this study. To ensure the evaluation achieved 30 project evaluations, Nexant targeted the 35 largest projects for evaluation and achieved 34, with one customer being unreachable. All 35 of these projects were derived from either the Energy Opportunities (EO) or Energy Conscious Blueprint (ECB) programs. 22 projects were derived from the EO program while 13 projects were derived from the ECB program.

3.2 Data Collection

3.2.1 Project File Request

The second of the three utility data requests involved asking for project files for the selected largest projects. While only the 30 largest projects were targeted for evaluation, project files for the 60 largest projects were requested from the utilities, with the additional 30 projects serving as potential alternates. Of the 60 projects, 45 project files were requested from Eversource and 15 project files were requested from UI.

Project file documents requested in this data request encompassed all pertinent savings documentation for each project, which included the following:

- Utility tracking documents: application forms, approval forms, audit forms, installation confirmation documentation;
- Equipment specifications, invoices, certifications;
- Savings calculation worksheets;
- Walk through inspection or commissioning reports;
- Energy simulation models and modeling input information; and
- Any other data, algorithms, and work provided by the implementer in support of the project and its application.

Additionally, billing data and key account manager information was requested for each project. The requested utility billing data covered the time frame from January 2011 through the most current bill at the time of the request in 2016. Where appropriate, this billing data was used during the project analyses. Utility key account managers were first notified of the evaluation to enable a smooth introduction to the appropriate contact(s) at each customer site.

3.2.2 Site Specific Measurement and Verification Plans (SSMVPs)

Once project files from the utilities were received, Nexant began developing site specific M&V plans (SSMVPs) for each targeted project. SSMVPs are a widely used tool in evaluations and serve the key role of documenting the anticipated activities and savings calculation approaches for each project. For reference, the SSMVP template used in this evaluation is located in **Appendix D**.

The following are the key components included in each SSMVP:

- Project background
- Site description
- List of ex ante savings
- Baseline conditions noted in the project documents
- Measure description
- Data analysis approach and algorithms
- Key data points and collection methods
- Anticipated sampling
- Level of expected evaluation rigor

Evaluation data collection and analyses can be divided in to two groups by the level of detail involved in the measure's verification by the evaluator: low rigor and high rigor. Approaches following the International Performance Measurement and Verification Protocol (IPMVP) generally are considered high rigor approaches. Lower rigor approaches typically involved the use of Technical Reference Manual (TRM) or PSD algorithms and assumptions with on-site verification that measures were installed and in operation. Utilizing different levels of rigor enabled the evaluation to balance the level of detail assessed with the level of effort (cost) required to evaluate each project.

For each project in this study, at least one measure was planned to be evaluated using a high rigor evaluation, i.e. using one of the four IPMVP Options. Typically, the selected measure was the largest contributor of avoided cost gross benefits to the project.

3.2.3 Site Data Collection

Site data collection began by first contacting the Key Account Manager (KAM) at the utility. Contacting the KAMs before attempting to reach out to the customer aided the evaluation in multiple ways. First, it allowed the evaluator to leverage the existing relationship the KAM had with the customer. Second, the site contact listed in the project files and tracking database may not be the best person for the evaluator to contact concerning the project and the KAM could direct the evaluator to the best customer contact. This was particularly useful for the large customers in this study, where there typically are multiple customer contacts. For example, the customer contact listed in the utility tracking database or who signed the Letter of Agreement on behalf of the customer company may have been the president of the company. However, the person who likely knows the savings project best, and with whom the evaluator is interested in meeting, may be the head of the engineering or facilities department. Working with the Utility KAM's enabled the evaluation team to streamline the outreach process.

Once the best customer contact was identified, Nexant engineers reached out to the site contact via phone and/or email to ask more detailed questions specific to the project and schedule a site visit. Asking pre-site visit questions helped Nexant plan for the site visit by understanding the project in better detail, what data was potentially already available, any personal protective equipment (PPE) requirements, and the need for any security/background checks. Because this study included only large facilities with large energy consumption, Nexant found that many customers utilized an Energy Management System (EMS), which generally had the ability to show real time operating conditions and equipment setpoints, and could also sometimes be set up to trend equipment operational parameters such as KW draw, runspeed, or on/off status.

Each site visit included, at a minimum, verification of each measure implemented. This level of evaluation was considered low rigor. Verification activities included the following:

- Gathering nameplate information from equipment
- Verifying equipment types and quantities
- Visually inspecting equipment for operation
- Inspecting EMS and equipment controller outputs
- Interviewing the site contact concerning equipment operation, such as setpoints and schedules

Measures receiving a high rigor evaluation had the above data collection performed and also included collecting site-specific measured data. Measure evaluations that used IPMVP Options A or B approaches relied on data trended at the individual equipment level, provided either by the customer’s EMS, Nexant logging equipment, or both. Measures that used an IPMVP Option C approach relied on utility supplied billing data as well as any supporting site gathered data. Measures that used an IPMVP Option D approach relied on information gathered as part of the on-site verification to update the energy simulation model and utility billing data to calibrate the model.

When Nexant logging equipment was deployed or additional data needed to be gathered, a second site visit was scheduled to pick up the equipment and ask any remaining questions that were not covered or able to be answered during the initial site visit. Of the 34 projects evaluated, Nexant revisited 12 sites. All metering equipment used by the evaluation team met the requirements required by Section 10.2 of the ISO New England Manual M-MVDR and is discussed further in the next section.

Within measure sampling was also performed when applicable and feasible. The majority of the measures that required sampling were lighting. When sampling was used, Nexant engineers generally followed an approach that would yield 80% and 10% confidence and precision, respectively.

For many of the projects, a post site visit phone call or email was necessary for one or more reasons. These reasons included missing data, erroneous data, confirmation of data gathered on site or provided by the contact, and following up with specific questions that came up during the analysis.

3.2.4 Metering Equipment

Metering equipment used in this evaluation was compliant with ISO New England’s M-MVDR manual. Specifically, items (6), (9), and (11) of M-MVDR’s Section 10.2 requires metering equipment have an accuracy of ±2%. **Appendix E** shows a summary of the types of metering equipment used and their corresponding measurement accuracy. Additionally, the evaluation team deployed the meters in a manner meant to exceed M-MVDR’s 15-minute metering frequency requirements by generally logging at 6 minute intervals or less. Metering was performed over a period of at least two weeks, but was typically performed over two to three months.

3.3 Analysis

3.3.1 Project Analyses

Data collected for each measure was analyzed to produce ex post savings estimates. As discussed previously, the level of evaluation rigor varied between measures. For measures evaluated with low rigor, the analysis typically involved first reviewing the algorithms and input parameters used to determine ex ante savings. Data collected during the evaluation (e.g. nameplate information, operational/scheduling data, customer interviews) were then used to update the inputs and/or algorithm approach to best reflect observed operating conditions. For measures evaluated with high rigor, the analyses relied on measured data such as kW metering, on/off logging, and billing data. These measured data were directly used to estimate post-retrofit energy and demand use. When applicable, metered data were also used to inform the baseline case, along with other collected data such as site contact interviews. In the event that the data collected on site was determined to be insufficient to support a high rigor analysis (e.g. inadequate sample size, small quantity of metered data, erroneous data) the measure was considered to be verified with a low rigor evaluation.

In cases were equipment use was subject to an independent variable such as outdoor weather or production volume, data from pre and/or post retrofit timeframes was normalized to yield an expected average annual savings. Weather dependent measures typically relied on comparing equipment usage with cooling degree days or heating degree days during the observed period. This correlation was then used to extrapolate the anticipated equipment use across an average weather year using typical meteorological year (TMY3) weather data.

The product of each analysis was an annual savings profile across each hour of the year, or an 8760 savings profile. The demand period defined by ISO New England was then overlaid on the 8760 savings profiles to estimate demand impacts. The demand savings methodology is covered in the following section.

3.3.2 Demand Savings Calculation

3.3.2.1 Definition

The PSD lists definitions for two distinct peak periods: “on-peak hours” and “seasonal peak hours”.

