DNV·GL

FINAL REPORT

C1635 Impact Evaluation of PY 2016 & 2017 Energy Opportunities (EO) Program

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1 ABSTRACT

This C1635 Energy Opportunities (EO) impact evaluation examined the performance of the 2016 and 2017 program years as well as 2018 C&I upstream lighting activity. This study was commissioned to understand the extent to which program performance is meeting program and policy goals and objectives and to recommend revisions to the Program Savings Document (PSD) to improve claimed savings estimates moving forward. The EO Program is the flagship C&I retrofit program offered by the companies with a 2020 savings goal of 114,405 MWh (39% of the overall portfolio goal)[1].

This study is important due to the high contribution of EO Program savings relative to the portfolio and the duration since the previous study of this program (2014). The objectives were to (1) determine evaluated energy and seasonal peak demand savings and retrospective and prospective[2] realization rates (RRs) for three electric end use groups (Lighting, HVAC, and Other) and two gas end use groups (HVAC/DHW and Other), (2) evaluate the 2018 Upstream lighting program and update PSD assumptions accordingly, and (3) update the PSD for lighting hours of use and seasonal peak coincidence factors based on data leveraging[3].

On-site visits, including measurement and verification (M&V) were performed at a statistically selected sample of 88 Upstream lighting[4], 65 EO lighting, 26 electric HVAC, 26 electric other sites, 20 gas HVAC/DHW sites, and 12 gas "other" sites. Equipment level analysis performed at International Performance Measurement and Verification Protocol (IPMVP) standard accompanied a statistical expansion to produce aggregate impacts, realization rates, and precisions. On the whole, the EO program is tracking most impacts reasonably well with pockets of improvement available, as evidenced in the realization rates below. The evaluation team recommends updating the following PSD realization rate assumptions by end use based on the results of this study.

End Use	Electric Energy RR	Summer Seasonal Peak Demand Realization Rate		Winter Seasonal Peak Demand Realization Rate		Gas Energy Realization Rate
		Actual Population[5]	If Fully Populated[6]	Actual Population[5]	If Fully Populated[6]	
Cooling	102.1%	192.5%	146.4%	146.2%	125.0%	-
Heating	102.1%	192.5%	146.4%	146.2%	125.0%	76.5%
Lighting	97.9%	98.9%	98.9%	115.3%	115.3%	-
Custom	93.8%	106.7%	103.1%	122.7%	120.1%	77.3%
EMS	67.6%	123.9%	114.7%	179.8%	162.1%	78.2%
Motors	67.6%	123.9%	114.7%	179.8%	162.1%	-
Other	67.6%	123.9%	114.7%	179.8%	162.1%	78.2%
Process	67.6%	123.9%	114.7%	179.8%	162.1%	78.2%
Refrigeration	67.6%	123.9%	114.7%	179.8%	162.1%	-
DHW	-	-	-	-	-	76.5%

[1] 2020 Plan Update to the 2019-2021 Conservation & Load Management, Submitted by: Eversource Energy, United Illuminating, Connecticut Natural Gas Corporation, and Southern Connecticut Gas, p 91.

[2] Prospective realization rates were calculated by examining the changes that occurred in the PSD between the evaluation program years and the 2020 PSD. Whenever a measure that was in the sample experienced a PSD change during this timeframe, a new tracking savings estimate was calculated. Prospective realization rates were calculated using this new tracking savings estimate as the numerator.

[3] Using lighting logger data from 266 sites and 2,699 loggers from the current study, the C14: 2014 CT EO evaluation, the C20: 2015 CT Energy Conscious Blueprint evaluation, and the 2014 and 2018 CT Small Business Energy Advantage studies (C9 and C1639, respectively).

[4] Verification was performed at all 88 sites, while measurement was performed at 25 of these sites.

[5] Recommended realization rates if tracking system estimates for some sites are 0.00 kW as found in the current study tracking population.

[6] Recommended realization rates if tracking system estimates are fully populated with non-zero values moving forward.

The evaluation team recommends revising the PSD to explicitly call for the use of site-specific hours of use assumptions when calculating EO lighting energy savings. The evaluation team recommends using the following C&I upstream lighting hours of use assumptions by building type below.

Building Type	Upstream Hours of Use	Summer Seasonal Peak Coincidence Factor	Winter Seasonal Peak Coincidence Factor
24x7 lighting	8,760	100.0%	100.0%
Automotive	2,807	68.3%	36.9%
Education	2,967	36.8%	46.0%
Grocery	7,698	90.6%	85.6%
Health Care	5,564	82.5%	69.6%
Hotel/Motel	3,112	40.6%	37.5%
Industrial	5,793	83.0%	66.5%
Large Office	4,098	77.9%	58.2%
Other	6,211	86.9%	76.7%
Parking Lot/Streetlights	6,887	67.2%	87.3%
Religious Building/Convention Center	913	17.0%	9.2%
Restaurant	6,072	83.1%	77.0%
Retail	6,318	98.4%	85.6%
Small Office	3,595	76.8%	44.1%
Warehouse	5,667	89.3%	72.4%

The evaluation team recommends incorporating the following PSD upstream lighting savings factor assumptions by product type based on the results of this study.

Upstream Lighting Product Type	Short-term In-service Rate	Long-term In-service Rate	Delta Watts	Electric Energy Interactive Factor	Summer Demand Interactive Factor
LED Linear	97.1%	97.4%	15.33	1.081	1.199
LED Downlights	85.9%	86.4%	41.16	1.023	1.189
LED A-line/Decorative	71.4%	74.9%	40.32	1.024	1.176
LED High/Low Bay	99.6%	99.7%	157.33	1.008	1.047

IMPACT EVALUATION OF THE ENERGY OPPORTUNITIES PROGRAM

Executive summary

INTRODUCTION

This study evaluated the Connecticut Energy Opportunities (EO) retrofit program years 2016 and 2017 and the 2018 C&I upstream lighting program. This study was commissioned by the Connecticut Energy Efficiency Board (EEB) and performed under the guidance of the EEB consulting team. The EO Program is the flagship C&I retrofit program offered by the companies with a 2020 savings goal of 114,405 MWh (39% of the overall portfolio goal).

Core objectives

The purpose of the study is to understand the extent to which program performance is meeting program and policy goals and objectives and to recommend PSD revisions to improve claimed savings estimates moving forward. This study examined the performance of EO electric and gas installations for the following categories of measures.

EO Electric Measure Categories

- Lighting
- DHW and HVAC
- Other

EO Gas Measure Categories

- DHW and HVAC
- Other

Upstream Measure Category

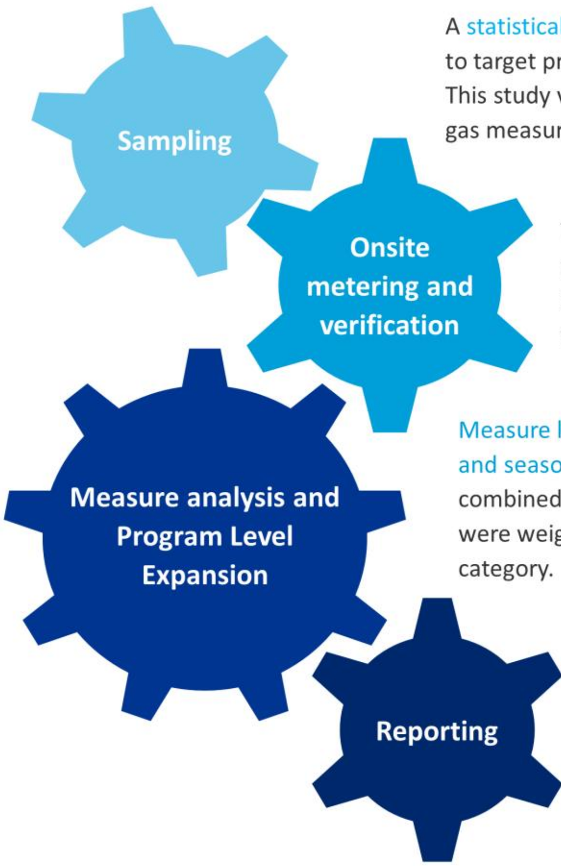
- Lighting

There are three key objectives of the study.

- Assess energy savings (ccf, kWh) and realization rate
- Determine summer on-peak and winter on-peak kW realization rates
- Update Program Savings Document

METHODS

There were four primary methods used in this study.



A statistical sample design and sample selection were performed to target precisions around electric and gas measure groups. This study visited 117 sites with EO electric measures, 32 with gas measures, and 88 with upstream lighting purchases

The study performed on-sites based upon metering and verification plans developed for each site. Measure installation was verified and extensive metering was installed to understand equipment seasonal and overall performance.

Measure level analysis was performed to calculate energy (kWh and ccf) and seasonal peak savings. Logger data from this study and 4 others were combined to inform recommended PSD updates. The site level results were weighted to provide overall impacts and realization rates by measure category.

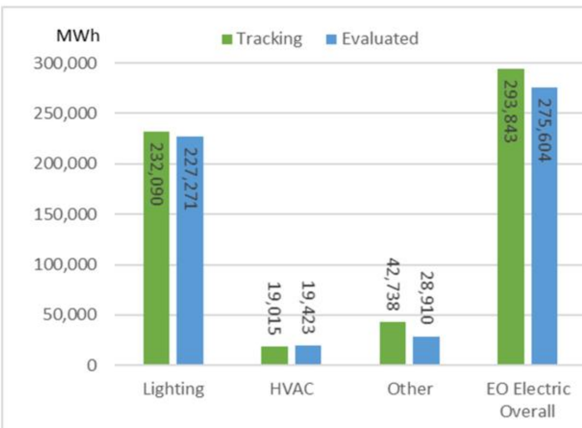
Reporting was performed with conclusions and recommendations designed to provide appropriate retrospective and prospective realization rates and guidance on their application in the PSD.

1. Nearly 2,700 loggers from this study and four previous Connecticut C&I studies were gathered for leveraging and to inform recommended hours of use and coincident factor updates to the PSD.
2. Prospective and retrospective realization rates were calculated as appropriate to ensure changes in PSD savings assumptions and methods since the program years evaluated are properly accounted for in future savings claims.

IMPACT RESULTS

On the whole, the EO program is tracking most impacts reasonably well with pockets of improvement available, as evidenced in the realization rates below.

EO Electric Energy Savings



The overall EO Program achieved electric savings of 275,604 MWh with a realization rate of 93.8% ±7.3% at the 90% confidence interval.

The lighting energy savings realization rate is 97.9% ±8.1% at the 90% confidence interval.

The HVAC realization rate is 102.1% ±35.0% at the 90% confidence interval.

The Other realization rate is 67.6% ±14.6% at the 90% confidence interval.

The lighting summer and winter peak realization rates are 98.9% and 115.3%.

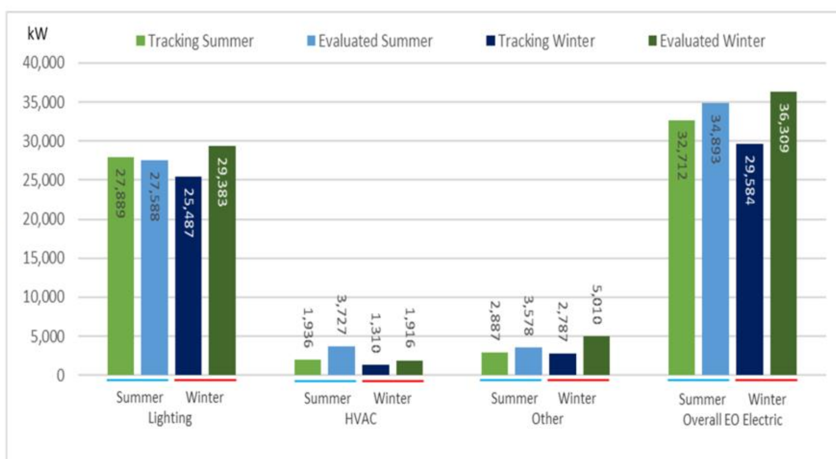
The HVAC summer and winter peak realization rates are 192.5% and 146.2%.

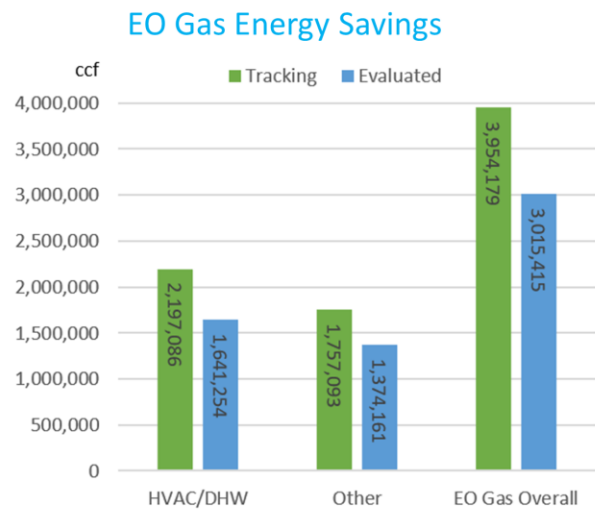
The Other summer and winter peak realization rates are 123.9% and 179.8%.

The Overall EO Electric summer and winter peak realization rates are 106.7 and 122.7%.

These non-lighting rates include sites without tracking estimates that were credited impacts in the evaluation.

EO Electric Seasonal Peak Demand Savings





The overall EO Program achieved gas savings of 3,015,415 ccf with a retrospective realization rate of 76.3% ±15.8% at the 90% confidence interval.

The HVAC/DHW gas savings retrospective realization rate is 74.7% ±17.4% at the 90% confidence interval.

The Other gas savings realization rate is 78.2% ±27.3% at the 90% retrospective confidence interval.

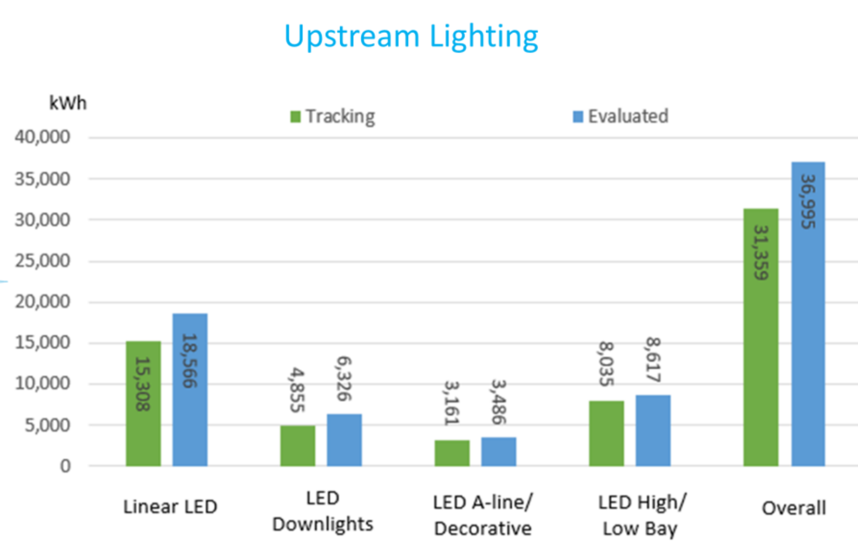
Changes in the calculation of gas measure savings in the PSD since the period studied required the calculation of prospective realization rates for the HVAC/DHW measure category.

- The HVAC/DHW gas savings prospective realization rate is 76.5% ±17.4% at the 90% confidence interval.

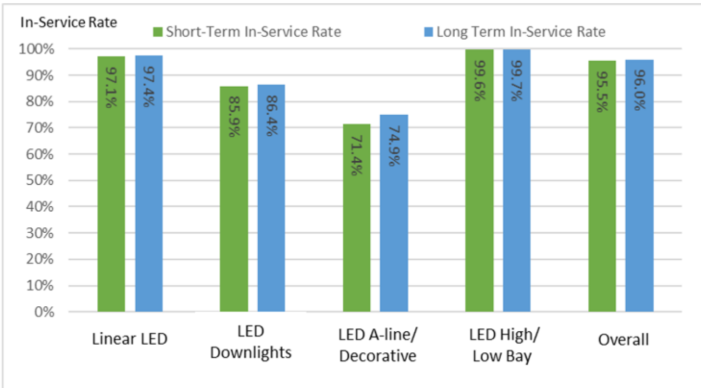
The overall upstream lighting realization rate is 118% ±12.7% at the 90% confidence interval.

Results by lighting category were very similar and over 100%, ranging from a realization rate of 107% for high and low bay LED fixtures to 130% for LED downlights.

The high realization rates were driven primarily by higher hours of use from the data leveraging results than were assumed in the tracking system



Upstream Lighting In-Service Rates



Tracking system savings assume 100% in-service rate.

Long term in-service rate calculated through use of a recent longitudinal study of upstream lighting in Massachusetts.

The overall short-term in-service rate is 95.5% and the overall long term in-service rate is 96.0%

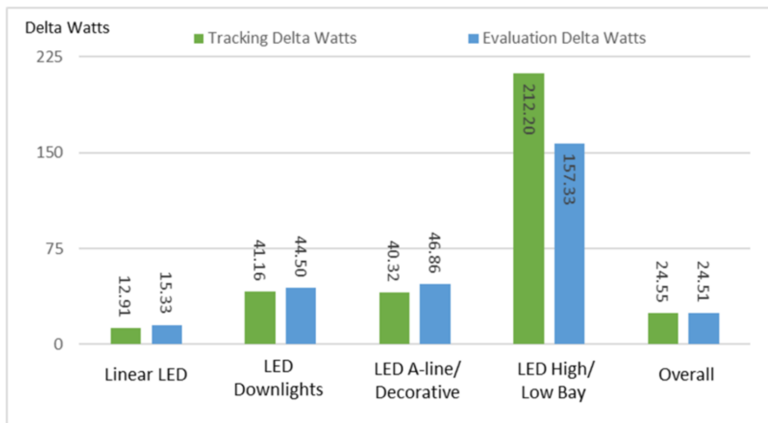
Tracking system delta watts assumptions are based on MA Bright Opportunities study and do not appear in the PSD.

Results by lighting category were generally very similar with realization rates over 100%.