- **On-Peak Hours** are hours 1:00-5:00 p.m., Monday through Friday on non-holidays during the months of June, July, and August and from 5:00-7:00 p.m., Monday through Friday on non-holidays during the months of December and January.
- **Seasonal Peak Hours** are those hours in which the actual, real-time hourly load Monday through Friday on non-holidays, during the months of June, July, August, December, and January, as determined by the ISO, is equal to or greater than 90 percent of the most recent 50/50 system peak load forecast, as determined by the ISO, for the applicable summer or winter season.

The PSD states that the Seasonal Peak Hours demand savings are used in the C&LM programs. Accordingly, this evaluation report uses the ISO New England "Seasonal Peak Hours" definition in determining summer and winter kW reductions.

3.3.2.2 Methodology

The method used to determine demand reductions follows these three steps:

1. Determine demand savings for each hour of a typical year (8760 hourly analysis). 8760 loadshapes for measures evaluated with high rigor utilized metered data or energy simulation software outputs. Measures evaluated with low rigor generally either referenced PSD assumptions or leveraged available non-measured site collected data such as site contact interviews or equipment run schedules. Techniques to determine a typical year's savings varied by measure type, but included normalizing by weather and production volume while also removing the effects of singular events (e.g. abnormally high/low production at a manufacturing facility).

2. Determine the applicable Seasonal Peak Hours per ISO New England's definition stated above. A more detailed description of the methodology and steps taken to derive the set of Seasonal Peak Hours in accordance with ISO New England's definition is located in **Appendix C**.

3. Average the demand reduction during all of the defined Seasonal Peak Hours.

3.4 Aggregate Analysis

The project level ex ante and ex post savings estimates were used to derive study level results, including: total ex ante savings, total ex post savings, realization rates, and coefficients of variation. Additionally, measure results were aggregated using different measure parameters, including source program (EO and ECB) and measure type.

Aggregating results by source program allowed for findings in this study to be compared to findings from the most recent EO and ECB evaluations. The most recent EO and ECB reports further provided some of their findings at the measure type level (e.g. lighting, non-lighting); therefore, results from this study were also aggregated at the measure type level to allow for more granular comparisons between this study and the previous evaluations.

Results were also aggregated by level of evaluation rigor in an effort to qualitatively examine the effect evaluation rigor has on key outputs, specifically realization rate. However, in order to make this comparison results needed to be organized by both evaluation rigor level, and measure type, thereby reducing sample sizes to generally below 10 observations per combination of rigor level and measure type. **Table 4-2** in the following section shows the quantity of observations made by measure type for both levels of rigor. Therefore, findings in the main body of this report are generally presented on a combined basis (low and high evaluation rigor results combined), and results broken out by evaluation rigor are provided in the appendices. Reporting the combined savings determined by low and high evaluation rigor techniques is a practice used in other jurisdictions, such as Pennsylvania, as a means of balancing level of detail (rigor) with evaluation effort (cost)[4].

[4] Evaluation Framework for Pennsylvania Act 129 Phase III Energy Efficiency and Conservation Programs, 10/21/16. http://www.puc.pa.gov/Electric/pdf/Act129/SWE_PhaseIII-Evaluation_Framework102616.pdf

4 Key Findings

4.1 Objective 1: Impact Evaluation Results

Table 4-1 below presents the ex ante savings, ex post savings, and corresponding realization rates for the overall Largest Savers Evaluation. The table also shows the split of the total savings by the source program. Versions of **Table 4-1** which breakout the results by high and low evaluation rigor are located in **Appendix A**.

Table 4-1: Total Ex Ante and Ex Post Savings by Program

		ECB	EO	Total
kWh	Ex Ante	21,673,179	19,995,729	41,668,908
	Ex Post	19,404,802	15,273,681	34,678,483
	Realization Rate	90%	76%	83%
Summer kW	Ex Ante	3,349	2,250	5,599
	Ex Post	3,093	2,166	5,259
	Realization Rate	92%	96%	94%
Winter kW	Ex Ante	2,776	1,799	4,575
	Ex Post	2,431	2,033	4,465
	Realization Rate	88%	113%	98%
Gas CCF	Ex Ante	237,786	1,186,833	1,424,619
	Ex Post	219,316	903,912	1,123,228
	Realization Rate	92%	76%	79%

Table 4-2 shows the quantity of measures evaluated by measure type and program. In a few instances, separate entries in the utility tracking databases were combined as one evaluated measure. These ex ante savings database entries concerned the same measure but were listed in separate entries – e.g. one entry listed kWh and kW savings while a separate entry listed gas CCF savings for the same measure. Additionally, the measures in the “whole building” measure type were generally listed in the utility tracking databases with multiple individual measure entries. The measures were aggregated during the evaluation to enable the energy simulation models to more accurately estimate savings, including interactive effects, resulting in aggregated savings values with no breakdown at the utility tracking level.

The “other” category was largely comprised of process related measures located in industrial facilities and municipal wastewater treatment plants.

Table 4-2: Quantities of Measures Evaluated by Measure Type and Program

Savings Type	EO	ECB	Total
Boiler	4	3	7
Compressed Air	1	0	1
EMS	9	0	9
Envelope	1	1	2
HVAC	10	9	19
Lighting	16	11	27
Motors	2	0	2
Other	9	5	14
Refrigeration	4	2	6
VFD	10	5	15
Whole Building	0	3	3
Total	66	39	105

Table 4-3 and **Table 4-4** show the total savings and realization rate by measure type. Additional tables with savings and realization rates broken out by measure type and level of evaluation rigor are located in **Appendix B**. Tables with savings and realization rates broken out by program are presented and discussed in **Section 4.2**.

Lighting measures contributed the largest share of the ex post electric savings, at 46%, 42%, and 41% of the total kWh, summer kW, and winter kW savings, respectively. The “other” measure type contributed the largest share of the ex post gas savings, with 39% of the total savings.

Overall realization rates indicated that ex post savings estimates generally mirrored ex ante savings estimates, which were largely influenced by the relatively high realization rates of the measure types with the greatest amounts of savings. This indicates that appropriate effort is being taken to ensure accurate ex ante savings for the measure types with the largest impacts.

At the other end of the spectrum, realization rates for the EMS, VFD, and refrigeration measure types were relatively low. Primary drivers for ex post savings being much lower than ex ante savings were:

- **EMS:** Two of the top three largest EMS measures involved having sub-metering equipment installed. In both cases, the new meters were verified to not lead to any directly attributable operational changes at the facilities. On another project, the EMS was found to be working as intended, but many of the assumed setpoints were confirmed to be set to conditions not as favorable to energy savings – e.g. lower cooling temperature setpoints, higher heating temperature setpoints, and lower outside air enthalpy setpoints for economizers.
- **VFD:** The project with the largest ex ante VFD savings was verified to have very low occupancy levels in the building during a multi-year period covering the time between measure installation and the evaluator’s site visit. It was also uncertain when the VFDs would be used in the future on this project. Therefore, the ex post savings were much lower than ex ante. Another project’s ex ante calculations used the incorrect quantity, motor horsepower, facility type, and flow controls to describe the baseline equipment.

- **Refrigeration:** The ex ante savings for the largest refrigeration measure, when ranked by ex ante kWh savings, used an incorrect baseline for its calculations. For this project, both a chiller and dry cooler were being upgraded at the same time; however, the baseline assumed for the dry cooler measure was the baseline chiller and not the new, efficient chiller.

There were negative ex post gas savings for lighting measures that were a result of the interactive effects efficient lighting has on building heating systems. These negative savings were not tracked in either of the utility tracking databases because the Utility Cost Test (UCT) used to determine cost effectiveness does not include gas interactive effects for electric measures. Despite not being needed for the UCT, the evaluation team believes that estimating the full energy and demand impacts of incentivized measures is important in order to fully understand the program impacts, and therefore suggests the utilities consider tracking all interactive savings/penalties for all incentivized measures.

The not applicable realization rate for the envelope measure gas savings was largely due to one project being verified (ex post) to have gas savings while there were no claimed (ex ante) gas savings. The utility did not track gas savings for this particular project because, at the time this project started, the utility did not provide gas service.

Table 4-3: Total kWh and Summer kW Savings by Measure Type

	kWh			Summer KW		
	Ex Ante	Ex Post	Real. Rate	Ex Ante	Ex Post	Real. Rate
Boiler	-	-	-	-	-	-
Compressed Air	17,326	6,836	39%	2	1	48%
EMS	3,441,692	1,551,077	45%	297	49	17%
Envelope	25,339	25,339	100%	47	47	100%
HVAC	5,518,113	4,401,083	80%	1,201	1,164	97%
Lighting	16,300,178	15,851,557	97%	1,981	2,184	110%
Motors	40,561	40,648	100%	-	-	154%
Other	5,966,455	6,537,348	110%	639	1,024	160%
Refrigeration	1,446,677	394,605	27%	70	44	63%
VFD	3,740,509	2,016,319	54%	437	206	47%
Whole Building	5,166,069	3,853,671	75%	924	540	58%
Total	**41,668,908**	**34,678,483**	**83%**	**5,599**	**5,259**	**94%**

Table 4-4: Total Winter kW and Gas CCF Savings by Measure Type

	Winter kW			Gas CCF		
Measure Type	Ex Ante	Ex Post	Real. Rate	Ex Ante	Ex Post	Real. Rate
Boiler	-	-	-	377,007	346,013	92%
Compressed Air	2	1	48%	-	-	-
EMS	18	52	295%	193,622	119,101	62%
Envelope	1	1	100%	-	4,150	N/A[1]
HVAC	323	315	98%	179,914	165,749	92%
Lighting	1,508	1,811	120%	-	-48,169	N/A[2]
Motors	0.2	0.4	154%	-	-	-
Other	853	1,259	148%	598,716	435,374	73%
Refrigeration	347	283	82%	-	-	-
VFD	561	222	40%	-	-	-
Whole Building	963	521	54%	75,360	101,010	134%
Total	**4,575**	**4,465**	**98%**	**1,424,619**	**1,123,228**	**79%**

[1] High realization rate largely due to one project being verified (ex post) to have gas savings while there were no claimed (ex ante) gas savings. Gas savings for this project were not tracked by the utility and the realization rate is therefore meaningless.

[2] The negative gas savings calculated for lighting measures was a result of the interactive effects penalty stipulated in the PSD for lighting measures. However, the utilities did not include these interactive effects in their tracking systems, as the Utility Cost Test (UCT) used to determine cost effectiveness does not include gas interactive effects for electric measures.

Coefficient of variation (c.v.) is a way to express the amount of variance in a given dataset and is defined as the standard deviation divided by the mean. **Table 4-5** below shows coefficients of variation for the overall evaluation as well as the four measure types with the largest quantity of individual measures evaluated in this study.

Table 4-5: Coefficient of Variation Values by Measure Type and Savings Type

Measure Type	Quantity of Measures Evaluated	kWh C.V.	Summer kW C.V.	Winter kW C.V.	Gas C.V.
Lighting	27	0.67	0.77	1.15	-
HVAC	19	0.44	0.41	0.66	0.19
VFD	15	0.75	1.42	2.19	-
Other[1]	14	0.61	0.38	1.32	0.45
Overall[2,3]	105	0.98	1.11	1.68	0.58

[1] “Other” category was largely comprised of process related measures located in industrial facilities and municipal wastewater treatment plants.

[2] Overall includes all measure types, including the measure types listed in this table as well as those not listed in this table, which have very few observations, such as compressed air and refrigeration.

[3] For the purposes of calculating c.v. values, lighting measures with a gas penalty were removed.

4.2 Objective 2: Findings Useful For Future Evaluations

4.2.1 Qualitative Observations of Savings Estimates

This section presents observations the evaluation team made both during and as a result of conducting Objective 1. While some of the findings and comparisons presented in this section are quantitative in nature, the reader is cautioned against drawing absolute conclusions from this data, as sample sizes in many cases were relatively small compared to sample sizes of full program evaluations. Moreover, this study used a mix of low and high rigor M&V approaches, which may be different from the M&V approaches used by other evaluations.

Table 4-6 and **Table 4-7** on the following pages display realization rates by program and end use. The end uses shown in these tables align with end uses listed in the most recent EO and ECB evaluation reports to allow for comparison.

Table 4-6 shows that both evaluations found HVAC measure realization rates below 100% for electric energy and demand, with kWh realization rates close to one another at 77% and 85% for the Largest Savers ECB measures and the most recent ECB program evaluation, respectively. The combined Largest Savers HVAC electric energy realization rate is 80%, further supporting the observation that ex post HVAC measure savings are, on average, about 20% less than ex ante.

Conversely, lighting measures in the ECB program have realization rates slightly greater than 100% in both evaluations. Again, this trend is also generally supported by the overall Largest Saver lighting results, with all three of the energy and demand savings realization rates each being within a few percent of the most recent ECB program evaluation results.

Also, the Largest Saver ECB boiler and other gas measure realization rates generally showed the same trend as the most recent ECB program evaluation results, as they are all below 100% but range between 68% and 96%. The overall Largest Savers gas results closely align with the most recent ECB program evaluation results, having differences of 4% and 6% in realization rates for boilers and other gas measures, respectively.

Table 4-6: Realization Rates for Measure Groups Listed In Most Recent ECB Evaluation Report

		Measure Quantity, n[1]	kWh	Summer KW	Winter kW	Gas CCF
		Most Recent ECB Evaluation				
Electric	Compressed Air	26	49%	55%	58%	
	HVAC	57	85%	66%	108%	
	Lighting	32	102%	114%	112%	
	Process	21	102%	105%	111%	
	HPBD/Other	10	96%	98%	45%	
Gas	Boiler	17				96%
	Other	26				68%
		Largest Savers - ECB Projects Only				
Electric	Compressed Air					
	HVAC	9	77%	99%	72%	
	Lighting	11	111%	111%	132%	
	Process[2]					
	HPBD/Other[3]	15	69%	68%	64%	
Gas	Boiler	3				88%
	Other	6				94%
		Largest Savers - Overall				
Electric	Compressed Air	1	39%	48%	48%	
	HVAC	19	80%	97%	98%	
	Lighting	27	97%	110%	120%	
	Process[2]					
	HPBD/Other[3]	46	73%	79%	85%	
Gas	Boiler	7				92%
	Other	19				74%

[1] Where applicable, Largest Savers measures were considered as two observations, one for electric, and one for gas.
[2] The Largest Savers Evaluation did not use a direct equivalent measure type to the "Process" category listed in the ECB evaluation report.
[3] The "HPBD/Other" category used in the ECB program evaluation is considered equivalent to the sum of all other electric measure types not listed above in this table from the Largest Savers Evaluation.

Table 4-7 on the following page shows that kWh realization rates for lighting measures in both the most recent EO program evaluation and the Largest Savers EO measures were lower than the lighting measure realization rates from both the most recent ECB program evaluation as well as the Largest Savers ECB evaluation. The trend in these results suggest that there may be tendencies for how each program's lighting savings are calculated – with the key difference between the programs being baseline. After reviewing the lighting measures derived from both EO and ECB programs, there did not appear to be any consistent sources in variance unique to a particular program. That is, in projects derived from both EO and ECB programs, realization rates fluctuated primarily due to differences in fixture quantities and hours of use. There were two instances in EO projects where the incorrect baseline lighting fixture types were used, but similarly, there were also two ECB projects that used incorrect baseline lighting power densities for the facility type. In general, the realization rates for lighting measures, observable across both of the most recent EO and ECB program evaluations as well as the Largest Savers Evaluation, is that demand realization rates tend to be both higher than their respective kWh realization rates and above 100% realization rate.

Over all three electric measure categories listed in **Table 4-7**, the Largest Saver Evaluation generally found lower realization rates than the most recent EO program evaluation found. The 76% gas realization rate found in the Largest Savers EO projects is less than the 84% realization rate found in the most recent EO program evaluation as well as the 79% realization rate found for the overall Largest Savers gas measures.

Table 4-7: Realization Rates for Measure Groups Listed In Most Recent EO Evaluation Report

	Measure Quantity, n[1]	kWh	Summer KW	Winter kW	Gas CCF
	Most Recent EO Evaluation				
Lighting	67	89%	115%	144%	
Non-Lighting Electric	44	112%	168%	228%	
Overall Electric	111	98%	127%	172%	
Gas	33				84%
	Largest Savers - EO Projects Only				
Lighting	16	75%	108%	100%	
Non-Lighting Electric	41	77%	92%	119%	
Overall Electric	57	76%	96%	113%	
Gas	18				76%
	Largest Savers - Overall				
Lighting	27	97%	110%	120%	
Non-Lighting Electric	65	74%	85%	87%	
Overall Electric	92	83%	94%	98%	
Gas	26				79%

[1] Where applicable, Largest Savers measures were considered as two observations, one for electric, and one for gas.