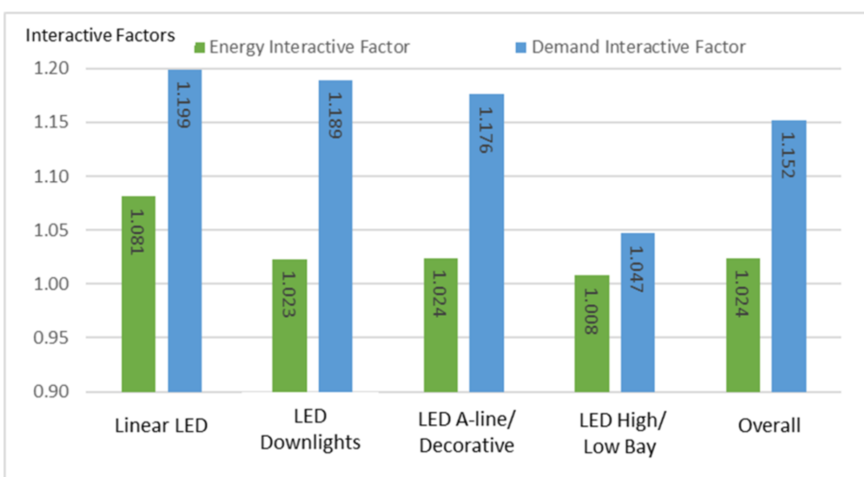
Delta watts for LED high/low bay fixtures were much lower than assumed (157.33 watts versus 212.20 watts)

The overall delta watts realization rate is 99.8%.

Upstream Lighting Delta Watts



Upstream Lighting Interactive Factors



Tracking system savings do not include interactive savings; implying demand and interactive factor assumptions of 1.000.

Lighting Logger Data Leveraging

Lighting Hours of Use and Coincidence Factor by Building Type

Building Type	Upstream Hours of Use	Summer Seasonal Peak Coincidence Factor	Winter Seasonal Peak Coincidence Factor
24x7 lighting	8,760	100.0%	100.0%
Automotive	4,056	68.3%	36.9%
Education	2,967	36.8%	46.0%
Grocery	5,468	90.6%	85.6%
Health Care	5,564	82.5%	69.6%
Hotel/Motel	3,064	40.6%	37.5%
Industrial	5,793	83.0%	66.5%
Large Office	4,098	77.9%	58.2%
Other	6,211	86.9%	76.7%
Parking Lot/Streetlights	6,887	67.2%	87.3%
Religious Building/Convention Center	913	17.0%	9.2%
Restaurant	5,018	83.1%	77.0%
Retail	4,939	98.4%	85.6%
Small Office	3,748	76.8%	44.1%
Warehouse	5,667	89.3%	72.4%

This table provides the recommended PSD updates to upstream lighting hours of use and C&I lighting seasonal peak coincidence factors by business type. These values were produced in the extensive data leveraging analysis which aggregated a total of 2,699 lighting logger files; including 834 from this study and 1,865 from four recent evaluations performed in Connecticut (C9, C14, C20, and C1639). Since the site specific hours used for EO lighting tracking savings estimates were very accurate, we do not recommend these hours of use results for that program activity, though we do recommend use of the coincident factors.

RECOMMENDATIONS

The following recommendations rest upon the findings of this study and are expected to improve PSD driven claimed savings estimates and measure performance.

- The PSD should be updated with the study estimated electric energy savings realization rates and prospective gas realization rates by end use.
- The PSD should be updated to explicitly guide the use of site-specific hours of use in the tracking estimation of EO lighting savings and the coincident factors recommended from the data leveraging analysis.
- The PSD should use one of the two seasonal peak realization rates provided by end use in this report, depending on whether new protocols are established to ensure fully populated EO tracking seasonal peak estimates or if the population rate observed in this study is expected to continue.
- The PSD should be updated to calculate upstream savings by lighting category using the in-service rates, delta watts, hours of use, and interactive factors derived form this study, including the hours of use and factors recommended from the data leveraging analysis.
- The EEB should consider two actions as a result of this study. 1) A study of hours of use reduction due to lighting controls to confirm or disconfirm the qualitative results observed in this study; and 2) to use the error ratios observed in this study to estimate samples in future studies of this program.

3 INTRODUCTION

This report presents the results from the C1635 Energy Opportunities (EO) Impact evaluation of the 2016 and 2017 program years. The EO Program is the flagship C&I retrofit program offered by the companies with a 2020 goal of 114,405 MWh in savings (roughly 39% of the overall portfolio goal of 292,783 MWh)[7]. This study is important due to the high contribution of EO Program savings relative to the portfolio and the duration since the previous study of this program (2014).

Consistent with the 2019-2021 C&LM plan and evaluation roadmap guidance, this study was performed through an independent process overseen by the Energy Efficiency Board. This study provides electric and natural gas retrospective and prospective realization rates as appropriate, recommend Program Savings Document (PSD) updates to refine future energy savings estimates, and verifies peak demand savings resources participating in ISO-NE's FCM.

3.1 Study Overview, Purpose, and Objectives

This impact evaluation of the EO Program was performed on program years 2016 and 2017. The EO program supports energy efficiency retrofit measures for C&I electric and gas customers of any size. The EO program includes a channel for upstream lighting purchases though the majority of electric energy savings (~90%) in the years studied came from traditional program activity characterized by prescriptive and custom measures delivered through incentives and technical assistance (for custom).

> "EM&V guides program administrators, policy makers, and stakeholders in better understanding the extent to which program activities are successfully meeting the goals and objectives they were created to achieve."
>
> – 2019-2021 C&LM Plan Update

The purpose of the study is to understand the extent to which program performance is meeting program and policy goals and objectives, and to recommend PSD revisions to improve claimed savings estimates moving forward. This evaluation includes three overarching objectives.

1. Determine ex-post evaluated energy and seasonal peak demand savings and calculate retrospective and prospective realization rates for three electric end use groups and two gas end use groups.
2. Evaluate the upstream lighting program portion of the EO program and savings.
3. Recommend updates to the PSD realization rates and assumptions used to calculate program savings and for lighting hours of use and coincidence factors based on this study and four previous C&I impact studies. These studies include the 2014 C14 Connecticut EO evaluation, 2015 C20 Energy Conscious Blueprint, and 2014 C9 and 2017 C1639 SBEA studies.

The study performed the following activities to achieve these objectives.

1. This study developed a statistically selected sample of participants with gas and electric efficiency measures for high rigor level M&V. This included an upstream lighting sample that received metering at a subset of sites with measure verification.
2. This study performed engineering calculations to quantify ccf, kWh, and summer and winter seasonal peak kW savings as appropriate for measures installed at the sampled sites. When

[7] 2020 Plan Update to the 2019-2021 Conservation & Load Management, Submitted by: Eversource Energy, United Illuminating, Connecticut Natural Gas Corporation, and Southern Connecticut Gas, p 91.

appropriate, alternative tracking savings were calculated based on updated PSD parameters to provide prospective realization rates. All realizations rates and key findings include associated precisions. All sites have individual reports detailing data gathered, analysis performed, and discussion of differences between tracking and evaluated estimates.

3. This study compiled and analyzed its lighting logger data, hours of use, and coincident factor estimates with previous C&I Program studies performed in Connecticut and compared those results to the Massachusetts TRM at the building level and overall. Recommendations are provided to guide the incorporation of these results into the PSD.

4. This study calculated retrospective realization rates with precisions for each measure group. Prospective realization rates are provided for measures where the PSD changed savings calculations since the years studied (i.e., 2016, 2017) or where a recommendation is made to change the PSD based on this study.

5. This study calculated upstream results for key lighting savings parameters (installation rates, watt reduction, hours of use, interactive factors) for incorporation into the PSD.

6. This study coordinated with the team performing the PSD update to review findings and planned recommendations to ensure seamless use of study outcomes.

3.2 Organization of Report

The remainder of this report is organized as follows:

Section 4: Methodology and Approach

Section 5: Analysis and Results

Section 6: Conclusions, Recommendations, and Considerations

Appendix A: Seasonal Peak Periods Definition

Appendix B: Detailed Population Summaries

Appendix C: Detailed Sample Summaries

Appendix D: Metering Equipment Used

Appendix E: Site Reports (Under Separate Cover)

4 METHODOLOGY AND APPROACH

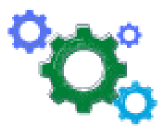
This section describes the methodologies that DNV GL used to guide data collection and analysis for this impact evaluation. Primary tasks and their associated subtasks are presented below in Figure 4-1. The key phases of the evaluation effort included development of sample plans, project documentation review, and data collection. This was followed by a measure analysis with site reporting and expansion of sample results to estimate program level impacts. The flow of the evaluation effort was generally sequential in nature, proceeding from left to right as depicted in Figure 4-1. Each stage in the figure is presented with more detail in following subsections.

Figure 4-1. Summary of Key Evaluation Methods

SAMPLE DESIGN AND SELECTION

Gather electric and gas account and measure level population data

Develop stratified sample designs by measure group and upstream lighting

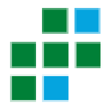


FILE REVIEWS AND M&V PLANS

Acquire files supporting savings claims for sampled sites

Perform file reviews with savings validation

Document planned M&V

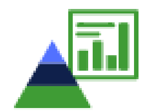


ON-SITE DATA COLLECTION

On-site recruitment

Measure verification, operating condition, meter deployment

Gather historical lighting hours of use, coincidence



SITE AND AGGREGATE SAVINGS ANALYSIS

Measure level engineering estimates of ccf, kWh, and seasonal peak demand savings

Statistical expansion of results and realization rates with precisions

4.1 Sample Design and Selection

There were two sample tasks undertaken in this study. One was of EO 2016 and 2017 activity delivered through traditional program channels. The other was of 2018 "upstream" lighting activity. Each of these is discussed in turn, including why the program years studied differed among the EO and upstream components.

4.1.1 EO 2016/2017 Sample

The first step in the EO sampling process was to acquire 2016 and 2017 program year population data from each utility. Data cleaning was performed on this data, including checks for duplicate entries between and within datasets and negative savings values that might reflect product returns, removals or savings adjustment entries. An examination of a small sample of activity was also performed to ensure the savings estimates were gross (not net). The final cleaned population was checked against expected participant and savings levels in filed company reports before developing the final sample frame.

Table 4-1 presents 2016 and 2017 EO electric activity by end use. Energy and peak demand estimates are provided as well as the number of projects that installed each end use. Lighting dominated the total energy (79%) and summer (85%) and winter (86%) seasonal peak demand savings. HVAC, process and refrigeration activity comprises another 16% of energy savings, with 5% of activity spread among the remaining end uses. Note that overall participant totals in this table is less than the number of projects listed by end use as more than one project occurred at some sites. A detailed population summary by company (Eversource and Avangrid) are provided in APPENDIX B.

Table 4-1. Summary of 2016 and 2017 EO Electric Tracking Data by End Use

End Use	# Projects (N)	Energy		Summer Seasonal Peak Demand		Winter Seasonal Peak Demand	
		Annual MWh Savings	%	kW	%	kW	%
HVAC	217	19,015	6.5%	1,935.9	5.9%	1,309.7	4.4%
Lighting	2,572	232,090	79.0%	27,889.0	85.3%	25,486.4	86.2%
Motor	75	7,223	2.5%	565.4	1.7%	554.3	1.9%
Process	54	16,487	5.6%	1,223.2	3.7%	776.6	2.6%
Refrigeration	101	12,092	4.1%	612.6	1.9%	1,143.7	3.9%
Other	99	6,936	2.4%	486.0	1.5%	312.3	1.1%
Total	**2,743**	**293,843**	**100.0%**	**32,712.1**	**100.0%**	**29,583.0**	**100.0%**

One of the goals of the sample design for the EO portion of the study was to develop three electric end-use categories. To accomplish this, we aggregated the end use savings presented in Table 4-1 into three electric categories (Lighting, HVAC, and Other[8]). The purpose of creating these categories was to refine the application and use of study outcomes in the PSD.

Table 4-2 shows the EO electric sample design using these measure categories. Model-based statistical sampling (MBSS) techniques were used to develop the sample design using an error ratio of 0.48, consistent with that observed in the last Energy Opportunity study conducted in 2013-2014[9]. Given the importance of lighting to overall program savings, sixty-five of the sample points were allocated to lighting measures, with the remainder divided evenly among the two remaining categories. These sizes offer precisions that target ±10% for lighting and at or better than ±15% for the others, with the precision around overall program savings at ±8.3%. Note that overall participant totals in these tables are less than the number of projects listed by end use as more than one project occurred at some sites. The final electric sample proportions by company (78% Eversource, 22% UI) are almost identical to the electric population proportions (79% Eversource, 21% UI). A detailed sample summary that includes strata cut points for each measure category and final cases weights is provided in APPENDIX C.

Table 4-2. Final EO Electric Sample Design

Measure Category	Population (N)	Total Annual Savings (MWh)	Sample Size	Expected Precision at 90% Confidence Interval
Lighting	2,572	232,090	65	±10.0%
HVAC	217	19,015	26	±14.8%
Other	284	42,738	26	±15.0%
Statewide	**2,743**	**293,843**	**117**	**±8.3%**

Table 4-3 presents 2016 and 2017 EO natural gas activity by end use. HVAC installations represent over half of all program savings. Process represents nearly 40% of savings. Note that overall participant totals in

[8] Other (electric) includes process, refrigeration, motor and VFD measures.

[9] C14: Evaluation of the Energy Opportunities Program: Program Year 2011, EMI Consulting, April 1, 2014, page 23, table 3-4.

this table is less than the number of projects listed by end use as more than one project occurred at some sites. A detailed population summary by company (Eversource and Avangrid) are provided in APPENDIX B.

Table 4-3. Summary of 2016 and 2017 EO Gas Tracking Data by End Use

End Use	# Projects (N)	Energy	
		Annual ccf Savings	%
DHW	14	38,964	1.0%
HVAC	156	2,159,105	54.6%
Process	26	1,554,898	39.3%
Other	43	201,213	5.1%
Total	**208**	**3,954,180**	**100.0%**

Like the electric sample design discussed above, one of the goals of the sample design was to develop two gas measure categories. To accomplish this, we aggregated the end use savings presented in Table 4-3 into two gas categories (HVAC/DHW, and Other[10]). The purpose of creating these categories was to refine the application and use of study outcomes in the PSD.

Table 4-4 provides the EO gas sample design using an error ratio of 0.60, which is consistent with those observed in similar gas studies in Massachusetts. The sample sizes yield better than ±20% precision for each of the gas categories and are comprised of 20 sites among HVAC and DHW measures and 12 for all other measure types. This approach provides more site work for those measures producing most of the program savings (HVAC and DHW). This sample of 32 sites offers a portfolio precision of ±13.6%. Note that overall participant totals in this table is less than the number of projects listed by end use as more than one project occurred at some sites. The final gas sample proportions by company (59% Eversource, 41% UI) are similar to the gas population proportions (53% Eversource, 47% UI). A detailed sample summary that includes strata cut points for each measure category and final cases weights is provided in APPENDIX C.

Table 4-4. Final EO Gas Sample Design

Measure Category	Population (N)	Total Annual Savings (ccf)	Sample Size	Expected Relative Precision at 90% Confidence Interval
HVAC/DHW	156	2,197,086	20	±18.9%
Other	76	1,757,093	12	±19.4%
Statewide	**208**	**3,954,180**	**32**	**±13.6%**

4.1.2 Upstream Lighting 2018 Sample

Table 4-5 summarizes the 2018 upstream lighting tracking data by lighting categories that are consistent with those used in Massachusetts for upstream lighting evaluations. Note that returns of purchases made in 2018 were netted out of this summary. In addition, returns from purchases made in previous years were removed from the population. Categories 1, 3, 4 and 7 account for over 97% of the savings. Note that overall participant totals in this table is less than the number of projects listed by category as products from more than one category were received by some sites.

[10] Other (gas) includes steam trap, demand control ventilation, discharge air reset, and energy management system measures.

Table 4-5. Summary of 2018 Upstream Lighting Tracking Data

MA Upstream Lighting Category	Lighting Category Description	# Accounts (N)	Annual MWh Savings	% of Total MWh
Category 1	Linear LEDs	2,800	15,308	47.5%
Category 2	LED Stairwell Kits	8	23	0.1%
Category 3	LED Downlights	1,157	4,855	15.1%
Category 4	LED A-line/Deco	493	3,161	9.8%
Category 5	GU24 LEDs	92	357	1.1%
Category 6	LED Exterior Wall Packs	161	340	1.1%
Category 7	High/Low Bay LEDs	467	8,035	25.0%
N/A	Linear Fluorescents	96	116	0.4%
	Total	**4, 272**	**32,195**	**100%**

Unlike the EO samples, which were drawn from 2016 and 2017 program years, it was decided to evaluate the upstream lighting 2018 program year as the lighting measure mix underwent several changes, a new implementation vendor was hired for the 2018 program year, and program procedures were introduced to ensure measure installation after purchase. Product changes included discontinuing fluorescent products and introducing new LED products; including LED troffers, high bay fixtures, and exterior products. Increases in inspection rigor implemented in 2018 were undertaken to ensure in-service rates reflected these new processes.

Table 4-6 shows the upstream lighting sample design using an error ratio of 0.90, which is consistent with the ratio observed in the first Massachusetts upstream lighting study and within the range of measure level ratios observed in the second Massachusetts study (0.71 - 1.33). This table only focuses on the four measure categories that represent over 97% of program savings, as noted above. The error ratio and subsampling focus on kWh were informed by the last comprehensive impact evaluation of Massachusetts' C&I Upstream Lighting program[11], which focused on data collection to inform component parameters (delta watts, HOU, HVAC interaction, in-service rate or ISR) rather than a more expensive monitoring study to collect HOU for all sites. The sample design in this study was designed to perform 95 sites (where in-service rates, delta watts, and HVAC interaction were gathered) that targeted a precision of ±17.4% around demand savings and hours of use metering performed at a subset of those sites (36) that targeted a precision of ±28.7% around kWh.

This approach collected data on component savings parameters for all sites, while only monitoring a subset of sites to update hours of use assumptions. Our experience with upstream lighting evaluations in Massachusetts is that installation rates present the greatest uncertainty around savings estimates and should be a primary focus of research to ensure claimed savings accuracy. Although each site is selected into the sample for a given lighting category, other lighting categories and products present at the site were audited as part of each site visit, but not included in the expansion of results to the population (i.e., they carry a weight of one).

Ultimately, 88 total visits (where in-service rates, delta watts, and HVAC interaction were gathered); including 25 HOU visits were performed due to the cancellation of field work caused by the COVID-19

[11] Impact Evaluation of PY2015 Massachusetts Commercial and Industrial Upstream Lighting Initiative, November 22, 2017. (http://ma-eeac.org/wordpress/wp-content/uploads/Upstream-Lighting-Initiative-Impact-Evaluation-PY2015.pdf)

pandemic. Due to the reduction in HOU visits, the logger data from these 25 sites was integrated with the logger data from the data leveraging effort discussed later to provide evaluation HOU for upstream lighting, which improved the rigor and precision around these results. Note that overall participant totals in this table is less than the number of projects listed by category as products from more than one category were received by some sites. The final upstream lighting sample proportions by company (98% Eversource, 2% UI) are similar to the upstream lighting population proportions (91% Eversource, 9% UI). It is important to mention that UI suspended the operation of their Upstream lighting program from August 2018 through December 2018 due to budget restrictions.

Table 4-6. Upstream Lighting Sample Design

Measure Category	Population (N)	kW		kWh	
		Design kW/ISR Sample	Final kW/ISR Sample	Design kWh Sample	Final kWh Sample
Cat 1 LED Linear	2,792	46	42	17	13
Cat 3 LED Downlights	1,152	15	14	6	4
Cat 4 LED A-line/Deco	491	10	8	4	2
Cat 7 LED High/Low Bay	467	24	24	9	6
Statewide	**4, 272**	**95**	**88**	**36**	**25**

4.1.3 Recruitment Disposition

The final response and refusal rates experienced for each of the three studies are provided in Table 4-7 below. Examining final dispositions of a sample in this way can help assess whether it might have non-response error and why. All unsuccessfully recruited sites were found to be in business at the time of outreach, meaning closed businesses were not observed in the primary or backup samples contacted.

The response rate calculated in the table below includes all customers that were in business and refused the on-site or were in business and were unable to be reached (non-contact). In developing this table, we have remained consistent with American Association for Public Opinion Research (AAPOR) definitions and calculation of Response and Refusal Rates[12]. The response and refusal rates for all three evaluation efforts are comparable to those from similar recently performed studies[13].

[12] https://www.aapor.org/Standards-Ethics/Standard-Definitions-(1).aspx
[13] Most recent MA C&I Custom Electric Study experienced a response rate of 70.8% and a refusal rate of 3.1% (http://ma-eeac.org/wordpress/wp-content/uploads/MA_CIEC_Stage5_Report_C07_Custom_Electric_Impact_Evaluation_PY2017_18_FINAL-2020-06-01.pdf). Most recent MA C&I Custom Gas Study experienced a response rate of 77.5% and a refusal rate of 2.5% (http://ma-eeac.org/wordpress/wp-content/uploads/MA19C05-G-CUSTGAS_PY-2017-Custom-Gas-Report_Final_2020.03.16.pdf). Most recent MA Small Business Study experienced a response rate of 42.9% and a refusal rate of 21.4% (http://ma-eeac.org/wordpress/wp-content/uploads/Final-Report-MA19C03-E-SBIMPCT-03202020.pdf).

Table 4-7. Final On-site Recruitment Response and Refusal Rates

Disposition description	EO Electric	EO Gas	Upstream Lighting	Overall
Complete	117	32	88	237
Refused – In business	9	0	20	29
Non-contact - In business	31	11	25	67
Total Contacts	157	43	133	333
Response Rate 1	74.5%	74.4%	66.2%	71.2%
Refusal Rate 1	5.7%	0.0%	15.0%	8.7%

4.2 Review Project Documents and Draft M&V Plans

Prior to data collection, the DNV GL team acquired detailed files for the sampled sites from the companies. The site engineers reviewed the project paperwork and conducted an initial assessment of the types and scope of measures installed. Using this project file information, project engineers performed preliminary recruitment to customer site contacts. During this initial outreach, the engineers discussed the purpose of the effort, the scope of measures installed, the availability of on-site trend data, and any other applicable parameters relevant to the evaluation. They also confirmed that the site contact would allow the visit. The M&V planning effort did not commence until the customer site contact indicated they would accommodate the on-site evaluation process. As noted earlier, backup site selection was needed to replace sites that refused a visit or that did not respond to recruitment efforts.

The study developed detailed site-specific M&V plans for all sites that went through the initial file review process and received preliminary approval for the M&V visit. These plans were submitted to the EA Consultant for comment and approval. Each site plan included the following:

Project description – A description of project type and measures implemented, along with how the project saves energy

Tracking savings – A short description of how the tracking savings were originally estimated, including:

- Analysis method used
- Key baseline assumptions
- Key proposed assumptions
- Evaluator assessment of tracking savings methods or assumptions

Project evaluation – A short description of the methods planned to evaluate the project, including but not limited to:

- How measure installation and current operation would be verified
- How building use and occupancy would be observed and/or assessed
- Identification of the tracking and expected evaluator baseline by measure
- The data to be collected by the DNV GL team, including any meter sampling planned within a site
- Any data available and expected to be provided by the site (e.g., EMS trends, production, pre-metering, etc.)
- The evaluation analysis method planned. In general, the study sought to use the same methodology used to estimate tracking savings to estimate evaluated savings.

- Key parameters gathered through the evaluation compared to those used in the original savings estimate

Planned data collection encompassed a variety of methods, including physical inspection and inventory, spot power measurements, interview with facility personnel, observation of site operating conditions and equipment, short-term metering of operation and power usage or other variables (such as temperature) that affect usage or runtime, and as EMS trend data. Senior engineers reviewed each M&V plan prior to their submission.

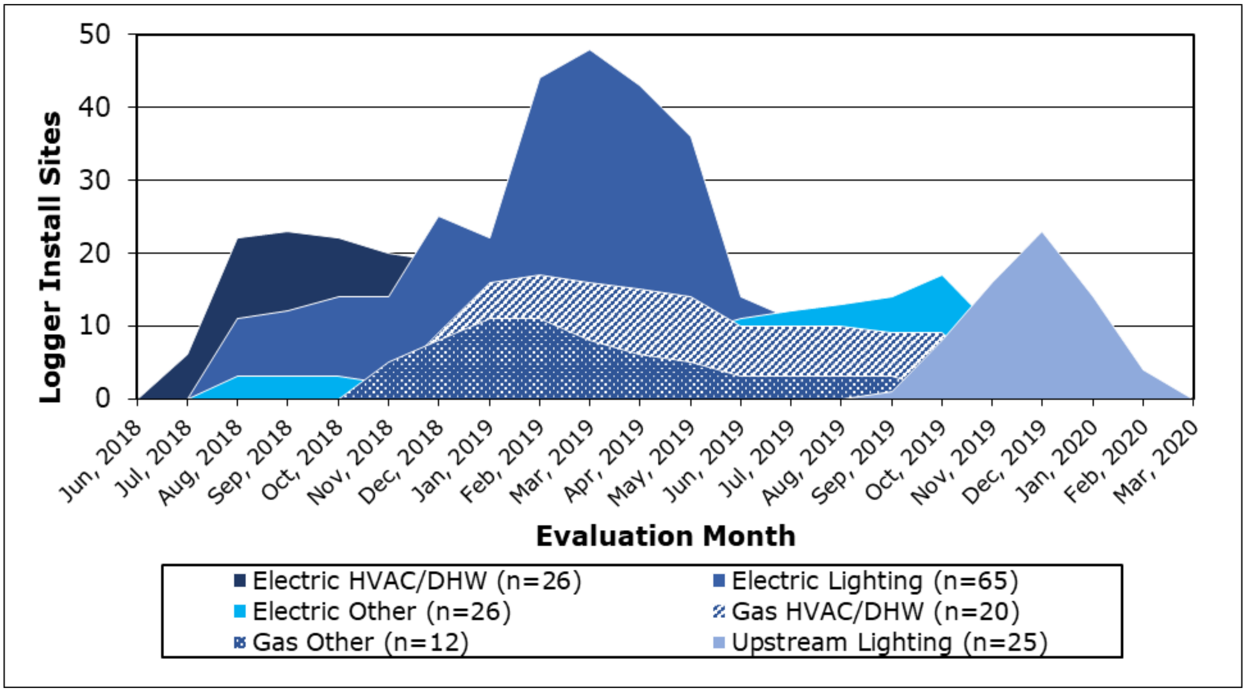
4.3 Data Collection

At each successfully recruited site, engineers performed data collection and meter deployment as guided by the M&V plan. In general, each site visit consisted of the verification of installed equipment, a discussion with facility personnel regarding the baseline (e.g., pre-existing) characteristics of the measure, the installation of measurement equipment, the collection of available trend data, and the installation of metering equipment. While not explicitly focused on in this evaluation, the vast majority of the projects in the sample were retrofit projects. There were a few projects that were replace on failure (ROF) projects, but they were isolated incidents.

Site visits were scheduled to acquire metering data for a range of temperatures for HVAC and other equipment that are temperature dependent. For example, cooling HVAC equipment was examined and metered in the summer months with some shoulder month activity; some monitoring was extended into early winter to gather heating season use. EO HVAC sites were metered for an average of over seven months, EO Lighting and Other sites for an average of five months, and Upstream lighting sites for an average of over 2.5 months.

Figure 4-2 presents the number of sites with metering in place by month for each sampling category and demonstrates the seasonal distribution of the metering period for weather-sensitive measures. Electric HVAC site metering occurred during the summer months and gas HVAC site metering occurred during the winter months to capture performance of equipment during the appropriate season. It is important to note that the foreground curves in the figure mask the background curves. For instance, meters at Electric Other sites were in place between October 2018 and June 2019, but the Gas HVAC/DHW and Gas Other curves during this period hide that information.

Figure 4-2. Sites Metered by Month and Sampling Category



4.3.1 Metering Equipment Used

A summary of the metering devices used in this study is provided in APPENDIX D. This includes equipment used to monitor electric equipment, operating hours, proxy gas operation, and other dimensions needed to quantify the impacts of installed measures (e.g. temperature, humidity, etc.).

Each metering device used in this study receives routine battery checks and synchronization performed before being deployed and has documentation noting when, where, and how long each was installed. Site reports, provided as an appendix to this report under a separate cover, contains metering details for each site, including summaries of the data gathered and how the information was used to calculate energy savings seasonal peak use.

4.4 Savings Analysis

There were three savings values calculated for each site in this study. These include energy savings (kWh for electric and ccf for gas) and summer and winter seasonal peak demand savings (kW). employed, including analysis results.

Figure 4-3 presents the major measure categories that were evaluated in this evaluation, the metering equipment typically deployed to capture operation, and the key gross savings inputs gathered as either part of the metering or the onsite audit itself. Sites reports provided as an appendix contain the detailed measure level data collection, metering, and savings methods employed, including analysis results. It is important to note that lighting controls were evaluated as part of this study but the sample of evaluated projects with lighting controls was not large enough (n=13) to provide a rigorous statistical sample.

Figure 4-3. Technology Metering and Data Collection

Fuel/Major Measure Categories	General Evaluation Approach/Metering	Key Savings Input(s)
Lighting	Lighting TOU loggers, EMS, time clock, or True RMS Power Loggers	Wattage (controlled), hours of use, HVAC types (for interactive), non sensor baseline
Compressed air (e.g., efficient compressor, cycling dryer, zero loss drains	Ultrasonic Meter True RMS Power Loggers, time-of-use loggers, instantaneous power	Size (capacity), pressure, size of leak, kW/CFM, storage, controls, dryer
Variable frequency drives	True RMS Power Loggers, Panel Data	Operating profile, weather, production or schedule dependent
Chillers, unitary and split system HVAC	True RMS Power Loggers, temperature loggers, EMS data	Spot measurements, size (capacity), efficiency, operating parameters, weather
Motors	True RMS Power Loggers, TOU Loggers, Instantaneous power	kW, horsepower, operating hours
Refrigeration (e.g., ECM, motor controls, anti-condensate, night covers, mizers)	True RMS Power Loggers, time-of-use loggers, instantaneous power, temperature loggers, humidity loggers	Motor HP, heater kW, True RMS Power, schedules, case temperatures, space temperature/humidity, refrigeration efficiency
Gas Pipe and Blanket Insulation	Distance measurements, Combustion analyzer, Temperature loggers	Treated area size, insulation thickness, system efficiency, operating temperature, weather, supply/return water temperature
Gas Steam Traps	Ultrasonic Meter, Combustion analyzer, Temperature loggers	Pressure, leak rate, functionality, operating temperature and hours, system efficiency

As part of reporting any changes in EO lighting savings from the tracking system estimate, the team used adjustment factors consistently across the sample to identify the cause of savings changes. These factors and their descriptions are provided in Figure 4-4 below and are used in the reporting of the evaluated lighting savings later in this report. These savings adjustments include out-of-business observations, administrative efforts, measure screening-related changes, and adjustments made based on on-site observations about the performance of installed equipment.

Figure 4-4. EO Lighting Savings Discrepancy Factors Discrepancy Factors

Adjustment Factor	Description
Documentation	Tracking savings were recalculated using all quantities, fixture types/wattages, and hours documented in the project file. Discrepancies and documentation errors are reflected in this adjustment.
Technology	Changes due to the identification of a different technology (fixture type and wattage) at the site than in the program data
Quantity	Changes due to the identification of a different quantity of lighting measures installed at the site than in the program data.
Operational	Changes due to the monitoring of different lighting operating hours at the site than assumed in the program data.
Interactive	Changes due to differences in savings caused by the interaction between lighting fixtures and the electric HVAC systems in the building versus the interactive savings assumptions in the program data.

4.4.1 Seasonal Peak Savings

This study calculated demand impacts in summer and winter seasonal peak periods as defined by ISO New England. Seasonal demand performance hours are defined as hours when the real-time ISO-NE system load meets or exceeds 90% of the predicted Seasonal Peak from the most recent Capacity, Electricity, Load and Transmission (CELT) report. The study calculated the hours of interest as described in APPENDIX A. Based on those methods, the 2018 seasonal peak summer and winter hours are provided in Table 4-8 and Table 4-9 below.

Table 4-8. 2018 Summer Seasonal Peak Hours

Date	Hour Ending	Date	Hour Ending	Date	Hour Ending
7/10/2018	14	7/13/2018	15	7/25/2018	16
7/10/2018	15	7/24/2018	13	7/25/2018	17
7/11/2018	13	7/24/2018	14	7/25/2018	18
7/11/2018	14	7/24/2018	15	8/6/2018	13
7/11/2018	15	7/24/2018	16	8/6/2018	14
7/11/2018	17	7/24/2018	17	8/6/2018	15
7/12/2018	13	7/25/2018	13	8/6/2018	16
7/12/2018	14	7/25/2018	14	8/6/2018	17
7/12/2018	15	7/25/2018	15	8/6/2018	18

Table 4-9. 2018 Winter Seasonal Peak Hours

Date	Hour Ending	Date	Hour Ending	Date	Hour Ending	Date	Hour Ending
1/4/2018	8	1/30/2018	21	1/31/2018	22	12/14/2018	8
1/24/2018	21	1/30/2018	22	12/11/2018	8	12/14/2018	9
1/24/2018	22	1/31/2018	8	12/13/2018	8	12/14/2018	10
1/25/2018	8	1/31/2018	9	12/13/2018	9	12/14/2018	11
1/30/2018	8	1/31/2018	10	12/13/2018	10	12/14/2018	18
1/30/2018	9	1/31/2018	11	12/13/2018	11	12/14/2018	19
1/30/2018	10	1/31/2018	18	12/13/2018	19	12/14/2018	20
1/30/2018	18	1/31/2018	19	12/13/2018	20	12/14/2018	21
1/30/2018	19	1/31/2018	20	12/13/2018	21	12/14/2018	22
1/30/2018	20	1/31/2018	21	12/13/2018	22	12/21/2018	8

4.4.2 PSD Review and Prospective Savings

One important element of this study was to provide retrospective and, as necessary, prospective realization rates. The need for a prospective realization rate that is different from a retrospective rate is triggered by changes in the PSD savings calculations between the evaluation program years (2016 and 2017) and the current program year (2020). When there are no changes in savings methods or assumptions the two realization rates are the same. When the savings method or assumptions change, the prospective realization rate uses the relationship between the evaluation savings estimates to what the tracking system savings estimates would have been for each site in the sample if this evaluation was based on the current 2020 program activity.

The assessment of the need for a prospective realization rate begins with the examination of PSD changes between the evaluation program years and the current PSD. This study went through all C&I retrofit measures in the PSD during this period and captured all changes in savings methods or assumptions observed. Many efficiency measures did not change savings methods during this period[14]. Those that did change are summarized below. Whenever a measure was in the study sample and a change occurred, a new

[14] lighting, pipe insulation, duct insulation and sealing, setback thermostats, small business blower door, RTU speed control, kitchen hoods, custom measures, refrigeration night covers, evaporator fan motor replacement, refrigeration door heater controls and refrigeration case doors.

tracking savings was estimated to derive a prospective realization rate. In these instances, retrospective and prospective realization rate are provided. Otherwise, a single realization rate is offered for application.

- **2017 PSD**: The 2017 PSD added a fan motor load factor assumption to the rooftop unit (RTU) variable frequency drive (VFD) savings calculation. One 2016 RTU VFD project is in the sample and it used a custom savings calculation. This PSD change has no effect on prospective savings.
- **2018 PSD**: Updated the steam trap loss adjustment factors for leaking and failed traps. Two steam trap projects are in the sample and both used the updated factors. This PSD change has no effect on prospective savings.
- **2018 PSD**: Updated energy savings factor for refrigerated beverage vending machines and glass front refrigerated cooler controls. There are no vending machine control sites are in the sample. This PSD change has no effect on prospective savings.
- **2019 PSD**: Updated showerhead savings assumption (ccf saved/unit). Two showerhead sites are in the sample and neither used the updated savings assumption. This PSD change does affect gas HVAC/DHW prospective savings.

4.4.3 Lighting Logger Data Leveraging

Another important element of this study involved the use of lighting logger data from the current study, the last two CT Small Business Energy Advantage (SBEA) studies[15] (C1639 and C9), the most recent CT Energy Conscious Blueprint (ECB) study[16] (C20), and the previous CT EO study[17] (C14) to update PSD savings input assumptions.