As **Table 4-6** and **Table 4-7** show, there are opportunities to close the gap between ex ante and ex post savings estimates. Variance between ex ante and ex post savings can stem from a variety of sources and can be specific to a single project or apply across the entire evaluation. The list below details observations made during this evaluation regarding sources of variance between ex ante and ex post savings and suggests potential solutions for consideration where appropriate. The observation list is categorized into two high level groups—technical analyses and program processes and procedures.

Observations Related To Technical Analysis

- For calculating peak demand savings, the PSD requires C&LM programs use the "Seasonal Peak Hours" definition and not the "On-Peak Hours" definition. Seasonal Peak Hours change each year based on weather conditions and ISO New England system loading. By definition, Seasonal Peak Hours therefore change from year to year. The constantly changing definition of Seasonal Peak Hours makes it relatively more complex for demand savings from a multi-year program cycle to be clearly and correctly calculated and tracked. Therefore, a potential solution would be to change the demand savings timeframe from the Seasonal Peak Hours definition (varies year to year) to the On-Peak Hours definition (constant each year).
- One of the most common sources of variance at the measure level was that equipment was verified to be operating differently than what was noted in the ex ante savings calculations. Often this difference would be the result of different hours of use for measures such as lighting, pumps, or fans, where the ex ante and ex post savings would rely on different datasets available at the time their respective savings estimates were produced. That is, the ex ante analyses tended to not have as much access to metered data as the ex post analyses did due to the timing of the data collection relative to the measure's implementation. In some cases, ex ante savings analyses did not document the source data used to produce savings estimates. At a minimum, it is recommended that program implementers diligently document relevant measure data. If possible, implementers should try to leverage available metered baseline data for retrofits and commissioning activity reports for new construction measures. A potential solution to the ex ante analyses not having access to post-retrofit data would be to allow program administrators or implementers to adjust reported savings after the measure is implemented based on data they can collect after the measure has been implemented and prior to the next evaluation. Of course, the burden of collecting and analyzing additional project data would likely bring about additional program implementation costs.
- Interactive effects were not always taken into account in ex ante savings calculations. Lighting measure analyses inconsistently accounted for the interactive effects from reduced cooling loads. Similarly, non-lighting measure analyses were generally inconsistent with capturing interactive effects of the implemented measures. A potential solution to ensuring interactive effects are taken into account, at least on common measures, would be to introduce state-wide standardized savings calculators by measure—particularly for lighting. This solution has worked well in other jurisdictions such as in Pennsylvania[5]. It is noted that when interactive effects affect another fuel type (e.g. electric savings leading to a gas penalty for lighting measures), the interactive effects are not tracked by utilities as they are not needed for cost effectiveness calculations.
- Use of the PSD algorithms and input parameters was inconsistent across ex ante savings calculations. Adopting a protocol that dictates when PSD algorithms and/or input parameters are to be used and/or are optional would create greater consistency across savings calculations.

[5] Standardized calculators for lighting measures ("TRM Appendix C" calculator) and Motor & VFD measures ("TRM Appendix D" calculator) are provided for implementers and evaluators to use by the Pennsylvania Public Utility Commission: http://www.puc.state.pa.us/filing_resources/issues_laws_regulations/act_129_information/technical_reference_manual.aspx

Observations Related to Program Processes and Procedures

- In some cases where ex ante savings estimates were derived from a whole-building energy simulation, the utility project files did not include an executable version of the energy simulation file. When the evaluator is not able to obtain the original energy simulation file used to produce the ex ante savings estimate, the evaluator must then either recreate the model themselves (which is often cost prohibitive), or evaluate the measure(s) using other methods. Moreover, without the energy simulation file, the evaluator is not able to clearly view the assumptions and input parameters used to derive the ex ante savings, so differences between how the ex ante and ex post savings were estimated cannot be compared. A potential solution to ensuring an energy simulation file is included in the project documentation, when applicable, would be to withhold the project incentive until the energy simulation file is received and verified to be executable by the program implementer.
- In some instances, the program tracking database contained savings entries that did not match any of the project documentation. Similarly, there were often many versions of single files within a particular project file without making it clear which version was the final version. Adopting a standard file structure and naming convention across all projects may help reduce lost files and time needed to locate specific files of interest.

4.2.2 Key Variables Impacting Sample Size

4.2.2.1 Coefficient of Variation

One of the most influential variables on sample size is coefficient of variation (c.v.). **Table 4-5** in **Section 4.1** presents c.v. values for the measure types with the largest quantity of observations in this study. **Table 4-8** and **Table 4-9** on the following pages provide a comparison between c.v. values found in the Largest Savers Evaluation and those reported in the most recent ECB and EO program evaluations, respectively. The most recent EO and ECB program evaluations reported c.v. values using different measure types. Results from the Largest Savers Evaluation were aggregated two different ways to best align with each program's measure grouping methodology and allow for a more direct comparison of each program.

Very important to note when comparing c.v. values between different evaluations is the quantity of measures evaluated. As shown in **Table 4-2** and again in **Table 4-8** and **Table 4-9**, individual measure quantities evaluated in this evaluation were relatively small when compared to previous evaluations. For example, the previous ECB evaluation sampled 57 HVAC measures and 32 lighting measures, while the previous EO evaluation sampled 67 lighting measures. In comparison, the Largest Savers Evaluation only surveyed 27 lighting measures and 19 HVAC measures.

Lighting c.v. values across all savings types generally were consistent between this evaluation and previous EO and ECB evaluations, with kWh and summer kW c.v. values varying by 0.11 or less across the two recent program evaluations and the overall Largest Saver Evaluation results. Winter kW had the largest c.v. for lighting in all three evaluations.

HVAC measures showed a much smaller amount of variation in this evaluation when compared to the previous ECB evaluation. According to the previous ECB evaluation report, "project-specific realization rates for HVAC measures ranged from -29% to 871% for energy savings and 0% to 1573% for summer demand savings." In comparison, the range of HVAC measure level realization rates in this evaluation were smaller than those noted in the previous ECB evaluation, ranging from 25% to 785% for kWh savings and 23% to 149% for summer demand savings.

The Overall Electric measure group's kWh c.v. values varied little across the three evaluations, with the overall Largest Savers value of 0.98 being almost identical to the 0.99 value reported for the most recent ECB program evaluation and 0.12 greater than the 0.86 value reported for the most recent EO program evaluation. The corresponding summer kW and winter kW c.v. values across the three evaluations each varied considerably but all were larger than 1.0, with both summer and winter demand c.v. values ranging approximately 1.1 to 1.7.

The 0.95 and 0.71 Overall Gas c.v. values found in the most recent EO and ECB program evaluations were slightly higher than the 0.58 value found in the Largest Savers Evaluation.

Table 4-8: Coefficients of Variation for Measure Groups Listed In Most Recent ECB Evaluation Report

		Measure Qty, n[1]	kWh	Summer KW	Winter kW	Gas CCF
		Most Recent ECB Evaluation				
Electric	Compressed Air	26	2.18	1.36	1.28	
	HVAC	57	1.41	1.82	1.62	
	Lighting	32	0.62	0.72	0.84	
	Process	21	0.69	2.54	2.19	
	HPBD/Other	10	0.76	1.7	1.7	
	Electric Overall	146	0.99	1.62	1.53	
Gas	Boiler	17				0.46
	Other	26				0.97
	Overall	43				0.71
		Largest Savers - ECB Projects Only				
Electric	Compressed Air[2]					
	HVAC	9	0.43	0.38	0.42	
	Lighting	11	0.38	0.65	0.92	
	Process[3]					
	HPBD/Other[4]	15	0.56	1.04	0.27	
	Electric Overall	35	0.82	0.93	1.17	
Gas	Boiler	3				0.03
	Other	6				0.28
	Overall[5]	9				0.28
		Largest Savers - Overall				
Electric	Compressed Air[2]					
	HVAC	19	0.44	0.41	0.66	
	Lighting	27	0.67	0.77	1.15	
	Process[3]					
	HPBD/Other[4]	48	1.01	1.49	1.86	
	Electric Overall	94	0.98	1.11	1.68	
Gas	Boiler	7				0.66
	Other	22				0.52
	Overall[5]	29				0.58

[1] Where applicable, Largest Savers measures were considered as two observations, one for electric, and one for gas.
[2] There was only one compressed air measure in the Largest Savers Evaluation, and it came from the EO program.
[3] The Largest Savers study did not use a direct equivalent measure type to the "Process" category listed in the ECB evaluation report.
[4] The "HPBD/Other" category used in the ECB program evaluation is considered equivalent to the sum of all measures that were not lighting or HVAC.
[5] For the purposes of calculating c.v. values, lighting measures with a gas penalty were removed.

Table 4-9: Coefficients of Variation for Measure Groups Listed In Most Recent EO Evaluation Report

	Measure Qty, n[1]	kWh	Summer KW	Winter kW	Gas CCF
	Most Recent EO Evaluation				
Lighting	67	0.59	0.66	1.17	
Non-Lighting Electric	44	1.37	1.74	0.91	
Overall Electric	111	0.86	1.23	1.09	
Gas	33				0.95
	Largest Savers - EO Projects Only				
Lighting	16	0.43	0.77	0.86	
Non-Lighting Electric	43	1.19	1.54	2.58	
Overall Electric	59	1.00	1.35	2.28	
Gas[2]	20				0.61
	Largest Savers - Overall				
Lighting	27	0.67	0.77	1.15	
Non-Lighting Electric	67	0.92	1.20	1.84	
Overall Electric	94	0.98	1.11	1.68	
Gas[2]	29				0.58

[1] Where applicable, Largest Savers measures were considered as two observations, one for electric, and one for gas.

[2] For the purposes of calculating c.v. values, lighting measures with a gas penalty were removed.

4.2.2.2 Review of the Sample Design in Previous Evaluations

Given the data available to the evaluation team and a review of pertinent industry literature, the evaluation team investigated whether an alternative one-stage (one evaluation per program cycle) sampling strategy could be identified that would out-perform the sampling designs implemented in prior ECB and EO evaluations in terms of relative precision[6]. The team reviewed the most recent ECB and EO evaluations. Both use slight variations on the same sampling approach. This approach relies on three observations. First, it notes that if the analyst has any information on the projects and measures being sampled that is related to their realization rate, expected energy savings, or expected demand savings, randomly sampling from sub-groups (strata) of the projects or measures provides more precision than randomly sampling from the full population of projects or measures. Second, strata that vary more in terms of the variables that proxy for outcomes (e.g., energy savings) should be sampled more, assuming all other parameters being held equal. A technique called “Neyman allocation” tells the analyst the optimal amount of over-sampling. Third, a given Neyman allocation and a single continuous proxy variable for the outcome of interest, cut points along the proxy can be selected

[6] Texts include Sampling: Design and Analysis (Sharon Lohr), Sampling (Steven Thompson), Sampling of Populations: Methods and Applications (Paul Levy and Stanley Lemeshow), and Elementary Survey Sampling (Richard Scheaffer, William Mendenhall III, Lyman Ott, and Kenneth Gerow); extensions to classic work are found using a snowball sample based on Google scholar searches for “Lavallée and Hidiroglou”, “Dalenius and Hodges”, “Sethi stratification”, “Kozak stratification”, and “Gunning and Horgan stratification”.

to produce the strata that produce the most precise estimate feasible. These observations imply that there is an optimal way to sample the population of projects or measures.

The EO and ECB evaluations were conducted using one of the stratification strategies suggested in the literature. While the evaluation team did not have sufficient data for determining which of the many reviewed approaches is best for these particular evaluations, the EO and ECB evaluations were sampled in a way that was viewed as being generally consistent with best practices. The strategy used in these prior evaluations is also consistent with the best practices as advised by National Renewable Energy Laboratory in the chapter on sample design from its document “The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures”.

Given that the strategy implemented in prior program evaluations selected a sample that is consistent with best practices in terms of how much it weighted toward larger measures or projects that are likely to contribute the most to the variance when estimating the portfolio energy savings or demand impacts, there are only two possible improvements that the team can envision for a future single-stage study.

1. Previous program evaluators used a ratio estimator to estimate the portfolio savings or realization rate. This estimator is implemented by the weighted average realization rate for the sample with larger projects receiving more weight in the calculation. The variance of this estimator is then calculated as a function of how far away from the average realization rate their ex post value is. So, the important source of variance when using the ratio estimator is highly discrepant projects, with larger projects having more weight. If the average realization rate and variance of the realization rate is constant across values of ex ante savings, the ex ante savings measurements will be good proxy measurements for purposes of assessing the impacts of stratification and sample size assumptions on the precision of future samples . Otherwise, using expected squared error from the average realization rate might be used to improve the precision of the estimate.

2. Future evaluators could relax the assumptions necessary for the selected strata to be optimal. The assumptions underlying the strata selection (based on Dalenius and Hodges, 1959) are ignorability of the finite population correction and a constant probability density within strata. Ekman’s 1959 paper on “An Approximation Useful in Univariate Stratification” and Winkler’s 2009 paper on “Strata Boundary Determination” for the Census Bureau relax these assumptions. Alternatively, evaluators could use a computer-based optimization for selecting the optimal strata. It is difficult to know in advance whether these changes would produce a precision improvement though.

After these changes, the main additional choice being made is the sample size. If the sample size were increased, the precision of the estimated realization rate would mechanically improve, and this may be necessary if the suggestions above ultimately make only a small difference in the expected variance of the realization rate.

4.2.3 Data Availability for Future Use

In an effort to allow the data collected during this evaluation to be leveraged as much as possible, the evaluation team is providing the Evaluation Administrator with the data necessary to potentially incorporate results from this evaluation into future program evaluations, including each evaluated project's SSMVP, measure and project level ex post savings estimates, and each project's evaluation report. Combining results from the Largest Savers Evaluation with future evaluations may be possible, but certain technical and administrative requirements must first be considered.

From an administrative standpoint, an important factor to bear in mind when considering merging the Largest Savers Evaluation data with future evaluations is the timeframe of the evaluation. **Table 4-10** below summarizes the key dates of the most recent evaluations.

Table 4-10: Key Dates of Recent Evaluations

Evaluation	Program Years Sampled	Evaluation Report Finalized
EO Program	2011	2014
ECB Program	2012-2013	2015
Largest Savers	2013-2015	2018

Section 15.2 of ISO New England's M-MVDR states that:

"All reports, studies, specifications and other documents referenced in the Project Sponsor's Measurement and Verification Plan shall have been prepared and published within five years of the Measurement and Verification Plan's submission date to the ISO."

Interpreting this passage to mean that evaluation findings are valid from five years of the date the evaluation report is finalized, the Largest Savers Evaluation findings may be incorporated into future evaluations, so long as the results are used to bid savings into the ISO's forward capacity market only through five years of this report's publication, which would be through 2023.

5 Observations and Recommendations

Discussed in this section are the observations made by the evaluation team during the Largest Savers Evaluation. Along with each observation is a corresponding recommendation for the consideration of program administrators, program implementers, program evaluators, the CT EEB, and other C&LM program stakeholders. The observations and recommendations are divided into program implementation and program evaluation categories; however, many of the observations/recommendations may apply to both areas.

5.1 Program Implementation

1. **Observation**: The definition of hours that are to be used to estimate peak demand savings for C&LM programs (Seasonal Peak Hours) creates a different set of peak hours each year, which adds complexity to calculating and tracking demand savings. Variance between ex ante and ex post savings measures, which have deemed peak demand savings or coincidence factors listed in the PSD, were found to be generally minimal, provided the appropriate PSD version was referenced and followed by both ex ante and ex post savings estimates. However, for measures without deemed peak demand savings or coincidence factors in the PSD, determining a new set of peak hours each year could lead to variance between ex ante and ex post savings estimates if the same procedure is not closely followed and appropriately tracked over the course of a multi-year program cycle.