Table 4-10 provides the site and lighting logger sample sizes based on the data collected. Overall, data from 266 sites and nearly 2,700 loggers (including 834 loggers from this study) installed for an average of three months was used. The logger data was analyzed and weighted by connected kW to provide updates to the annual hours of use and seasonal peak coincidence factor assumptions provided in the PSD by building type. The consultant does not believe there are any reasons to think that differences in project type (i.e., new construction, lost opportunity) would affect the hours of operation at a particular business. While differences may exist by business type (i.e., small, large), the results are weighted by connected kW and are heavily influenced by the logger data from the large C&I evaluation sites.

Table 4-10. Lighting Logger Data Leveraging Sample

Lighting Logger Data Leveraging	Current CT EO Study	Current CT Upstream Study	2014 CT SBEA Study	2014 CT EO & 2015 CT ECB Studies	2018 CT SBEA Study	Totals
Lighting Sites in Sample	65	25	42	80	54	266
Lighting Loggers Installed	755	79	370	1,223	272	2,699
Lighting Loggers/Site	11.6	3.2	8.8	15.3	5.0	10.1
Average Lighting Logger Duration (months)	4.6	2.7	5.6	1.0	2.0	3.0

[15] C1639: Impact Evaluation of the Connecticut Small Business Energy Advantage (SBEA) Program, 3/20/2018, Energy Resource Solutions (ERS) and C9: Impact Evaluation of the Connecticut Small Business Energy Advantage (SBEA) Program, April 2014, KEMA Inc.

[16] C20 Impact Evaluation of Energy Conscious Blueprint Program Years 2012-2013, 11/6/2015, EMI Consulting.

[17] C14: Evaluation of the Energy Opportunities Program: Program Year 2011, 4/1/2014, EMI Consulting.

5 ANALYSIS AND RESULTS

There are four subsections in this part of the report. They are results for EO electric, EO gas, upstream lighting, and PSD updates. These sections include scatter plots, realization rates, and impact estimates with precisions where appropriate.

5.1 EO Electric

As noted earlier, there are three EO electric measure categories that were examined in this study: lighting, HVAC, and other. Upstream lighting results are provided later in this report. The key energy savings results for each is presented in Table 5-1. Lighting and HVAC energy results have near 100% realization rates although the precision around the HVAC result is notably poorer at ±35%. The Other measure category experienced a lower realization rate of 67.6%. Details around these findings and their drivers are discussed below, in addition to summer and winter peak savings results.

Table 5-1. Summary of EO Electric Energy Results

Measure Category	Tracking Annual Energy Savings (MWh)	Evaluation Annual Energy Savings (MWh)	Realization Rate	Precision at 90% CI
Lighting	232,090	227,271	97.9%	±8.1%
HVAC	19,015	19,423	102.1%	±35.0%
Other	42,738	28,910	67.6%	±14.6%
Statewide	**293,843**	**275,604**	**93.8%**	**±7.3%**

As noted earlier, every sample point in each measure category received its own estimate of kWh and seasonal peak impacts. We compare the site level tracking versus evaluated sample results in scatterplots by measure category and savings dimension (energy, summer seasonal peak, winter seasonal peak) and provide savings estimates, realization rates and precisions below. The weighted sample results in these scatterplots produce the realization rates presented in Table 5-1.

5.1.1 Lighting

Figure 5-1 compares the tracking and evaluated annual energy savings for sites in the lighting sample (n=65). The diagonal dashed line indicates where each sample point would have plotted had the tracking estimates been 100% accurate. Note that there was one very large site in the sample in the upper right corner that was nearly 5 times the size of the next largest site. Refocusing this scatterplot on sites with tracking values less than 2,000 MWh shows most sample points trending near the dashed reference line, producing a gross realization rate of 97.9% with a precision of ±8.1% at the 90% confidence interval.

Figure 5-1. EO Electric Lighting Annual Energy Savings Scatterplot

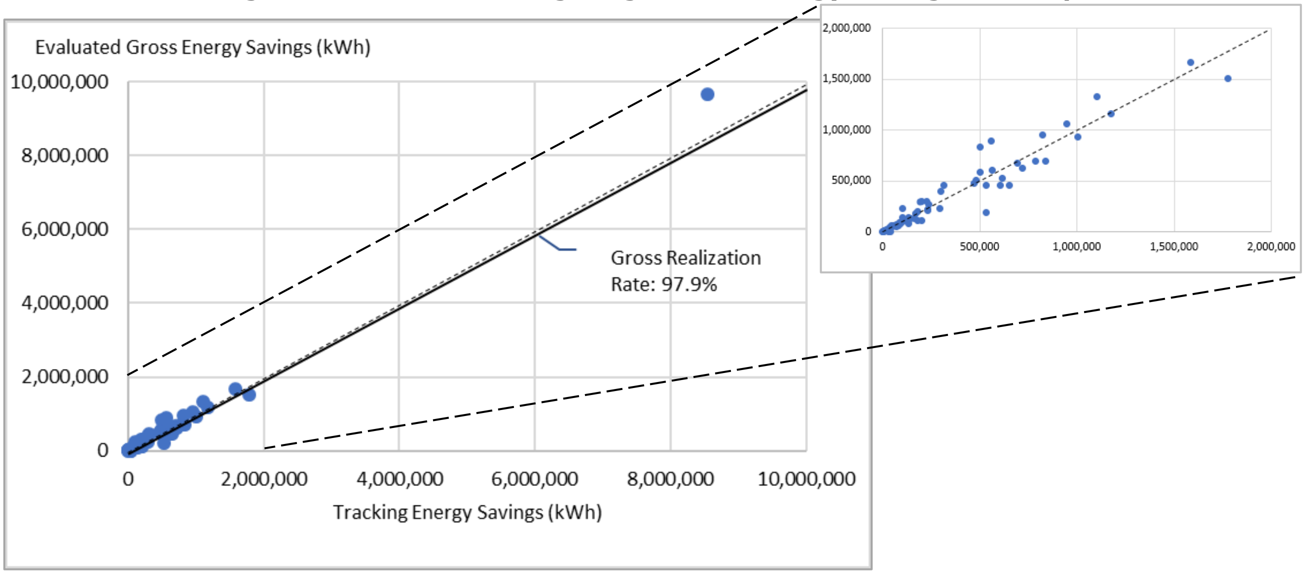


Figure 5-2 and Figure 5-3 show the relationship between the tracking and evaluated estimates of summer and winter peak demand savings in the lighting sample. The trending of these points in both summer and winter figures presents more variation around the 1:1 dashed reference line than the energy savings illustration above. This is due to an increased sensitivity in results from the narrowing of the performance period from a full year of operation (in the energy savings scatterplot) to a series of select hours of interest. This study estimates a seasonal summer peak savings of 27,588 kW with a realization rate of 98.9% and precision of ±10.6% at the 80% confidence interval. The winter seasonal peak savings estimate is 29,383 kW with a realization rate of 115.3% and precision of 7.6% at the 80% confidence interval. These results are further summarized below.

Figure 5-2. Lighting Summer Seasonal Peak kW Results Scatterplot

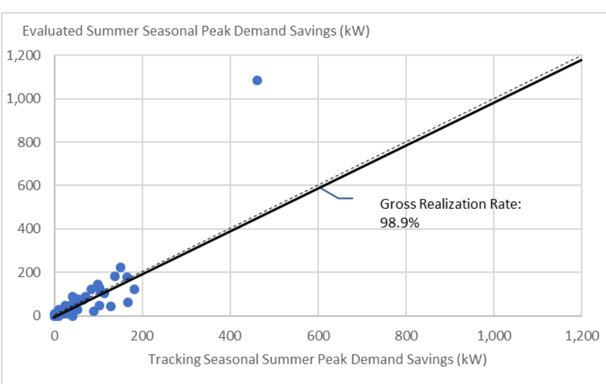
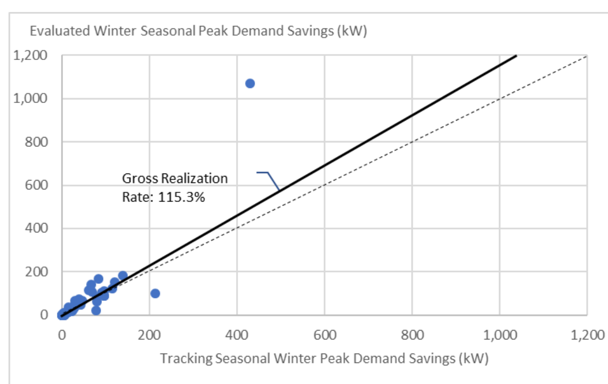


Figure 5-3. Lighting Winter Seasonal Peak kW Results Scatterplot



As noted earlier, lighting represents nearly 80% of program savings in the years examined. To examine this important program offering, Table 5-2 shows the influence of following adjustments made to develop the evaluated savings from the tracking estimate. It is important to note that the order in which these adjustments are provided matters since a site can have multiple adjustments. The realization rate in each row is the cumulative realization rate all adjustments made to that point (i.e., the technology realization rate includes both the documentation adjustment and the technology adjustment.

- **Documentation:** Tracking savings were recalculated using all quantities, fixture types/wattages, and hours documented in the project file. All tracking system discrepancies and documentation errors are reflected in this adjustment. For example, an error in the tracking system for one site caused savings to be entered that were 60% higher than was actually the case.
- **Technology:** Changes due to the identification of a different lighting technology (fixture type and wattage) at the site than in the program data system; provided that this technology was rebated by the program. For example, at one site, many of the program fixture wattages were found to be different than reported in the site documentation.
- **Quantity:** Changes due to the identification of a different quantity of lighting fixtures installed at the site than in the program data system. For example, at one site, none of the program fixtures were found to be installed and operating at the time of the site visit. The site contact at this site reported that the fixtures were received "a while ago" but was not sure when they would be installed.
- **Operational:** Changes due to the observation or monitoring of different lighting operating hours at the site than in the program tracking system. For example, lighting loggers at one site revealed that the program fixtures operated 4,308 hours per year, while the tracking system savings assumed that these fixtures operated 2,500 hours per year.
- **Interactive:** Changes due to interaction between lighting fixtures and the electric HVAC systems in the building. For example, the tracking system savings estimate at one site did not include interactive savings, but the program fixtures were found to be installed in a space served by a packaged DX cooling system.

It is clear that the information used to derive the EO lighting savings values are producing very stable estimates as evidenced by high realization rates among the various parameters studied (all in the 90% range).

Table 5-2: EO Lighting Savings Adjustments

Adjustment	Savings (kWh)	Change (kWh)	Realization Rate
Tracking System	232,090	N/A	N/A
Documentation	228,261	-3,829	98.4%
Technology	229,288	1,027	98.8%
Quantity	217,709	-11,579	93.8%
Operational	224,566	6,858	96.8%
Interactive	227,271	2,705	97.9%

Table 5-3 summarizes the EO lighting savings results. The energy and summer seasonal peak realization rates are both near 100% at 97.9% and 98.9%, respectively. The winter seasonal peak realization rate is moderately higher at 115.3%. Precisions around these estimates are all fairly tight at ±8.1% around energy at the 90% confidence interval and ±10.6% and ±7.6% around the summer and winter seasonal peaks at the 80% confidence interval.

Table 5-3. Lighting Savings Summary

Category	Tracking Savings	Evaluation Savings	Realization Rate	Relative Precision
Energy (MWh)	232,090	227,271	97.9%	±8.1%*
Summer Seasonal Peak (kW)	27,889	27,588	98.9%	±10.6%Ŧ
Winter Seasonal Peak (kW)	25,487	29,383	115.3%	±7.6%Ŧ

* 90% Confidence Interval Ŧ 80% Confidence Interval

5.1.2 HVAC

Figure compares the tracking and evaluated annual energy savings for sites in the electric HVAC measure category sample (n=26). As before, the diagonal dashed line provides a reference to illustrate differences between site level evaluated savings and their tracking counterpart. There were several sample points with savings either substantially higher or lower than their tracking estimate, which contributed to a higher precision rate for this measure category than seen above for lighting. This is most clearly seen when comparing performance in the focused pull out graphics where there is greater dispersion evident along the HVAC reference line than that seen in lighting. The final HVAC overall realization rate was just over 102% with a precision of ±35% at the 90% confidence interval.

Figure 5-4. EO Electric HVAC Annual Energy Savings Scatterplot

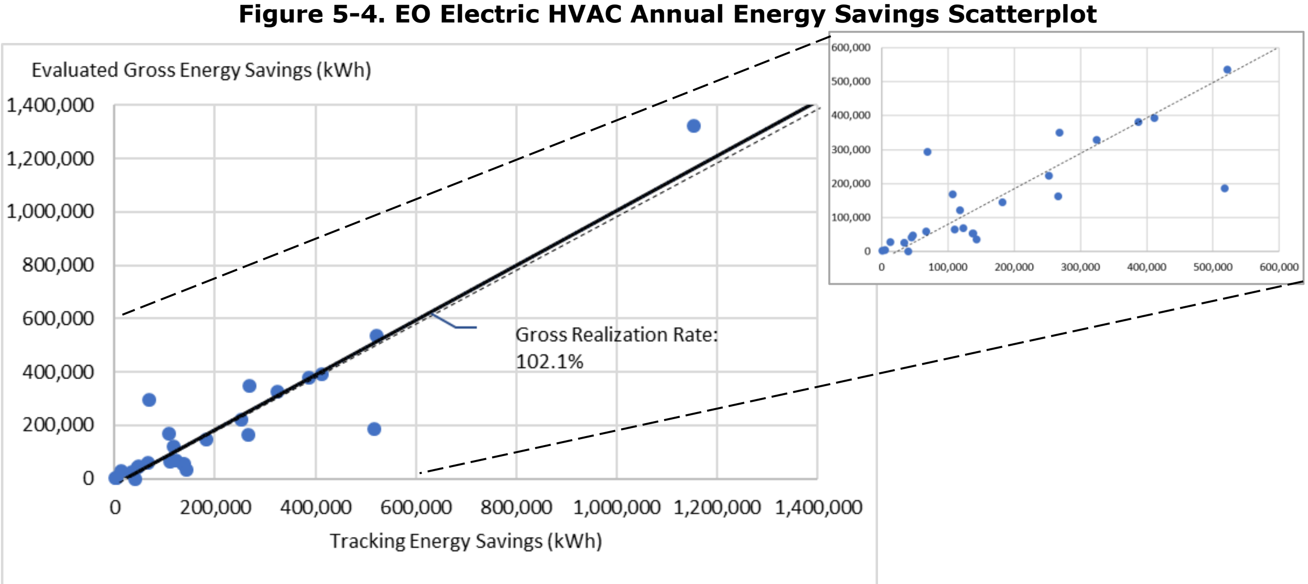


Figure 5-5 and Figure 5-6 show the relationship between the tracking and evaluated estimates of summer and winter peak demand savings in the HVAC sample. The realization rates accompanying these results are both well above 100%, with summer seasonal peak demand at 192.5% and winter seasonal peak demand at 146.2%. Precisions at the 80% confidence interval around the summer and winter realization rates are ±44.6% and ±31.7%, respectively.

Figure 5-5. HVAC Summer Seasonal Peak kW Results Scatterplot

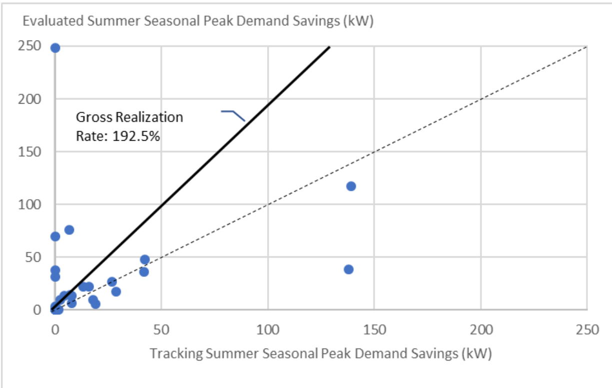
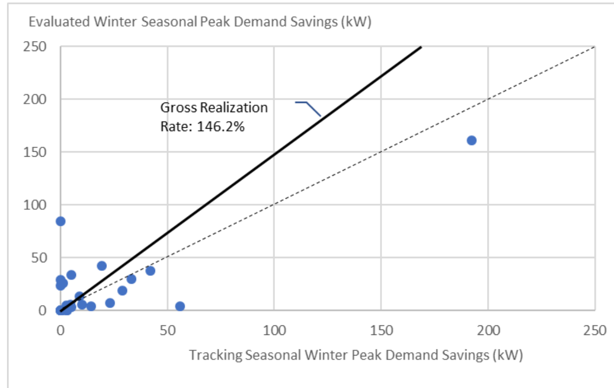


Figure 5-6. HVAC Winter Seasonal Peak kW Results Scatterplot



The key issue of note is that peak demand tracking savings are not being consistently estimated for all measures in this category, as evidenced in the vertical line of sites with zero savings on the Y-axis but not on the X-axis. There are six sites without summer seasonal peak demand tracking estimates that had evaluation savings, four of which also did not have winter seasonal peak demand tracking estimates that had evaluated savings. The measures installed at these sites included one site with setback thermostats, two with VFDs and three with EMSs.

The absence of seasonal summer and winter peak estimates in the tracking system for measures that are expected to have impacts (and, in fact, were credited with impacts in the evaluation), jeopardizes the applicability of these realization rates to future program years. Specifically, the future application risk is this realization rate will artificially increase claimed seasonal peak impacts if these tracking savings estimates are more fully populated in future years. To explore this further, this study developed alternative HVAC seasonal summer and winter realization rates by removing the sites with evaluated savings absent tracking savings. These results provide realization rates of 146.4% for summer seasonal peak (±47.0% at the 80% confidence interval), and a realization rate of 125.0% for winter seasonal peak (±31.1% at the 80% confidence interval).

Table 5-4 summarizes the HVAC savings results. The energy realization rate is near 100% with relative precision of ±35.0% at the 90% confidence interval. While this precision is poorer than expected, this study recommends the use of this realization rate for reasons discussed later in this report. The summer and winter seasonal peak realization rates are notably higher at 192.5% ±44.6% at the 80% confidence interval and 146.2% ±31.7% at the 80% confidence interval, respectively.