   Recommendation: C&LM programs should consider using a definition that references a standard time/day window each year. This approach would eliminate any variance stemming from potentially different peak period definitions either between implementers and evaluators, or between years of a multi-year program cycle. A standard peak timeframe would also be more conducive to generating and periodically updating prescribed coincidence factors in the PSD using consistent peak period assumptions.

   After reviewing this recommendation, both Eversource and UI each noted two advantages in favor of maintaining the current peak hours definition:

   1) Previous analysis found that the current definition more closely aligns with the actual ISO-NE system peak.

   2) Changing definitions would involve costly changes to the companies' tracking systems and processes for calculating savings and bidding them into the ISO-NE Forward Capacity Market, which may not prove cost effective to implement.

   Without a full review of the data and underlying assumptions that support these claimed advantages, Nexant is not able to provide additional detail to the recommendation noted above. In a similar vein as the utilities' comments, Nexant stresses that C&LM program stakeholders understand that changing the peak demand definition brings with it broad and complex cost and policy implications, which would require further review and discussion

2. **Observation:** Differences between reported and verified measure operation (e.g. schedule, loading, governing setpoints) was one of the largest contributors to variance between ex ante and ex post savings. The reasons for these differences varied and included: changes in customer practices over time, inaccurate assumptions used to derive ex ante savings estimates, and evaluators having access to data the implementers did not have access to (namely, post-implementation meter data). The effects of each of these reasons were not explicitly tracked for their influence during the evaluation so their individual impact on the overall evaluation is not clear.

   Recommendation: Program implementers may wish to consider conducting more pre-installation metering on retrofit measures and commissioning activities on new construction measures. Also, there may be benefits in performing post-implementation surveys with participants via phone or email aimed at confirming key savings calculation parameters, while still maintaining a low cost to perform.

   Another approach to consider in future program cycles is using real-time evaluation. In other words, getting the evaluator involved during the project implementation phase. This approach would help implementers screen out projects that will likely have very low realization rates before the program's resources are committed to the project. The approach would also lay out clear evaluability requirements, such as tracking key project parameters over time prior to the project receiving incentives. Real-time evaluation requires additional coordination between implementers and evaluators; therefore, the extra cost necessary to use this approach would likely prohibit its use on small or medium sized projects. Also, real-time evaluation requires that evaluator contractors be selected by the EEB and involved with implementers very early in each program cycle, which would likely require shifting some of the evaluation timing in Connecticut.

3. **Observation:** Savings calculators largely appeared to be custom-built for each project, including common measure types (e.g. lighting or VFDs).

   Recommendation: The CT EEB should consider creating standardized savings workbooks for common measures, which would be used by program implementers and evaluators across the utilities. The primary function of the workbooks would be to automate calculations for select measures already in the PSD, which would ensure: the PSD is consistently applied, reduce time per measure needed to calculate savings, minimize calculation errors, and allow for faster review by utility staff and evaluators.

4. **Observation:** Interactive effects were inconsistently taken into account.

   Recommendation: Consider developing measure workbooks for common and/or prescriptive measures, which would ensure interactive effects are appropriately taken into account.

5. **Observation:** Projects that relied on energy simulation files (e.g. eQUEST, Trane Trace 700) for savings calculations only sometimes included the energy simulation files with the project documentation.

   Recommendation: Consider requiring program implementation staff to save energy simulation files prior to closing out projects. Consider requiring program implementation staff to certify that the energy simulation files saved on the utility's server are executable and are the most current version before issuing the customer the program incentive.

6. **Observation:** For several projects, project documentation was either sparse, missing, or did not match the savings values listed in the utility tracking database.

   Recommendation: To ensure all relevant project documentation is gathered and organized, it is recommended that program administrators use a standardized file structure and file naming convention within each project file that would enable implementation staff to quickly locate files. For example, consider creating and standardizing names of file sub-folders such as "Letter of Agreement", "Savings Calculations", "Customer Correspondence", "Specification Sheets", and "Invoices". Within these folders, project administrators could use a standardized file naming protocol, indicating which file is the final version used to support the tracking database entry (e.g. "XXX_Final").

   Similarly, program administrators should consider using a checklist during project closeout to ensure all key documents are present, current, and match the tracking database. Also, if there are noteworthy details that may make review more clear and were not included in the existing project documentation, it may be beneficial to include a short project narrative that is more comprehensive than what is typically contained in the existing documents, such as the Letter of Agreement.

7. **Observation:** Ex ante savings calculations appeared to have no consistent protocol as to when to use the PSD.

   Recommendation: The CT EEB should provide program implementers and evaluators guidance on instances when use of the PSD is recommended or required. For example, the CT EEB may consider adding estimated measure savings thresholds to the PSD, where if the initial estimate of savings is at or below the threshold, the use of PSD savings algorithms and assumptions is required. Similarly, the CT EEB may consider adding a threshold above which the PSD requires site specific inputs are used in lieu of assumed values for certain parameters, such as hours of use for lighting measures.

5.2 Program Evaluation

1. **Observation:** Utility tracking databases sometimes contained what appeared to be redundant measure line items (i.e. same measure description, savings values, etc.) without any indication of the difference between the two entries.

   Recommendation: When providing evaluators program tracking data in the future, make sure redundant entries are either removed or noted for their differences.

2. **Observation:** In the Eversource tracking database, the measure level savings did not sum to the project level savings reported across all projects.

   Recommendation: Before providing evaluators program tracking data in the future, ensure that measure level savings rolled up to project level match the reported project savings. If a project's savings are known to be different than the sum of the project's measure savings (e.g. taking into account interactive effects), the affected projects and measures should be noted in the database.

3. **Observation:** ISO New England's M-MVDR specifies that for demand reduction values, sampling must achieve statistical accuracy and precision of at least 80% confidence at 10% relative precision. The previous EO and ECB evaluations appeared to interpret this requirement to apply at the program level. However, there does not appear to be any guidance from ISO New England or the CT EEB specifying sampling expectations for on-site measure sampling, which is chiefly applicable to lighting measures.

   Recommendation: The CT EEB should consider adding a section to the PSD or creating a separate guidance document detailing expected sampling procedures for within measure sampling while on site. As a reference, the CT EEB may wish to consider guidance already employed in Pennsylvania, detailed in Section 3.3.3.2.3 of Pennsylvania Evaluation Framework[7].

4. **Observation:** Coefficient of variation values found in this evaluation generally agree with those found in the previous EO and ECB evaluations, indicating a much larger amount of variance than originally assumed by ISO New England, particularly for summer and winter electric demand savings. ISO New England's M-MVDR specifies that, in the absence of more specific data relevant to the sampled population, the assumed c.v. should be 0.5 for homogeneous populations and 1.0 for heterogeneous populations.

   Recommendation: In order to reduce c.v. values, and thus sample size and evaluation cost, program administrators should seek opportunities to create better alignment of ex ante and ex post savings values using the observations and recommendations provided in this report and previous evaluation reports. If steps are not taken to reduce future c.v. values, future program evaluations in Connecticut should base sample sizes on the larger observed c.v. values, referencing the c.v. values determined in this evaluation and the previous EO and ECB evaluations, in lieu of using the default M-MVDR values, in order to ensure confidence and precision targets are met.

5. **Observation:** Data used in previous evaluations, such as project and measure level ex post savings, were not collected and retained in a data repository for future use and reference.

   Recommendation: Compile a standardized set of files from all evaluations and retain them in a data repository that is well organized and documented. The repository should also be stored in a location that is not dependent upon changes in evaluation administrators, evaluation contractors, or utility companies.

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[7] *Evaluation Framework for Pennsylvania Act 129 Phase III Energy Efficiency and Conservation Programs*, 10/21/16, http://www.puc.state.pa.us/Electric/pdf/Act129/SWE_PhaseIII-Evaluation_Framework102616.pdf

6. **Observation:** The results of this evaluation could possibly be used to augment future evaluation studies, thus reducing sample sizes; and the findings of this evaluation may be useful as a reference (e.g. expected realization rates and c.v. values) for future evaluators.

   Recommendation: Future EO and/or ECB program evaluators should consider using the results and findings of this study to augment and inform their evaluation efforts.

Appendix A Total Ex Ante and Ex Post Savings by Level of Evaluation Rigor and Program

A.1 Energy Conscious Blueprint

		Low Rigor	High Rigor	Total
kWh	Ex Ante	13,029,280	8,643,899	21,673,179
	Ex Post	13,079,692	6,325,110	19,404,802
	Realization Rate	100%	73%	90%
Summer kW	Ex Ante	1,856	1,493	3,349
	Ex Post	1,961	1,132	3,093
	Realization Rate	106%	76%	92%
Winter kW	Ex Ante	1,496	1,280	2,776
	Ex Post	1,673	759	2,431
	Realization Rate	112%	59%	88%
Gas CCF	Ex Ante	162,426	75,360	237,786
	Ex Post	118,306	101,010	219,316
	Realization Rate	73%	134%	92%

A.2 Energy Opportunities

		Low Rigor	High Rigor	Total
kWh	Ex Ante	4,434,211	15,561,518	19,995,729
	Ex Post	2,498,383	12,775,298	15,273,681
	Realization Rate	56%	82%	76%
Summer kW	Ex Ante	211	2,039	2,250
	Ex Post	234	1,932	2,166
	Realization Rate	111%	95%	96%
Winter kW	Ex Ante	108	1,691	1,799
	Ex Post	192	1,841	2,033
	Realization Rate	178%	109%	113%
Gas CCF	Ex Ante	549,110	637,723	1,186,833
	Ex Post	442,550	461,362	903,912
	Realization Rate	81%	72%	76%

Appendix B Savings and Realization Rates by Measure Type and Level of Evaluation Rigor

B.1 High Evaluation Rigor

	kWh			Sumer kW			Winter kW			Gas CCF		
	Ex Ante	Ex Post	RR	Ex Ante	Ex Post	RR	Ex Ante	Ex Post	RR	Ex Ante	Ex Post	RR
Boiler	-	-	-	-	-	-	-	-	-	-	-	-
Compressed Air	-	-	-	-	-	-	-	-	-	-	-	-
EMS	729,807	552,900	76%	297	49	17%	3	30	1002%	15,789	10,921	69%
Envelope	-	-	-	-	-	-	-	-	-	-	-	-
HVAC	3,732,217	2,746,874	74%	651	682	105%	174	182	104%	55,274	56,987	103%
Lighting	5,810,233	4,344,514	75%	604	649	108%	525	512	98%	-	-9,865	N/A[2]
Motors	-	-	-	-	-	-	-	-	-	-	-	-
Other	10,268,457	9,542,362	93%	1,105	1,407	127%	1,728	1,714	99%	607,138	460,451	76%
Refrigeration	189,388	37,461	20%	43	16	38%	- [1]	21	2,100%	-	-	-
VFD	2,930,200	1,439,197	49%	395	154	39%	482	142	29%	-	-	-
Whole Building	5,166,069	3,853,671	75%	924	540	58%	963	521	54%	75,360	101,010	134%
Total	**24,205,417**	**19,100,408**	**79%**	**3,532**	**3,064**	**87%**	**2,970**	**2,600**	**88%**	**713,083**	**562,372**	**79%**

[1] Value is zero but assumed to be one for the purposes of calculating a realization rate.

[2] The negative gas savings calculated for lighting measures was a result of the interactive effects penalty stipulated in the PSD for lighting measures. However, the utilities did not include these interactive effects in their tracking systems, as the Utility Cost Test (UCT) used to determine cost effectiveness, does not include gas interactive effects for electric measures.

B.2 Low Evaluation Rigor

	kWh			Sumer kW			Winter kW			Gas CCF		
	Ex Ante	Ex Post	RR	Ex Ante	Ex Post	RR	Ex Ante	Ex Post	RR	Ex Ante	Ex Post	RR
Boiler	-	-	-	-	-	-	-	-	-	377,007	346,013	92%
Compressed Air	17,326	6,836	39%	2	1	48%	2	1	48%	-	-	-
EMS	2,711,885	998,177	37%	-	-	-	15	22	148%	177,833	108,180	61%
Envelope	25,339	25,339	100%	47	47	100%	1	1	100%	- [1]	4,150	N/A[2]
HVAC	1,785,896	1,654,209	93%	550	482	88%	149	134	90%	124,640	108,762	87%
Lighting	10,489,945	11,507,043	110%	1,377	1,535	111%	983	1,299	132%	- [1]	-38,304	N/A[3]
Motors	40,561	40,648	100%	0.2	0.4	154%	0.2	0.4	154%	-	-	-
Other	318,952	411,557	129%	22	50	228%	31	67	218%	32,056	32,055	100%
Refrigeration	1,257,289	357,144	28%	27	28	101%	347	262	76%	-	-	-
VFD	810,309	577,122	71%	42	52	123%	78	80	102%	-	-	-
Whole Building	-	-	-	-	-	-	-	-	-	-	-	-
Total	**17,463,491**	**15,578,075**	**89%**	**2,067**	**2,195**	**106%**	**1,605**	**1,865**	**116%**	**711,536**	**560,856**	**79%**

[1] Value is zero but assumed to be one for the purposes of calculating a realization rate.
[2] High realization rate due to one project being verified (ex post) to have gas savings while there were no claimed (ex ante) gas savings. Gas savings for this project were not tracked by the utility and the realization rate is therefore meaningless.
[3] The negative gas savings calculated for lighting measures was a result of the interactive effects penalty stipulated in the PSD for lighting measures. However, the utilities did not include these interactive effects in their tracking systems, as the Utility Cost Test (UCT) used to determine cost effectiveness, does not include gas interactive effects for electric measures.

Appendix C Seasonal Peak Hour Analysis

C.1 Definition

The PSD lists definitions for two distinct peak periods: “On-Peak Hours” and “Seasonal Peak Hours”.

- **On-Peak Hours** are hours 1:00-5:00 p.m., Monday through Friday on non-holidays during the months of June, July, and August and from 5:00-7:00 p.m., Monday through Friday on non-holidays during the months of December and January.
- **Seasonal Peak Hours** are those hours in which the actual, real-time hourly load Monday through Friday on non-holidays, during the months of June, July, August, December, and January, as determined by the ISO, is equal to or greater than 90 percent of the most recent 50/50 system peak load forecast, as determined by the ISO, for the applicable summer or winter season.

The PSD states that the Seasonal Peak demand savings are used in the C&LM programs. Accordingly, this evaluation report uses the ISO New England “Seasonal Peak Hour” definition in determining summer and winter kW reductions.

C.2 Methodology

The method used to determine demand reductions follows these three steps.

1. Determine demand savings for each hour of a typical year (8760 hourly analysis). Techniques to determine a typical year’s savings vary by measure type but include weather normalization and removing the effects of singular events (e.g. abnormally high/low production at a manufacturing facility).

2. Determine the applicable Seasonal Peak Hours per ISO New England’s definition sated above.

3. Average the demand reduction during the determined Seasonal Peak Hours.

C.3 Summer Seasonal Peak Hours

The Peak Load Model described in *Forecast Model Structures of the ISO New England Long-Run Energy and Seasonal Peak Load Forecasts for the 2016 CELT Report* involves two components that incorporate weather conditions: Temperature-Humidity Index (THI) and Weighted Temperature-Humidity Index (WTHI). The THI includes outdoor air temperature and humidity parameters while the WTHI adds a historical weighting element to the THI calculation by including the previous two days’ THI values.

Equation 1 and **Equation 2** on the following page show the equations used to determine THI and WTHI, respectively.