Table 5-4. HVAC Savings Summary

Category	Tracking Savings	Evaluation Savings	Realization Rate	Relative Precision
Zero Seasonal Peak Savings Sites Included				
Energy (MWh)	19,015	19,423	102.1%	±35.0%*
Summer Seasonal Peak (kW)	1,936	3,727	192.5%	±44.6%Ŧ
Winter Seasonal Peak (kW)	1,310	1,916	146.2%	±31.7%Ŧ
Zero Seasonal Peak Savings Sites Removed				
Energy (MWh)	19,015	19,423	102.1%	±35.0%*
Summer Seasonal Peak (kW)	1,936	2,834	146.4%	±47.0%Ŧ
Winter Seasonal Peak (kW)	1,310	1,638	125.0%	±31.1%Ŧ

* 90% Confidence Interval Ŧ 80% Confidence Interval

5.1.3 Other[18]

Figure 5-7 compares the tracking and evaluated annual energy savings for sites in the Other sample (n=26). The diagonal dashed line indicates where each sample point would have plotted had the tracking estimates been 100% accurate. This sample produces a gross realization rate of 67.6% with a precision of ±14.6% at the 90% confidence interval. The two largest sites (shown in red) greatly influenced these results as each site had a realization rate below 50%. The largest discrepancy for each of these sites is due to incorrect assumptions in the tracking baseline conditions.

The largest site (rightmost red point) had an evaluated energy savings estimate roughly 51% lower than its tracking counterpart. The tracking calculations assumed that in the baseline, a few pumps did not have VFDs, but the contractor who designed the project, informed us that those specific pumps already had VFDs prior to them completing any of their work. The second project involved VFD retrofits on a chiller plant where there were inconsistencies between the tracking baseline conditions and what was observed in the baseline trend data. This reduced the project's energy savings by 54% from the tracking estimate.

[18] Includes motor (i.e., VFDs), process (i.e., compressed air), refrigeration (i.e., door heater controls), and other (i.e., PC power management) measures.

Figure 5-7. EO Electric Other Annual Energy Savings Scatterplot

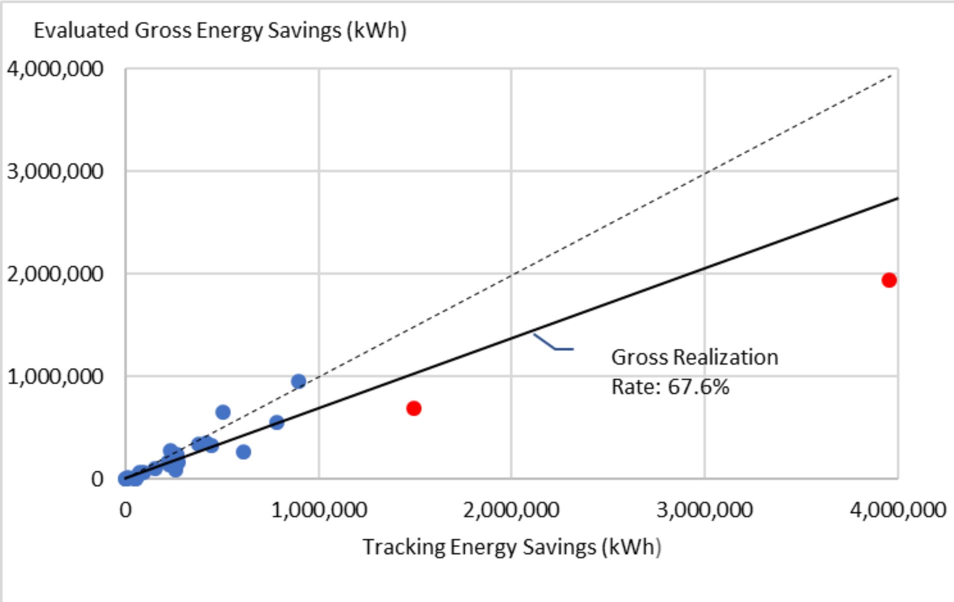


Figure 5-8 and Figure 5-9 show the relationship between the tracking and evaluated estimates of summer and winter peak demand savings in the other sample. This study estimates a seasonal summer peak savings of 3,578 kW with a realization rate of 123.9% and precision of ±15.4% at the 80% confidence interval. The winter seasonal peak savings estimate is 5,010 kW with a realization rate of 179.8% and precision of ±19.6% at the 80% confidence interval. These results are further summarized below.

Figure 5-8. Other Summer Seasonal Peak kW Results Scatterplot

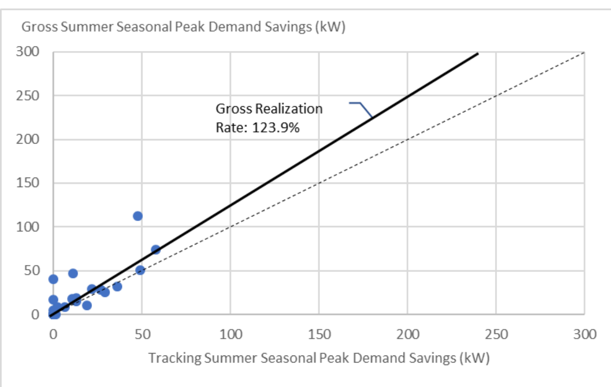
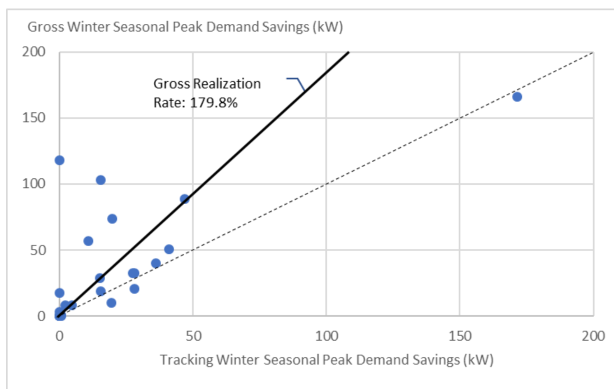


Figure 5-9. Other Winter Seasonal Peak kW Results Scatterplot



As was the case with the electric HVAC/DHW peak results, the key trend of note is that the Other seasonal peak demand tracking savings are not being consistently estimated for all measures, as evidenced in the vertical line of sites with savings on the Y-axis but not on the X-axis. There are three sites without summer or winter seasonal peak demand tracking estimates that had evaluation savings. The measures installed at these sites included one site with compressor leak repair and solenoid air valves, one with VFDs and one with VFDs, chiller plant optimization, and compressor air dryer controls.

Like the HVAC results above, this absence of the tracking system estimates for measures that are expected to have impacts (and, in fact, were credited with impacts in the evaluation) carries a risk of artificially increasing claimed seasonal peak impacts if these tracking savings estimates were to become more fully populated. To explore this further, alternative Other seasonal summer and winter realization rates were developed by removing the sites with evaluated savings absent tracking savings. These results provide realization rates of 114.7% for summer seasonal peak (±16.4% at the 80% confidence interval), and a realization rate of 162.1% for winter seasonal peak (±17.2% at the 80% confidence interval).

Table 5-5 summarizes the EO Electric Other savings results. The energy realization rate is 67.6%, while the summer and winter seasonal peak realization rates are much higher at 123.9% and 179.8%, respectively. Precisions around these estimates are all relatively tight at ±14.6% around energy at the 90% confidence interval and ±15.4% and ±19.6% around the summer and winter seasonal peaks at the 80% confidence interval.

Table 5-5. EO Electric Other Savings Summary

Category	Tracking Savings	Evaluation Savings	Realization Rate	Relative Precision
Zero Seasonal Peak Savings Sites Included				
Energy (MWh)	42,738	28,910	67.6%	±14.6%*
Summer Seasonal Peak (kW)	2,887	3,578	123.9%	±15.4%Ŧ
Winter Seasonal Peak (kW)	2,787	5,010	179.8%	±19.6%Ŧ
Zero Seasonal Peak Savings Sites Removed				
Energy (MWh)	42,738	28,910	67.6%	±14.6%*
Summer Seasonal Peak (kW)	2,887	3,311	114.7%	±16.4%Ŧ
Winter Seasonal Peak (kW)	2,787	4,518	162.1%	±17.2%Ŧ

* 90% Confidence Interval Ŧ 80% Confidence Interval

5.2 EO Gas

As noted earlier, there are two gas measure categories that were examined in this study: HVAC/DHW and Other. The key energy savings results for each is presented in Table 5-6. As noted in section 4.4.2, changes in PSD savings calculations between the program year(s) studied and the current PSD can trigger the need for prospective realization rates that complement the new savings analysis approach. There were two gas measures that experienced changes in their savings assumptions between the 2016 PSD (the program year from which part of this sample was drawn) and the 2020 PSD. These changes happened for steam traps in the 2018 and 2019 PSD and showerheads in the 2019 PSD. Due to these changes we provide a retrospective and prospective realization rate for this measure category that propagates to the overall realization rate also.

The overall EO gas realization rate is 76.3% with a precision of ±15.7% at the 90% confidence interval. The two measure category results were very similar with a HVAC/DHW measure category realization rate of 74.7% and Other realization rate of 78.2%%. The following two subsections compare the site level tracking versus evaluated savings results in scatterplots with discussions of primary drivers when appropriate. The weighted sample results in these scatterplots produce the realization rates presented in Table 5-6.

Table 5-6. Summary of EO Gas Energy Results

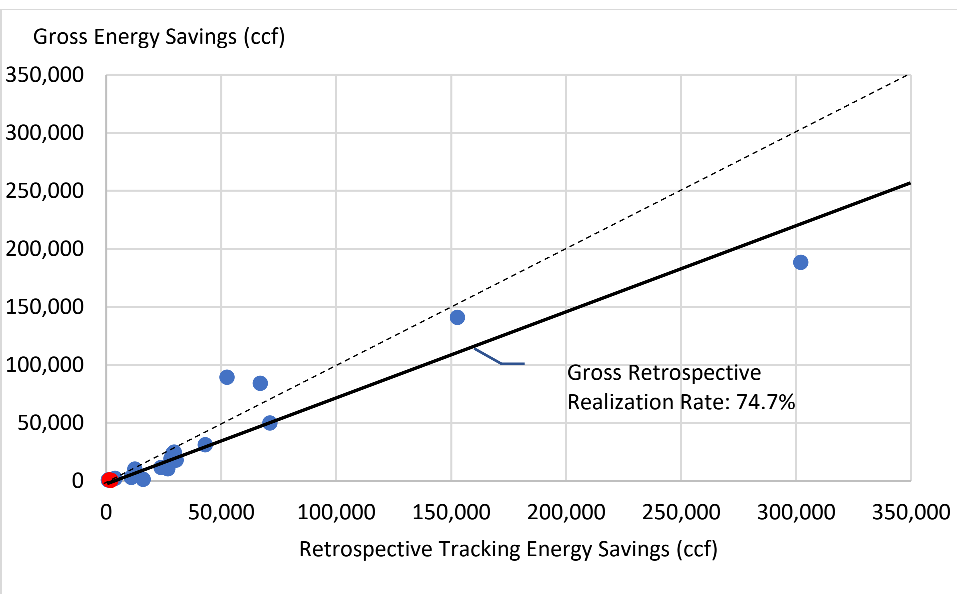
Measure Category	Tracking Annual Energy Savings (ccf)	Retrospective			Prospective		
		Evaluated Savings (ccf)	Realization Rate	Precision at 90% CI	Evaluated Savings (ccf)	Realization Rate	Precision at 90% CI
HVAC/DHW	2,197,086	1,641,254	74.7%	±17.4%	1,641,254	76.5%	±17.5%
Other	1,757,093	1,374,161	78.2%	±27.3%	1,374,161	78.2%	±27.3%
Statewide	**3,954,180**	**3,015,415**	**76.3%**	**±15.8%**	**3,015,415**	**77.3%**	**±15.7%**

5.2.1 HVAC/DHW

Figure 5-10 compares the retrospective tracking and evaluated annual energy savings for sites in the HVAC/DHW sample (n=20), with the two sites with measures (showerheads) that triggered the prospective realization rate shown as red points. The dashed reference line indicates where each sample point would have plotted had the tracking estimates been 100% accurate. This sample produces a gross realization rate of 74.7% with a precision of ±17.4% at the 90% confidence interval.

The largest site (shown as the blue point just past 300,000 ccf on the x-axis in Figure 5-10) had a realization rate of 62.4%. This was due to several measures performing lower than assumed in the tracking system for a variety of reasons. These included lower surface temperatures assumed in an insulation calculation and some duplication of measures in the tracking system that reduced savings when corrected.

Figure 5-10. EO Gas HVAC/DHW Retrospective Annual Energy Savings Scatterplot



As seen in the figure above, the two sites that triggered the need for a prospective gas HVAC/DHW realization rate were very small (shown as red dots). Figure 5-11 and Figure 5-12 presents a scatterplot of sites with under 10,000 ccf in tracking savings to show how these two sites impacted the prospective EO gas HVAC/DHW realization rate. In Figure 5-11 the two red points both fall below the dashed reference line while in Figure 5-12 one of these sites is above the reference line and the other close to it. The movement of these sample points closer to the reference line provides evidence the change in PSD savings approach for this measure is working. Since both sites are strata 1 sites which represent many other sites in the population, the improvement in the realization rate for these two sites results in a 1.8% increase in the overall HVAC/DHW realization rate.

Figure 5-11. Refocused EO Gas HVAC/DHW Retrospective Annual Energy Savings Scatterplot

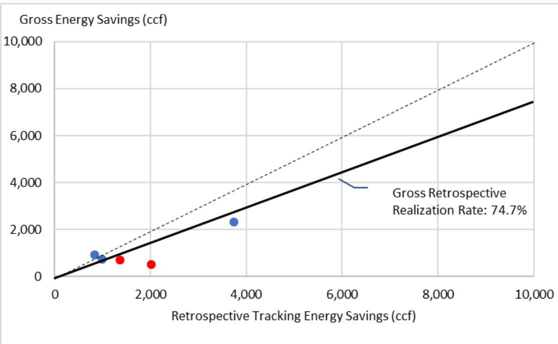


Figure 5-12. Refocused EO Gas HVAC/DHW Prospective Annual Energy Savings Scatterplot

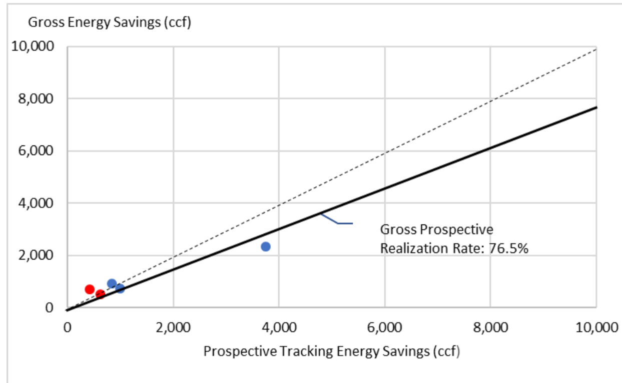


Table 5-7 summarizes the EO gas HVAC/DHW savings results. The retrospective energy realization rate is 74.7% with ±17.4% precision at the 90% confidence interval, while the prospective energy realization rate is 76.5% with ±17.5% precision at the 90% confidence interval.

Table 5-7. EO Gas HVAC/DHW Savings Summary

Category	Tracking Savings	Evaluation Savings	Realization Rate	Relative Precision at 90% CI
Retrospective Energy (ccf)	2,197,086	1,641,254	74.7%	±17.4%
Prospective Energy (ccf)	2,145,240	1,641,254	76.5%	±17.5%

5.2.2 Other[19]

Figure 5-13 compares the tracking and evaluated annual energy savings for sites in the Other sample (n=12). The dashed reference line indicates where each sample point would have plotted had the tracking estimates been 100% accurate. The third largest site (shown as a red point in Figure 5-13) had a realization rate of 14.3% for the installation of pipe/blanket insulation primarily due to a calculation error.

[19] Includes measures categorized as process in the tracking system; primarily pipe insulation and blanket insulation).

Figure 5-13. EO Gas Other Annual Energy Savings Scatterplot

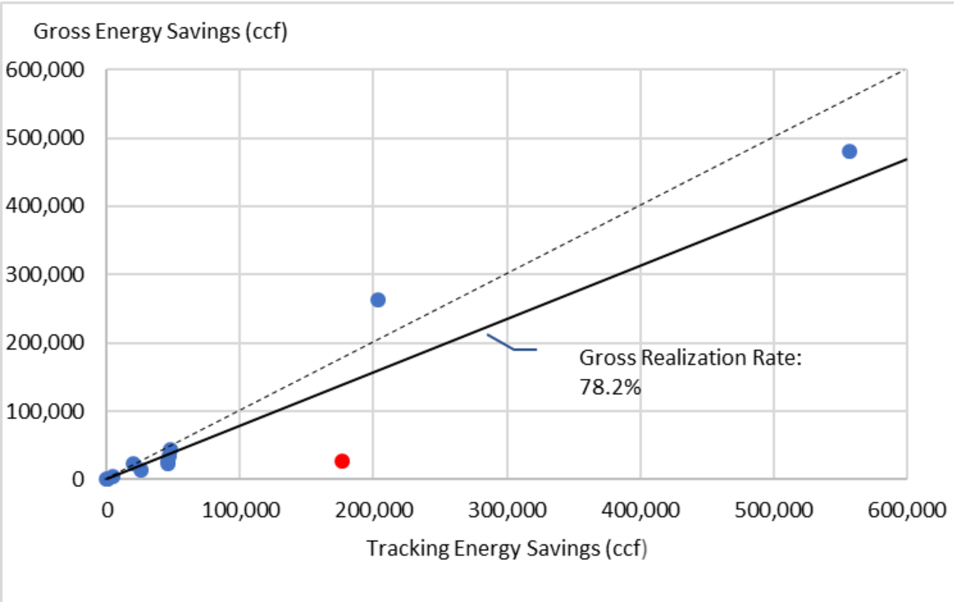


Table 5-8 summarizes the EO gas Other savings results. The energy realization rate is 78.2% with ±27.3% precision at the 90% confidence interval. The evaluated Other gas energy savings estimate is 1,374,161 ccf.

Table 5-8. EO Gas Other Savings Summary

Category	Tracking Savings	Evaluation Savings	Realization Rate	Relative Precision at 90% CI
Energy (ccf)	1,757,093	1,374,161	78.2%	±27.3%

5.3 Upstream Lighting

Table 5-9 provides the Upstream lighting energy savings results. The overall realization rate is 118.0% with a precision of ±12.7% at the 90% confidence interval. Recall, lighting loggers were retrieved from 25 of the 36 upstream sites with loggers due to the cancellation of field work caused by the COVID-19 pandemic. To calculate energy savings, hours of use from the lighting logger data leveraging effort (discussed later in this section) were used. The data leveraging study included data from the loggers that were retrieved from the 25 upstream sites. The largest driver of the 118.0% realization rate is due to differences in hours of use. The upstream lighting tracking savings for the majority interior spaces were based on the PSD annual HOU assumption for offices (3,748 hours), though some spaces used 70% of 8,760 (6,132 hours) for other interior spaces. As shown in Table 5-18, the hours of use by building type from the data leveraging study are much higher than the upstream lighting tracking savings assumption in many cases. The key savings parameters for upstream lighting are provided in the remainder of this section.

Table 5-9: Summary of Upstream Lighting Energy Savings Results

Category	Tracking Annual Energy Savings (MWh)	Evaluation Annual Energy Savings (MWh)	Realization Rate	Precision at 90% CI
Upstream Lighting	31,358	36,995	118.0%	±12.7%

Table 5-10 summarizes the Upstream lighting in-service rate (ISR) results. As discussed earlier, the sample for the upstream study effort was of 2018 activity following the implementation of activities to ensure the installation of purchased lighting. The combination of higher installation rates associated with certain upstream measure types and the companies' activities in this area are producing a very high ISR compared to early studies of the recent MA Upstream lighting study[20]. The short-term ISR is calculated by dividing the quantity of products found installed during the site visits by the total number of products listed as received according to the tracking system. The overall short-term ISR is 95.5% with a precision of ±2.5% at the 90% confidence interval.

Since the ISR rate is based on observations made within a year of purchase it is necessary to use factors from other studies to estimate the long-term ISR. To estimate a long-term upstream lighting ISR, the study used a multiplier of 117.5%[21] from a two-stage study performed in Massachusetts that examined the installation rate of C&I upstream lighting over a year period. In applying this the quantity of products installed over the long term cannot exceed the sum of the products found installed and in storage during the site visit for each site visited. The overall long term ISR of 96.0% (with ±2.4% precision at the 90% confidence interval) can be applied one year after upstream lighting measures are installed.

Table 5-10. Upstream Lighting In-Service Rate Results

Category	Tracking System In-Service Rate[22]	Evaluation Short-Term In-Service Rate	Precision at 90% CI	Evaluation Long Term In-Service Rate	Precision at 90% CI
Cat 1 LED Linear	100.0%	97.1%	±1.9%	97.4%	±1.8%
Cat 3 LED Downlights	100.0%	85.9%*	±22.5%	86.4%*	±22.3%
Cat 4 LED A-line/Deco	100.0%	71.4%	±15.7%	74.9%	±13.8%
Cat 7 LED High/Low Bay	100.0%	99.6%*	±0.6%	99.7%*	±0.5%
Total	**100.0%**	**95.5%***	**±2.5%**	**96.0%***	**±2.4%**

*Results that are statistically different from the tracking system assumption at the 90% confidence interval.

Table 5-11 presents the Upstream lighting delta watts results based on the 2018 Program Year tracking system delta watts. The evaluation delta watts are based on interviews with site contacts about the lighting products that were replaced. The overall tracking and evaluation delta watts are weighted by connected kW to produce a delta watts realization rate of 99.8% with a precision of ±10.7% at the 90% confidence interval.

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20 http://ma-eeac.org/wordpress/wp-content/uploads/Upstream-Lighting-Initiative-Impact-Evaluation-PY2015.pdf, Table 1-2, page 7. Short-term ISRs ranged from 58.6% for category 3 products to 89.8% for category 1 products. Long-term ISRs ranged from 62.2% for category 3 products to 92.0% for category 1 products.

21 Ibid. Page D-3.

22 The PAs applied an in-service rate of 84.6% for LED lamps in the 2020 program year.

Table 5-11. Retrospective Upstream Lighting Delta Watts Results

Category	Tracking Delta Watts	Evaluation Delta Watts	Realization Rate	Precision at 90% CI
Cat 1 LED Linear	12.91	15.33*	118.8%	±8.9%
Cat 3 LED Downlights	41.16	44.50	108.1%	±17.0%
Cat 4 LED A-line/Deco	40.32	46.86	116.2%	±16.0%
Cat 7 LED High/Low Bay	212.20	157.33*	74.1%	±30.4%
Overall	**24.55**	**24.51**	**99.8%**	**±10.7%**

*Results that are statistically different from the tracking system assumptions at the 90% confidence interval.

It is important to note that the 2020 PSD includes upstream lighting delta watts assumptions by measure type. The 2018 Program Year tracking delta watts were recalculated using the 2020 PSD assumptions. Using these PSD delta watts, the prospective Upstream lighting delta watts results are provided in Table 5-12 below.

Table 5-12. Prospective Upstream Lighting Delta Watts Results

Category	PSD Delta Watts	Evaluation Delta Watts	Realization Rate	Precision at 90% CI
Cat 1 LED Linear	14.60	15.33	105.0%	±5.6%
Cat 3 LED Downlights	35.95	44.50*	123.8%	±15.4%
Cat 4 LED A-line/Deco	28.02	46.86*	167.2%	±10.0%
Cat 7 LED High/Low Bay	212.20	157.33*	74.1%	±30.4%
Overall	**25.37**	**24.51**	**96.6%**	**±9.9%**

*Results that are statistically different from the tracking system assumptions at the 90% confidence interval.

Table 5-13 shows the Upstream lighting connected demand savings results. The overall realization rate is 98.1% with a precision of ±8.3% at the 80% confidence interval. The poor realization rate for Category 7 LED High/Low Bay fixtures is due to a tracking savings weighted delta watts assumption of 212.2 watts, while the evaluation found the weighted average delta watts to be 157.3 watts for these products based on customer reports (as shown in Table 5-11).

Table 5-13. Upstream Lighting Connected Demand Savings Results

Category	Tracking Connected Demand Savings (kW)	Evaluation Connected Demand Savings (kW)	Realization Rate	Precision at 80% CI
Cat 1 LED Linear	3,669	4,222	115.1%*	±7.0%
Cat 3 LED Downlights	1,277	1,254	98.2%	±16.3%
Cat 4 LED A-line/Deco	840	724	86.2%	±11.6%
Cat 7 LED High/Low Bay	2,144	1,580	73.7%*	±23.7%
Total	**7,930**	**7,781**	**98.1%**	**±8.3%**

*Results that are statistically different from the tracking system assumption at the 90% confidence interval.

Table 5-14 provides the Upstream lighting energy interactive factor results, which are based on logger data from the 25 upstream lighting sites where loggers were installed and retrieved. The overall tracking and evaluation energy interactive factors are weighted by connected kW to produce an evaluation energy interactive factor of 1.024 with a precision of ±2.4% at the 90% confidence interval. This result is statistically the same as the tracking system assumption at the 90% confidence interval. It is important to note that these results are for electric only. The effect of fossil fuels was not part of this evaluation's scope.

Table 5-14. Upstream Lighting Energy Interactive Factor Results

Category	Tracking Energy Interactive Factor	Evaluation Energy Interactive Factor	Precision at 90% CI
Cat 1 LED Linear	1.000	1.081*	±3.6%
Cat 3 LED Downlights	1.000	1.023	±4.3%
Cat 4 LED A-line/Deco	1.000	1.000	±0.0%
Cat 7 LED High/Low Bay	1.000	1.008	±1.2%
Overall	**1.000**	**1.024**	**±2.4%**

*Results that are statistically different from the tracking system assumptions at the 90% confidence interval.

Table 5-15 provides the Upstream lighting energy savings results including interactive. The overall realization rate is 118.0% with a precision of ±12.7% at the 90% confidence interval. This evaluated energy savings estimate applied the leveraged hours of use results by business type as presented in the next section (Table 5-18 and Table 5-21). Seasonal peak demand realization rates for upstream lighting could not be provided since seasonal peak demand tracking savings estimates were not provided for most sites.

Table 5-15. Upstream Lighting Energy Savings Results

Category	Tracking Annual Energy Savings (MWh)	Evaluation Annual Energy Savings (MWh)	Realization Rate	Precision at 90% CI
Cat 1 LED Linear	15,308	18,566	121.3%	±11.5%
Cat 3 LED Downlights	4,855	6,326	130.3%	±24.4%
Cat 4 LED A-line/Deco	3,161	3,486	110.3%	±27.7%
Cat 7 LED High/Low Bay	8,035	8,617	107.2%	±33.4%
Total	**31,358**	**36,995**	**118.0%**	**±12.7%**

Table 5-16 summarizes the Upstream lighting demand interactive factor results, which are based on data gathered at all 88 upstream lighting site visits. The overall tracking and evaluation demand interactive factors are weighted by connected kW to produce a demand interactive factor of 1.152, which is statistically different from the tracking system assumption at the 90% confidence interval.

Table 5-16. Upstream Lighting Demand Interactive Factor Results

Category	Tracking Demand Interactive Factor	Evaluation Demand Interactive Factor	Precision at 90% CI
Cat 1 LED Linear	1.000	1.199*	±3.5%
Cat 3 LED Downlights	1.000	1.189*	±4.7%
Cat 4 LED A-line/Deco	1.000	1.176*	±7.1%
Cat 7 LED High/Low Bay	1.000	1.047*	±3.9%
Overall	**1.000**	**1.152***	**±3.4%**

*Results that are statistically different from the tracking system assumptions at the 90% confidence interval.

5.4 Lighting Data Leveraging

The study undertook a significant effort to pull together lighting logger data from this study and several other recently performed evaluations in Connecticut. This subsection of the report provides lighting parameters analyzed from the data by building type. The other evaluations where lighting logger information was gathered include the last two CT Small Business Energy Advantage (SBEA) studies[23] (C1639 and C9), the most recent CT Energy Conscious Blueprint (ECB) study[24] (C20), and the previous CT EO study[25] (C14). Table 5-17 shows that this data leveraging effort compiled data from nearly 2,700 loggers installed at 266 sites for an average of three months.

Table 5-17. Lighting Logger Data Leveraging Sample

Lighting Logger Data Leveraging	Current CT EO Study	Current CT Upstream Study	2014 CT SBEA Study	2015 CT ECB & 2018 CT EO Studies	2018 CT SBEA Study	Total
Lighting Sites in Sample	65	25	42	80	54	266
Lighting Loggers Installed	755	79	370	1,223	272	2,699
Lighting Loggers/Site	11.6	3.2	8.8	15.3	5.0	10.1
Average Lighting Logger Duration (in months)	4.6	2.7	5.6	1.0	2.0	3.0

Table 5-18 presents the weighted (by connected kW) interior fixture annual hours of use (HOU) results by building type with precisions at the 90% confidence interval. The rightmost two columns compare these results to the current PSD and MA Technical Reference Manual (TRM) upstream lighting assumptions. Since the study results are being compared to both the current PSD and current MA TRM assumptions, the identifiers that signify where statistical differences occur reside in those columns.

The tracking energy savings for interior fixtures at all but one lighting site in the EO sample[26] were based on site-specific annual HOU assumptions. The PSD states that retrofit lighting calculations can use either site specific hours or assumed hours from the PSD for that building type. The Massachusetts TRM explicitly guides the use of site-specific hours for its direct install programs and hours by building type for upstream

[23] C1639: Impact Evaluation of the Connecticut Small Business Energy Advantage (SBEA) Program, 3/20/2018, Energy Resource Solutions (ERS) and C9: Impact Evaluation of the Connecticut Small Business Energy Advantage (SBEA) Program, April 2014, KEMA Inc.

[24] C20 Impact Evaluation of Energy Conscious Blueprint Program Years 2012-2013, 11/6/2015, EMI Consulting.

[25] C14: Evaluation of the Energy Opportunities Program: Program Year 2011, 4/1/2014, EMI Consulting.

[26] The tracking savings for this education facility utilized the PSD annual HOU assumption (2,187 hours) for most spaces in the application and used a site-specific assumption (3,120 annual HOU) for the gym. and 4,380 annual HOU for exterior fixtures).

activity.   The upstream lighting tracking savings for the majority interior spaces were based on the PSD annual HOU assumption for offices (3,748 hours), though some spaces used 70% of 8,760 (6,132 hours) for other interior spaces. This has been changed for the 2020 program year where tracking hours of use are based on PSD assumptions by building type.

The overall weighted average of hours from the logger data gathering and leveraging is 5,550 hours per year. This is much higher than the estimate of 3,628 (derived when weighting the 2020 PSD assumed hours of use by the connected kW from the data leveraging by business type) but is slightly higher than the weighted estimate of 5,319 from the MA TRM assumed hours; although these results are not statistically different. The overall weighted average of 5,140 annual hours is much higher than the PSD annual HOU assumption applied for the majority of upstream lighting interior applications (3,748 hours). This is the largest driver of the 118.0% energy savings realization rate for upstream lighting.

Table 5-18. Interior Fixture Hours of Use Results by Building Type

Building Type	Sites with Interior Systems Installed	Total Connected kW	Weighted Average Annual HOU	Precision at 90% Confidence Interval	2020 PSD Assumption	MA TRM Upstream Assumption
24x7 lighting	2	14.7	8,760	±0.0%	N/A	N/A
Automotive	3	5.7	2,807	±46.1%	4,056	N/A
Education	22	1,108.7	2,967	±14.0%	2,187*	2,788
Grocery	14	194.6	7,698	±10.9%	4,055*	5,468*
Health Care	15	249.9	5,564	±15.2%	7,666*	5,413
Hotel/Motel	1	21.8	3,112	N/A	3,064	4,026
Industrial	20	960.6	5,793	±13.3%	4,730*	4,988*
Large Office	6	504.0	4,098	±8.0%	3,748*	4,181
Other	25	706.9	6,211	±11.5%	N/A	4,332*
Religious Building/ Convention Center	6	8.3	913	±71.1%	1,955*	N/A
Restaurant	14	44.4	6,072	±12.3%	4,182*	5,018*
Retail	30	665.7	6,318	±9.0%	4,057*	4,939*
Small Office	30	169.0	3,595	±11.1%	3,748	4,181*
Warehouse	15	896.0	5,667	±19.9%	2,602*	6,512
Overall	**203**	**5,550.4**	**5,140**	**±5.2%**	**3,628***	**5,319**

*Results that are statistically different from the 2020 PSD or MA TRM Upstream lighting assumptions at the 90% confidence interval.

Table 5-19 provides the weighted (by connected kW) interior fixture summer seasonal coincidence factor (CF) results by building type with precisions at the 80% confidence interval. As above, the two columns on the right compares these results to the current PSD and MA Technical Reference Manual (TRM) on-peak assumptions. Similar to the hours of use summary above, the weighted average summer coincidence factor from the leveraged data is higher than that derived from the PSD using the same weights but is very similar to the overall weighted MA TRM value. The EO tracking summer seasonal peak savings were nearly always based on the PSD summer coincidence factor assumptions. Summer seasonal peak savings estimates were not provided in the Upstream lighting tracking data.

Table 5-19. Interior Fixture Summer Seasonal Coincidence Factor Results by Building Type

Building Type	# of Sites w/Interior Systems Installed	Total Connected kW	Weighted Average Summer Seasonal Peak CF	Precision at 80% Confidence Interval	2020 PSD Summer Seasonal Peak CF Assumption	MA TRM Summer On-peak Assumption
24x7 lighting	2	14.7	100.0%	±0.0%	N/A	80.0%*
Automotive	3	5.7	68.3%	±33.7%	N/A	80.0%
Education	22	1,108.7	36.8%	±22.0%	59.9%*	80.0%*
Grocery	14	194.6	90.6%	±9.3%	90.4%	80.0%*
Health Care	15	249.9	82.5%	±5.9%	74.0%*	80.0%
Hotel/Motel	1	21.8	40.6%	N/A	N/A	80.0%
Industrial	20	960.6	83.0%	±5.1%	67.1%*	80.0%
Large Office	6	504.0	77.9%	±12.4%	70.2%	80.0%
Other	25	706.9	86.9%	±9.0%	47.6%*	80.0%
Religious Building/ Convention Center	6	8.3	17.0%	±91.2%	N/A	80.0%*
Restaurant	14	44.4	83.1%	±7.2%	77.5%	80.0%
Retail	30	665.7	98.4%	±3.8%	79.5%*	80.0%*
Small Office	30	169.0	76.8%	±8.0%	70.2%*	80.0%
Warehouse	15	896.0	89.3%	±9.2%	72.7%*	80.0%*
Overall	**203**	**5,550.4**	**76.4%**	**±3.4%**	**67.2%***	**80.0%***

*Results that are statistically different from the 2020 PSD or MA TRM Upstream lighting assumptions at the 80% confidence interval.

Table 5-20 summarizes the weighted (by connected kW) interior fixture winter seasonal coincidence factor results by building type with precisions at the 80% confidence interval and compares them to the current PSD and MA Technical Reference Manual (TRM) on-peak assumptions. The trend of the overall weighted leveraged results being substantially different than the current PSD but similar to the overall weighted MA TRM estimate remains here. The EO tracking winter seasonal peak savings were nearly always based on the PSD winter coincidence factor assumptions. Winter seasonal peak savings estimates were not provided in the Upstream lighting tracking data.

Table 5-20. Interior Fixture Winter Seasonal Coincidence Factor Results by Building Type

Building Type	# of Sites w/Interior Systems Installed	Total Connected kW	Weighted Average Winter Seasonal Peak CF	Precision at 80% Confidence Interval	2020 PSD Winter Seasonal Peak CF Assumption	MA TRM Winter On-Peak Assumption
24x7 lighting	2	14.7	100.0%	±0.0%	N/A	61.0%*
Automotive	3	5.7	36.9%	±48.1%	N/A	61.0%*
Education	22	1,108.7	46.0%	±11.5%	38.8%*	61.0%*
Grocery	14	194.6	85.6%	±9.7%	77.0%*	61.0%*
Health Care	15	249.9	69.6%	±9.0%	61.8%*	61.0%*
Hotel/Motel	1	21.8	37.5%	N/A	N/A	61.0%
Industrial	20	960.6	66.5%	±12.9%	43.2%*	61.0%
Large Office	6	504.0	58.2%	±14.6%	53.9%	61.0%
Other	25	706.9	76.7%	±9.9%	42.8%*	61.0%*
Religious Building/ Convention Center	6	8.3	9.2%	±87.8%	N/A	61.0%*
Restaurant	14	44.4	77.0%	±6.8%	64.4%*	61.0%*
Retail	30	665.7	85.6%	±9.5%	64.7%*	61.0%*
Small Office	30	169.0	44.1%	±14.0%	53.9%*	61.0%*
Warehouse	15	896.0	72.4%	±16.3%	53.5%*	61.0%
Overall	**203**	**5,550.4**	**66.2%**	**±4.3%**	**50.1%***	**61.0%***

*Results that are statistically different from the 2020 PSD or MA TRM Upstream lighting assumptions at the 80% confidence interval.