Equation 1: Temperature-Humidity Index

$$THI = 0.5 * DryBulbTemp + 0.3 * DewPointTemp + 15$$

Where:

THI = temperature humidity index

DryBulbTemp = outdoor air dry bulb temperature

DewPointTemp = outdoor air dew point temperature

Equation 2: Weighted Temperature-Humidity Index

$$WTHI = \left\{\frac{10 * THI_d + 5 * THI_{d-1} + 2 * THI_{d-2}}{17}\right\} - 55$$

Where:

WTHI = 3-day weighted temperature-humidity index

THId = total heat index for current day

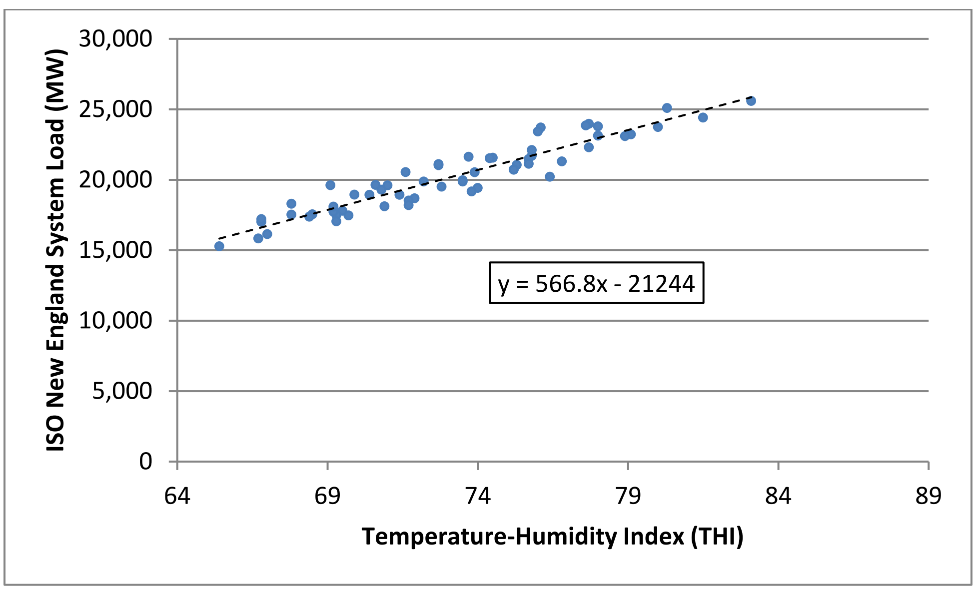
THId-1 = total heat index for previous day at the same hour

THId-2 = total heat index for two days prior at the same hour

Both THI and WTHI were plotted against hourly system load provided in ISO New England's *2016 SMD Hourly* data file. **Figure 5-1** below shows this comparison's results for THI.

This same regression analysis was performed on both THI and WTHI, which yielded the same peak hours. Therefore, this description only describes the THI analysis.

Figure 5-1: ISO New England System Load vs. Temperature-Humidity Index



ISO New England's *2016-2015 Forecast of Capacity, Energy, Loads, and Transmission* report provided the 50/50 system peak load forecast for summer 2016, estimating it to be 28,583 MW. Therefore, 90% of this peak load is 25,689 MW, which was used to determine the THI threshold above which hours would be considered part of the Seasonal Peak. The THI threshold was found to be 82.8.

TMY3 data for Hartford, Connecticut was used to determine a THI for every hour of the typical year. Then, the hours meeting the ISO New England requirements and THI threshold were filtered out to arrive at the list of TMY3 hours used in determining demand savings. This filtration unfortunately produced no applicable hours. The reason for no hours meeting this requirement was found to be the relatively high THI threshold produced by the 2016 data compared to weather data contained in the TMY3 dataset. In other words, 2016 was much warmer than the TMY3 observed years and very few TMY3 hours qualified based on THI.

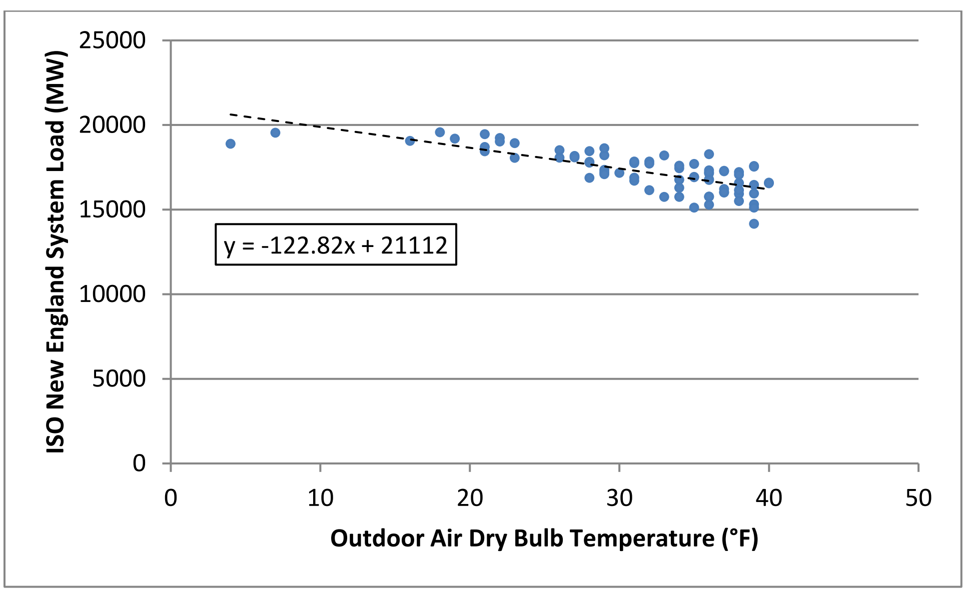
To scale 2016 findings to TMY3 observed data, the 2016 hours that either met or exceeded the THI threshold were separated and compared against all non-holiday weekday summer hours. The results showed that the hours meeting or exceeding the THI threshold were in the 98.6 percentile and above when ranking by THI value. Therefore, the TMY3 THI values were ranked and those meeting the top 1.4 percentile by THI value were considered the Seasonal Peak Hours for the summer.

C.4 Winter Seasonal Peak Hours

The Winter Seasonal Peak Hours analysis followed the same methodology as the Summer Seasonal Peak Hours analysis except for a few aspects:

- The 50/50 system peak load forecast for winter 2015/2016 was 22,740 MW. 90% of this peak load, 20,466 MW, which was used to set the threshold above which corresponding hours would qualify as the seasonal peak.
- Using the 20,466 MW threshold, and the regression found in **Figure 5-2** below, the THI threshold was found to be 5.3°F.
- Humidity is not expected to impact winter peak loads, so only outdoor dry bulb temperature was analyzed.

Figure 5-2: ISO New England System Load vs. Outdoor Air Dry Bulb Temperatures



Appendix D Site Specific M&V Plan Template

C1630: Largest Savers: Site Specific Measurement and Verification Plan (SSMVP)

Utility:

Participant:

Project Unique ID:

SSMVP date created

Contents

1 Project Overview

Table 1 Project and Site Information

Item	Comment
Site (business) name	
Facility address	
Project completion/commissioning date	
Site contact person	
Contact title	
Contact phone number	
Contact e-mail address	
Key Account Manager/Account Exec.	
KAM/EA phone number	
KAM/EA e-mail address	

2 Background

2.1 Project description

Table 2 Project Measure(s) with Participant's Savings Estimates

Measure #	Measure	kWh/yr Savings	kW - Summer Demand Saved	kW – Winter Demand Saved	MMBtu Gas savings	Avoided Cost ($)	% Avoided Cost
Associated Avoided Cost:		*$0.07*	*$100.00*	*$100.00*	*$5.00*		
1							
2							
3							

2.2 Site description

3 M&V Plan

3.1 Sampling

3.2 Measure 1:

3.2.1 Baseline

.

3.2.2 Measure Description

3.2.3 Data Analysis Approach and Algorithms

3.2.4 Key Data Points and Collection Method(s)

3.3 Measure 2:

3.3.1 Baseline

.

3.3.2 Measure Description

3.3.3 Data Analysis Approach and Algorithms

3.3.4 Key Data Points and Collection Method(s)

4 Estimated Schedule

5 Additional Notes

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Appendix E Metering Equipment Used During this Evaluation

Measure Type	Metering Equipment	Measurement Accuracy
Lighting	Onset Hobo UX-90-001 Light On/Off Data Logger	Time accuracy ±1 minute per month
	Onset Hobo U12-012 Temperature, Relative Humidity, and Light Intensity Data Logger (used to determine on/off status of lights – not lumen level)	Time accuracy ±1 minute per month
Temperature	Onset Hobo U12-012 Temperature, Relative Humidity, and Light Intensity Data Logger	± 0.35°C from 0° to 50°C
kW	Dent ElitePro Energy Logger	±1% (<0.2% typical) of reading
	Continental Control Systems Wattnode Pulse Revenue	±0.5% of reading

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