Table 5-21 presents the weighted (by connected kW) exterior fixture annual hours of use (HOU) and seasonal peak coincidence factor results. The two columns on the right compare these values to the current CT PSD and MA TRM assumptions. Asterisks identify results that are statistically different from the PSD assumption at the 90% confidence interval (CI) for HOU and at the 80% confidence interval for seasonal peak CFs.

The tracking energy savings for exterior fixtures in the EO sample were based on site-specific annual HOU assumptions, which is stated as an option in the PSD. Over 47% (or 319 kW) of the total connected exterior fixture kW in the data leveraging sample was due to parking garage lighting which operate 8,760 hours per year and have seasonal peak CFs of 100.0%. This heavily influenced the greater HOU estimate from this study (6,887) when compared to the current PSD assumption. The high presence of parking garages also drove up the summer and winter seasonal peak estimates.

Table 5-21. Exterior Fixture Results

Exterior: Parking Lot/streetlights	Sites w/Exterior Systems Installed	Total Connected kW	Weighted Average Result	Precision at 90% CI for HOU; at 80% CI for Seasonal Peak CFs	2020 PSD Assumption	MA TRM Assumption
Annual HOU	66	677.0	6,887	±5.6%	4,368*	N/A
Summer Seasonal Peak CF	66	677.0	67.2%	±7.4%	1.5%*	0.0%*
Winter Seasonal Peak CF	66	677.0	87.3%	±5.1%	66.9%*	100.0%*

*Results that are statistically different from the 2020 PSD and MA TRM assumptions at the 90% confidence interval for HOU and at the 80% confidence interval for Seasonal Peak CFs.

Occupancy sensors were metered at 13 EO lighting sites and at 45 sites in the four other studies that were part of the data leveraging effort. At the 13 EO lighting sites, baseline hours of use were gathered by metering similar space types that were manually controlled. For example, if a site had occupancy sensors installed in a restroom, loggers were installed in the restroom with the occupancy sensors and another restroom that was manually controlled. The hours of use from this manually controlled restroom were used as proxy baseline hours for the restroom where the occupancy sensors were installed. Similar proxy baseline hours of use were not provided for the 45 sites with occupancy sensors from the four other studies that were part of the data leveraging effort and could not be included in the occupancy sensor hours of use reduction factor analysis. The 13 EO sites for which occupancy sensor and proxy baseline hours were metered generated a weighted average occupancy sensor hours of use reduction factor of 0.429. This indicates that the occupancy sensor hours of use were 57.1% of the baseline hours (or a 42.9% reduction in hours). The current PSD assumes that occupancy sensor hours of use are 70.0% of the baseline hours (or a 30.0% reduction in hours). Due to the small sample size (n=13), a recommendation to update the current PSD occupancy sensor hours of use reduction factor could not be made based on the data collected as part of this study.

Table 5-22 presents the weighted (by connected kW) occupancy sensor summer seasonal peak coincidence factor results with precision at the 80% confidence interval. The overall baseline summer seasonal percent-on result for interior fixtures is from Table 5-19, while the overall occupancy sensor summer seasonal percent-on result is based on the logger data from 58 data leveraging sites. The summer seasonal occupancy sensor coincidence factor reduction is 22.1% with ±22.8% at the 80% confidence interval. This is statistically the same as the current PSD assumption of 20.5%.

Table 5-22. Occupancy Sensor Summer Seasonal Peak Coincidence Factor Result

Building Type	Sites	Weighted Average Summer Seasonal Peak CF	Precision at 80% Confidence Interval	2020 PSD Assumption	MA TRM Assumption
Overall Baseline Percent-On	203	76.4%	±3.4%	67.2%*	80.0%*
Overall Occupancy Sensor Percent-On	58	54.4%	±7.9%	N/A	N/A
Occupancy Sensor Reduction	N/A	22.1%	±22.8%	20.5%	15.0%*

*Results that are statistically different from the 2020 PSD and MA TRM assumptions at the 80% confidence interval.

Table 5-23 provides the weighted (by connected kW) occupancy sensor winter seasonal peak coincidence factor results with precision at the 80% confidence interval. The overall baseline winter seasonal percent-on result for interior fixtures is from Table 5-20, while the overall occupancy sensor winter seasonal percent-on result is based on the logger data from 58 data leveraging sites. The winter seasonal occupancy sensor coincidence factor reduction is 14.3% with ±38.4% at the 80% confidence interval. This is statistically the same as the current PSD assumption of 18.9%.

Table 5-23. Occupancy Sensor Winter Seasonal Peak Coincidence Factor Result

Building Type	Site Count	Weighted Average Winter Seasonal Peak CF	Precision at 80% Confidence Interval	2020 PSD Assumption	MA TRM Assumption
Overall Baseline Percent-On	203	66.2%	±4.3%	50.1%*	61.0%*
Overall Occupancy Sensor Percent-On	58	51.8%	±9.1%	N/A	N/A
Occupancy Sensor Reduction	N/A	14.3%	±38.4%	18.9%	13.0%

*Results that are statistically different from the 2020 PSD and MA TRM assumptions at the 80% confidence interval.

5.5 Study Error Ratios

Table 5-24 presents the final study energy error ratios by end use group for the EO portion of the study and for energy and connected demand for the upstream lighting of the study. With the exception of the electric HVAC error ratio, the study error ratios are all consistent with or better than those assumed in the sample design[27] for each of the samples in this study. These final experienced error ratios can be used to inform future sample designs for similar studies of C&I retrofit programs in Connecticut. The end uses with the higher error ratios should expect to have larger sample sizes in future studies.

Table 5-24. Study Error Ratios

End Use Group/Parameter	Error Ratio
EO Electric Lighting Energy	0.37
EO Electric HVAC Energy	0.83
EO Electric Other Energy	0.47
EO Gas HVAC/DHW Energy	0.48
EO Gas Other Energy	0.43
Upstream Lighting Energy	0.56
Upstream Lighting Connected Demand	0.50

5.6 Study Realization Rates Compared to Those from Similar Programs

This section compares the energy realizations rates from this study to those from similar programs offered in Connecticut and other jurisdictions. Table 5-25 compares this study's electric energy realization rates to those from similar programs offered in other jurisdictions, while Table 5-26 makes the same comparison to

[27] 0.48 for EO electric, 0.60 for EO gas, and 0.90 for upstream lighting.

previous evaluations of the EO Program. The realization rates in these tables are sorted from the highest realization rate to the lowest with the results from this study in bold. In both tables this study's results compare favorably to those from similar programs and past EO evaluations as the HVAC and Lighting realization rates are among the highest and closest to 100%. While the Other realization rate is lower, the error ratio around it is relatively good compared to the error ratios around similar results. Custom study results are included in this comparison because the EO study also included custom measures though they were dispersed among the end uses reported.

Table 5-25: Electric Energy Realization Rates Compared to Those from Similar Program in Other Jurisdictions

Program Administrator	Program	State	Electric Realization Rate	Electric ER/CV
Consumers Custom	2013 Custom C&I[28]	MI	1.088	Not Provided
All MA Custom Electric Lighting	2020 Custom Electric Program[29]	MA	1.067	0.26
Consumers Custom	2012 Custom C&I[26]	MI	1.024	Not Provided
All CT EO HVAC	**2020 Energy Opportunities**	**CT**	**1.021**	**0.83**
All CT EO Lighting	**2020 Energy Opportunities**	**CT**	**0.979**	**0.37**
All NH Large C&I	2015 Large Commercial and Industrial Retrofit Program[30]	NH	0.976	0.27
Efficiency Vermont	Efficiency Vermont 2017 Custom Program[31]	VT	0.966	Not Provided
ComEd	2019 Custom C&I[32]	IL	0.940	Not Provided
All MA Custom Electric Lighting	2019 Custom Electric Program[33]	MA	0.924	0.26
ComEd	2018 Custom C&I[30]	IL	0.910	Not Provided
Energy Trust of Oregon	2017 Existing Buildings Program[34]	OR	0.900	0.32
Efficiency Maine	2014 -2015 Business Incentive Program[35]	ME	0.866	Not Provided
NYSERDA	2014–2017 Industrial and Process Efficiency Program[36]	NY	0.860	0.34
Consumers Custom	2011 Custom C&I[26]	MI	0.859	Not Provided
PGE 2018	Custom 2018 Commercial, Industrial, Agricultural[37]	CA	0.820	Not Provided
All MA Custom Electric Non-Lighting	2020 Custom Electric Program[27]	MA	0.766	0.52
SCE 2018	Custom 2018 Commercial, Industrial, Agricultural[35]	CA	0.690	Not Provided
All CT EO Other	**2020 Energy Opportunities**	**CT**	**0.676**	**0.47**
All MA Custom Electric Non-Lighting	2019 Custom Electric Program[31]	MA	0.670	0.47
SDGE 2013-2015	Custom 2013-2015, Industrial, Agricultural and Large Commercial[38]	CA	0.660	0.87
PGE 2013-2015	Custom 2013-2015, Industrial, Agricultural and Large Commercial[36]	CA	0.640	0.97
SDGE 2018	Custom 2018 Commercial, Industrial, Agricultural[35]	CA	0.530	Not Provided
SCE&G 2013-2015	Custom 2013-2015, Industrial, Agricultural and Large Commercial[36]	CA	0.440	0.98
MCE 2018	Custom 2018 Commercial, Industrial, Agricultural[35]	CA	0.280	Not Provided

28 https://www.michigan.gov/documents/mpsc/Consumers_Energy_CI_Evaluation_Highlights_Presentation_2014.09.16_468671_7.pdf.

29 http://ma-eeac.org/wordpress/wp-content/uploads/MA_CIEC_Stage5_Report_C07_Custom_Electric_Impact_Evaluation_PY2017_18_FINAL-2020-06-01.pdf.

30 https://www.puc.nh.gov/Electric/Monitoring%20and%20Evaluation%20Reports/New%20Hampshire%20Large%20C&I%20Program%20Impact%20Study%20Final%20Report.pdf.

31 https://publicservice.vermont.gov/sites/dps/files/documents/EVT%202017%20Savings%20Verification%20Report.pdf.

32 https://s3.amazonaws.com/ilsag/ComEd-Incentives-Custom-CY2019-Impact-Evaluation-Report-2020-04-10-Final.pdf.

33 http://ma-eeac.org/wordpress/wp-content/uploads/MA_CIEC_Stage5_Report_P80_Custom_Impact_Evaluation_PY2016_Final.pdf.

34 https://www.energytrust.org/wp-content/uploads/2019/10/2017_ExistingBuildings_Impact_Evaluation.pdf.

35 https://www.efficiencymaine.com/docs/EMT-BIP-Impact-Evaluation-Report-11_5_17.pdf.

36 https://www.nyserda.ny.gov/-/media/Files/Publications/PPSER/Program-Evaluation/2018-IPE-ConcurrentEvaluation-2017-18.pdf.

37 https://pda.energydataweb.com/#!/documents/2378/view

38 http://calmac.org/publications/PY2015_On-Bill_Finance_Impact_Evaluation_FINAL.pdf

It is important to note that, unlike the current study (which provides results for HVAC and Other electric end uses), previous EO evaluations did not provide results for multiple non-lighting end uses but only provided a singular non-lighting realization rate. The current study's HVAC and Other end use results are provided separately in Table 5-26 below but when combined achieve a non-lighting realization rate of 78.3%.

Table 5-26: Electric Energy Realization Rates Compared to Those from Previous EO Evaluations

CT Program/End Use (Project Number)	Electric Realization Rate	Electric ER/CV
2014 Energy Opportunities Non-Lighting (C14)[39]	1.123	0.48
2020 Energy Opportunities HVAC (C1635)	**1.021**	**0.83**
2010 Energy Opportunities Lighting[40]	0.988	Not Provided
2020 Energy Opportunities Lighting (C1635)	**0.979**	**0.37**
2014 Energy Opportunities Lighting (C14)[39]	0.885	0.48
2010 Energy Opportunities Non-Lighting[40]	0.843	Not Provided
2020 Energy Opportunities Other (C1635)	**0.676**	**0.47**

Table 5-27 compares the gas energy realization rates from this study to those from similar programs in Connecticut and other jurisdictions and the most recent EO evaluation (the 2010 EO evaluation did not include gas results). While this study's realization rates are not among the highest, they are comparable to those experienced in MA and the most recent EO study and have associated error ratios that are similar to those from most of the other studies.

[39] https://www.energizect.com/sites/default/files/C14%20Energy%20Opportunities%20Impact%20and%20Process%20Evaluation-%20Program%20Year%202011%204-1-2014.pdf.

[40] https://www.energizect.com/sites/default/files/KEMA%202008%20CT%20EO%20Impact%20FINAL%201006181.pdf.

Table 5-27: Gas Energy Realization Rates Compared to Those from Similar Programs in Other Jurisdictions and Previous EO Evaluations

PA	State	Program	Gas Realization Rate	Gas ER/CV
Consumers Custom	MI	2011 Custom C&I	1.291	Not Provided
Consumers Custom	MI	2013 Custom C&I	1.191	Not Provided
Consumers Custom	MI	2012 Custom C&I	1.106	Not Provided
All NH Large C&I	NH	2015 Large Commercial and Industrial Retrofit Program	0.917	0.16
Energy Trust of Oregon	OR	2017 Existing Buildings Program	0.870	0.41
All MA Custom Gas	MA	2020 Custom Gas Program	0.870	0.40
All CT EO Overall	CT	2014 Energy Opportunities Overall (C14)	0.837	Not Provided
All MA Custom Gas	MA	2019 Custom Gas Program	0.820	0.49
All CT EO Other	**CT**	**2020 Energy Opportunities Program Other (C1635)**	**0.782**	**0.43**
All CT EO HVAC/DHW	**CT**	**2020 Energy Opportunities Program HVAC/DHW (C1635)**	**0.765**	**0.48**
PGE 2013-2015	CA	Custom 2013-2015, Industrial, Agricultural and Large Commercial	0.630	0.54
SCE&G 2013-2015	CA	Custom 2013-2015, Industrial, Agricultural and Large Commercial	0.550	0.92
SDGE 2013-2015	CA	Custom 2013-2015, Industrial, Agricultural and Large Commercial	0.500	1.31

Table 5-28 compares the upstream lighting energy realization rate to those from the upstream lighting program offered in Massachusetts. This study is the first upstream lighting study performed in Connecticut so comparisons to previous upstream lighting evaluations performed in Connecticut could not be made. The realization rates compare very favorably to those from recent studies of the MA program as the current study results are among the highest and have better error ratios.

Table 5-28: Upstream Lighting Energy Realization Rates Compared to Those from Similar Program in MA

PA	State	Program	Electric Realization Rate	Electric ER/CV
All MA Upstream Lighting Category 1 (Linear LEDs)	MA	2017 Upstream Lighting Program[41]	1.952	0.73
All CT Upstream Lighting Category 3 (LED Downlights)	**CT**	**2020 Upstream Lighting Program**	**1.303**	**0.60**
All CT Upstream Lighting Category 1 (Linear LEDs)	**CT**	**2020 Upstream Lighting Program**	**1.213**	**0.43**
All CT Upstream Lighting Category 4 (LED A-line/Deco)	**CT**	**2020 Upstream Lighting Program**	**1.103**	**0.64**
All CT Upstream Lighting Category 7 (LED High/Low Bay)	**CT**	**2020 Upstream Lighting Program**	**1.072**	**0.68**
All MA Upstream Lighting All LEDs	MA	2014 Upstream Lighting Program[42]	1.019	0.90
All MA Upstream Lighting Category 3 (LED Downlights)	MA	2017 Upstream Lighting Program[37]	0.514	1.33
All MA Upstream Lighting Category 4 (LED A-line/Deco)	MA	2017 Upstream Lighting Program[37]	0.272	1.11

[41] http://ma-eeac.org/wordpress/wp-content/uploads/Upstream-Lighting-Initiative-Impact-Evaluation-PY2015.pdf.

[42] http://ma-eeac.org/wordpress/wp-content/uploads/Upstream-Lighting-Impact-Evaluation-Final-Report.pdf

6 CONCLUSIONS, RECOMMENDATIONS, AND CONSIDERATIONS

This section summarizes the conclusions and recommendations of this study based on the results presented above. EO electric energy, EO seasonal peak demand, and upstream lighting energy and connected demand savings results are favorable with very good realization rates. Poorer realization rates were found for EO gas energy savings estimates.

6.1 EO Electric Conclusions and Recommendations

Conclusion 1: The EO electric energy savings realization rates that can be used retrospectively and prospectively with accompanying precisions by sampling category are:

Table 6-1: EO Electric Energy Savings Realization Rate Results

Sampling Category	Realization Rate	Precision at 90% CI
HVAC	102.1%	±35.0%
Lighting	97.9%	±8.1%
Other	67.6%	±14.6%
Overall	93.8%	±7.3%

Recommendation 1: Update the EO electric energy savings realization rates by end use in the PSD so that they are consistent with the realization rates found in this study as follows. While the precision around the HVAC result is poorer than expected, after examining the sites which were the largest contributors, there are various drivers behind the site level results. The observed drivers are reasonably representative of what might be expected to occur within a sample of this nature (i.e., tracking system errors and differences in performance), and therefore support the application of this result despite the poor precision associated with it. Adjustments may be needed as program design changes.

Table 6-2: EO Electric Energy Savings Realization Rate Recommendations by End Use

End Use	2020 Program Savings Document (PSD) Assumption	Recommended Realization Rate
Cooling	101.0%	102.1%
Heating	101.0%	102.1%
Lighting	101.0%	97.9%
Custom	101.0%	93.8%
EMS	100.0%	67.6%
Motors	101.0%	67.6%
Other	101.0%	67.6%
Process	101.0%	67.6%
Refrigeration	101.0%	67.6%

Conclusion 2: The EO lighting tracking energy savings estimates for all but one of the sites in the EO lighting sample (n=65) were based on the application of site-specific annual hours of use assumptions, which is stated as an option in the PSD and is consistent with the MA TRM for downstream lighting. The EO lighting realization rate using this method is very stable and near 100% overall.

Recommendation 2: Revise the PSD to explicitly call for the use of site-specific annual hours of use assumptions when calculating EO lighting energy savings and to use upstream lighting recommended annual hours of use by business type when site-specific assumptions do not exist, which the 2020 Upstream lighting program does.

Conclusion 3: This EO study sample included nine non-lighting sites (out of 52) that had evaluated summer seasonal peak savings results without a tracking counterpart. The table on the left shows the realization rate relative to the raw tracking savings (including zeros) while the table on the right provides a realization rate that approximates a realization rate had all tracking estimates of summer peak been populated (by removing sites with zero tracking savings with evaluated savings). The realization rate on the left is retrospective, while the result used as the prospective realization rate is dependent on any actions taken to improve the population of tracking values as noted in recommendation #3 below.

Table 6-3: EO Electric Summer Seasonal Peak Demand Realization Rate Results Relative to Tracking Savings (with Zero Tracking Estimates)

Sampling Category (n)	Summer Seasonal Peak Realization Rate	Precision at 80% CI
HVAC (n=26)	192.5%	±44.6%
Lighting (n=65)	98.9%	±10.6%
Other (n=26)	123.9%	±15.4%
Overall (n=117)	106.7%	±10.1%

Table 6-4: EO Electric Summer Seasonal Peak Demand Realization Rate Results (with Zero Tracking Estimates Removed)

Sampling Category (n)	Summer Seasonal Peak Realization Rate	Precision at 80% CI
HVAC (n=20)	146.4%	±47.0%
Lighting (n=65)	98.9%	±10.6%
Other (n=23)	114.7%	±16.4%
Overall (n=108)	103.1%	±10.2%

Recommendation 3: We recommend the PSD or companies either establish a new protocol to ensure fully populated seasonal summer peak tracking estimates and uses the realization rates in the rightmost column prospectively or use the realization rates in the second column prospectively in the event the rate of unpopulated/zero seasonal summer peak estimates is expected continue in future years.

Table 6-5: EO Electric Summer Seasonal Peak Demand Realization Rate Recommendations by End Use

End Use	Prospective realization rate if populated summer seasonal peak tracking estimates …	
	Remain similar to that observed in this study	Are fully populated moving forward
Cooling	192.5%	146.4%
Heating	192.5%	146.4%
Lighting	98.9%	98.9%
Custom	106.7%	103.1%
EMS	123.9%	114.7%
Motors	123.9%	114.7%
Other	123.9%	114.7%
Process	123.9%	114.7%
Refrigeration	123.9%	114.7%

Conclusion 4: The EO lighting tracking summer seasonal peak demand savings estimates are typically based on the application of the PSD summer seasonal coincidence factor assumptions by building type. The

data leveraging summer seasonal coincidence factor results by building type are as follows. The weighted average of these results is 76.4%, which is higher than the current PSD average of 67.2% but very similar to the on peak MA TRM average of 80% when both are weighted the same way.

Table 6-6: EO Electric Summer Seasonal Peak Coincidence Factor Results by Building Type

Building Type	Summer Seasonal Peak CF	Building Type	Summer Seasonal Peak CF
24x7 lighting	100.0%*	Other	86.9%*
Automotive	68.3%*	Parking Lot/Streetlights	67.2%*
Education	36.8%*	Religious bldg/Convention center	17.0%*
Grocery	90.6%	Restaurant	83.1%
Health Care	82.5%*	Retail	98.4%*
Hotel/Motel	40.6%*	Small Office	76.8%*
Industrial	83.0%*	Warehouse	89.3%*
Large Office	77.9%		

*Results that are statistically different from the current PSD assumptions at the 80% CI or for which there are no current assumptions in the PSD.

Recommendation 4: Update the EO lighting summer seasonal peak coincidence factor assumptions by building type in the PSD so they are consistent with those that are statistically different from the current PSD assumption and retain the current PSD assumption for those results that are not statistically different from the current PSD assumption. These values are provided below. The MA TRM assumption did not influence these recommendations since it assumes a single coincidence factor (80.0%) for all building types.

Table 6-7: EO Electric Summer Seasonal Peak Coincidence Factor Recommendations by Building Type

Building Type	Summer Seasonal Peak CF	Building Type	Summer Seasonal Peak CF
24x7 lighting	100.0%	Other	86.9%
Automotive	68.3%	Parking Lot/Streetlights	67.2%
Education	36.8%	Religious bldg/Convention center	17.0%
Grocery	90.4%	Restaurant	77.5%
Health Care	82.5%	Retail	98.4%
Hotel/Motel	40.6%	Small Office	76.8%
Industrial	83.0%	Warehouse	89.3%
Large Office	70.2%		

Conclusion 5: This EO study sample included seven non-lighting sites (out of 52) that had evaluated winter seasonal peak savings results without a tracking counterpart. The table on the left shows the realization rate relative to the raw tracking savings (including zeros) while the table on the right provides a realization rate that approximates a realization rate had all tracking estimates of winter peak been populated (by removing sites with zero tracking savings with evaluated savings). The realization rate on the left is retrospective, while the result used as the prospective realization rate is dependent on any actions taken to improve the population of tracking values as noted in recommendation #5 below.

Table 6-8: EO Electric Winter Seasonal Peak Demand Realization Rate Results Relative to Tracking Savings (with Zero Tracking Estimates)

Sampling Category (n)	Winter Seasonal Peak Realization Rate	Precision at 80% CI
HVAC (n=26)	146.2%	±31.7%
Lighting (n=65)	115.3%	±7.6%
Other (n=26)	179.8%	±19.6%
Overall (n=117)	122.7%	±7.0%

Table 6-9: EO Electric Winter Seasonal Peak Demand Realization Rate Results (with Zero Tracking Estimates Removed)

Sampling Category (n)	Winter Seasonal Peak Realization Rate	Precision at 80% CI
HVAC (n=21)	125.0%	±31.1%
Lighting (n=65)	115.3%	±7.6%
Other (n=23)	162.1%	±17.2%
Overall (n=109)	120.1%	±7.0%

Recommendation 5: We recommend the PSD or companies either establish a new protocol to ensure fully populated seasonal winter peak tracking estimates and uses the realization rates in the rightmost column prospectively or use the realization rates in the second column prospectively in the event the rate of unpopulated seasonal summer peak estimates is expected to continue in future years.

Table 6-10: EO Electric Winter Seasonal Peak Demand Realization Rate Recommendations by End Use

End Use	Prospective realization rate if populated winter seasonal peak tracking estimates …	
	Remain similar to that observed in this study	Are fully populated moving forward
Cooling	146.2%	125.0%
Heating	146.2%	125.0%
Lighting	115.3%	115.3%
Custom	122.7%	120.1%
EMS	179.8%	162.1%
Motors	179.8%	162.1%
Other	179.8%	162.1%
Process	179.8%	162.1%
Refrigeration	179.8%	162.1%

Conclusion 6: The EO lighting tracking winter seasonal peak demand savings estimates are typically based on the application of the PSD winter seasonal coincidence factor assumptions by building type. The data leveraging winter seasonal coincidence factor results by building type are as follows. The weighted average of these results is 66.2%, which is higher than the current PSD average of 50.1% but very similar to the on peak MA TRM average of 61.0% when both are weighted the same way.

Table 6-11: EO Electric Winter Seasonal Peak Coincidence Factor Results by Building Type

Building Type	Winter Seasonal Peak CF	Building Type	Winter Seasonal Peak CF
24x7 lighting	100.0%*	Other	76.7%*
Automotive	36.9%*	Parking Lot/Streetlights	87.3%*
Education	46.0%*	Religious bldg/Convention center	9.2%*
Grocery	85.6%*	Restaurant	77.0%*
Health Care	69.6%*	Retail	85.6%*
Hotel/Motel	37.5%*	Small Office	44.1%*
Industrial	66.5%*	Warehouse	72.4%*
Large Office	58.2%		

*Results that are statistically different from the current PSD assumptions at the 80% CI or for which there are no current assumptions in the PSD.

Recommendation 6: Update the EO lighting winter seasonal peak coincidence factor assumptions by building type in the PSD so they are consistent with those that are statistically different from the current PSD assumption and retain the current PSD assumption for those results that are not statistically different from the current PSD assumption. These values are provided below. The MA TRM assumption did not influence these recommendations since it assumes a single coincidence factor (61.0%) for all building types.

Table 6-12: EO Electric Winter Seasonal Peak Coincidence Factor Recommendations by Building Type

Building Type	Winter Seasonal Peak CF	Building Type	Winter Seasonal Peak CF
24x7 lighting	100.0%	Other	76.7%
Automotive	36.9%	Parking Lot/Streetlights	87.3%
Education	46.0%	Religious bldg/Convention center	9.2%
Grocery	85.6%	Restaurant	77.0%
Health Care	69.6%	Retail	85.6%
Hotel/Motel	37.5%	Small Office	44.1%
Industrial	66.5%	Warehouse	72.4%
Large Office	53.9%		

6.2 EO Gas Conclusions and Recommendations

Conclusion 7: The retrospective and prospective EO gas energy savings realization rates by sampling category are below.

Table 6-13: EO Gas Energy Savings Realization Rate Results

Sampling Category	Retrospective		Prospective	
	Realization Rate	Precision at 90% CI	Realization Rate	Precision at 90% CI
HVAC/DHW	74.7%	±17.4%	76.5%	±17.5%
Other	78.2%	±27.3%	78.2%	±27.3%
Overall	76.3%	±15.8%	77.3%	±15.7%

Recommendation 7: Update the gas energy savings realization rates by end use in the PSD so they are consistent with the prospective realization rates found in this study as provided in the rightmost two columns presents in conclusion 7 above.

6.3 Upstream Lighting Conclusions and Recommendations

Conclusion 8: The tracking system savings assume a 100% in-service rate for all products. The Upstream lighting short- and long-term[43] in-service rates by sampling category are shown in the table below.

Table 6-14: Upstream Lighting In-Service Rate Results

Sampling Category	Short Term		Long Term	
	In-Service Rate	Precision at 90% CI	In-Service Rate	Precision at 90% CI
Category 1 LED Linear	97.1%	±1.9%	97.4%	±1.8%
Category 3 LED Downlights	85.9%	±22.5%	86.4%	±22.3%
Category 4 LED A-line/Deco	71.4%	±15.7%	74.9%	±13.8%
Category 7 LED High/Low Bay	99.6%	±0.6%	99.7%	±0.5%
Overall	95.5%	±2.5%	96.0%	±2.4%

Recommendation 8: Include Upstream lighting in-service rates in the PSD so that they are consistent with the short-term results of this study as provided in conclusion 8 above.

Conclusion 9: The Upstream lighting delta watts and realization rates by sampling category are presented in the table below. Although the magnitude between the LED linear result (15.3 delta watts) is not large when compared to the average observed in the tracking data (12.9 watts), they are still statistically different at the 80% confidence interval. The result of 157.3 in the LED high and low bay category is substantially different than that observed in the tracking data (212.2 watts).

[43] Long term in-service rates apply to projects where measure have been installed at a purchaser's site for one year or more.

Table 6-15: Upstream Lighting Delta Watts Results

Sampling Category	Delta Watts	Realization Rate	Precision at 90% CI
Category 1 LED Linear	15.33*	118.8%	±8.9%
Category 3 LED Downlights	44.50	108.1%	±17.0%
Category 4 LED A-line/Deco	46.86	116.2%	±16.0%
Category 7 LED High/Low Bay	157.33*	74.1%	±30.4%
Overall	N/A	99.8%	±10.7%

*Results that are statistically different from the current tracking system savings assumptions at the 90% CI

Recommendation 9: Continue to use the measure type delta watts assumptions provided in the 2020 PSD. Include the kWh realization rates without the in-service rates (which is a separate assumption in the 2020 PSD) by upstream lighting product category in the PSD as shown in recommendation 11.

Conclusion 10: The Upstream lighting tracking savings for the majority of interior spaces were based on the PSD annual HOU assumption for offices (3,748 hours), though some spaces used 70% of 8,760 (6,132 hours) for other interior spaces. The data leveraging annual hours of use results by building type are below.

Table 6-16: Data Leveraging Hours of Annual Hours of Use Results by Building Type

Building Type	Annual Hours of Use	Building Type	Annual Hours of Use
24x7 lighting	8,760*	Other	6,211*
Automotive	2,807	Parking Lot/Streetlights	6,887*
Education	2,967*	Religious bldg/Convention center	913*
Grocery	7,698*	Restaurant	6,072*
Health Care	5,564*	Retail	6,318*
Hotel/Motel	3,112	Small Office	3,595
Industrial	5,793*	Warehouse	5,667*
Large Office	4,098*		

*Results that are statistically different from the current PSD assumptions at the 90% CI or for which there are no current assumptions in the PSD.

Recommendation 10: Update the Upstream lighting annual hours of use assumptions by building type in the PSD so they are consistent with those reported in the table below. These recommendations have been made based on the statistical significance testing performed around the results as compared to both the current PSD assumptions and the current MA TRM assumptions. The recommendations have also been made after making judgements based on the data leveraging results and taking into consideration the sample size and precision around them.

Table 6-17: Upstream Lighting Annual Hours of Use Recommendations by Building Type

Building Type	Annual Hours of Use	Building Type	Annual Hours of Use
24x7 lighting	8,760	Other	6,211
Automotive	4,056	Parking Lot/Streetlights	6,887
Education	2,967	Religious bldg/Convention center	913
Grocery	5,468*	Restaurant	5,018*
Health Care	5,564	Retail	4,939*
Hotel/Motel	3,064	Small Office	3,748
Industrial	5,793	Warehouse	5,667
Large Office	4,098		

*Based on the MA TRM assumption since the data leveraging result assumes hours of operation which seem unreasonable for the average building of this type.

<u>Conclusion 11</u>: The tracking system savings do not account for interactive effects, implying an energy and demand interactive factor of 1.000. The Upstream lighting energy and summer demand interactive factors by sampling category are below.

Table 6-18: Upstream Lighting Interactive Factor Results

Sampling Category	Energy		Demand	
	Interactive Factor	Precision at 90% CI	Summer Interactive Factor	Precision at 90% CI
Category 1 LED Linear	1.081*	±3.6%	1.199*	±3.5%
Category 3 LED Downlights	1.023	±4.3%	1.189*	±4.7%
Category 4 LED A-line/Deco	1.000	±0.0%	1.176*	±7.1%
Category 7 LED High/Low Bay	1.008	±1.2%	1.047*	±3.9%
Overall	1.024	±2.4%	1.152*	±3.4%

*Results that are statistically different from the current tracking system savings assumptions at the 90% CI

<u>Recommendation 11</u>: Include the energy and demand interactive factors in the tracking savings through the application of the kWh realization rates by upstream lighting product category as shown below.

Table 6-19: Upstream Lighting kWh Realization Rate Recommendations Without In-Service Rates

Sampling Category	Delta Watts RR	HOU RR*	Interactive Factor RR	kWh RR w/o ISR
Category 1 LED Linear	105.0%	100.0%	108.1%	113.5%
Category 3 LED Downlights	123.8%	100.0%	102.3%	126.7%
Category 4 LED A-line/Deco	167.2%	100.0%	102.4%	171.2%
Category 7 LED High/Low Bay	74.1%	100.0%	100.8%	74.7%
Overall	96.6%	100.0%	102.4%	98.9%

*Assume 100.0% HOU RR due to application of building type annual HOU assumptions provided in recommendation 10.

6.4 Considerations

Consideration 1: Only 13 sites in the EO lighting sample included the installation of occupancy sensors. The current PSD hour reduction assumption is 0.3, which is consistent with the MA TRM assumption. As discussed earlier in this report, sensor performance at these sites suggest that there may be more reduction occurring. However, due to the small sample size we do not make a recommendation on the use of the HOU reduction factor from this study. However, to the extent that lighting occupancy sensors become installed more prominently through the EO program and this factor becomes increasingly important, a more robust study or examination of existing studies (including those performed in MA) may be needed to confirm or disconfirm the current PSD assumption.

Consideration 2: We suggest the EEB consider using the error ratios experienced in this study to size samples in future impact studies of the EO program. This will help ensure future sample sizes are planned in a way that is optimized based on the findings of this study.

APPENDIX A. SEASONAL PEAK PERIODS METHODOLOGY

In the ISO New England Forward Capacity Market, a participant may submit energy-efficiency "other demand resources" as one of three different types: On-Peak, Seasonal Peak, and Critical Peak. In Connecticut, Eversource and United Illuminating participates in FCM as a Seasonal Peak Demand Resource. The distinction is simply that the demand reduction value is computed as the average demand across the corresponding "Peak Hours" period. The following definitions are taken from ISO New England's FERC Electric Tariff No. 3:

> **"Demand Resource On-Peak Hours** are hours ending 1400 through 1700, Monday through Friday on non-holidays during the months of June, July, and August and hours ending 1800 through 1900, Monday through Friday on non-holidays during the months of December and January.
>
> **"Demand Resource Seasonal Peak Hours** are those hours in which the actual, Real-Time hourly load for 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% of the most recent 50/50 system peal load forecast, as determined by the ISO, for the applicable summer or winter season."[44]

It is considerably more complex to assess coincidence relative to the Demand Resource Seasonal Peak Hours because they are conditional in nature and depend upon the relationship between real time system load and the most recent 50/50 system peak load forecast. The remainder of this section details DNV GL's analytical approach to this challenge.

The calculation of the summer seasonal peak demand reduction was based on the performance hours that were used to evaluate the Demand Reduction Values (DRV). Seasonal demand performance hours for ISO-NE FCM are defined as hours when the real time ISO-NE system load meets or exceeds 90% of the predicted seasonal peak from the most recent Capacity, Electricity, Load and Transmission Report (CELT report). The peak load forecast for the summer 2018 season was 26,512 MW, and 90% of which was 23,861 MW. There were 30 hours during the summer 2018 season when the load exceeded 23,861 MW. The evaluation used Hartford, CT real weather data for the summer of 2018 to calculate the weighted Total Heat Index (THI) at each hour. The Total Heat Index is a forecast variable used by ISO-NE and it is calculated as follows;

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

THI = Total Heat Index

DBT = Dry Bulb Temperature (°F)

DPT = Dew Point Temperature (°F)

[44] ISO New England, FERC Electric Tariff No. 3, General Terms and Conditions, Section I.2 – Rules of Construction; Definitions, Effective: January 24, 2010, Original Sheet No. 15L.

Table 6-20 provides the summer 2018 seasonal peak hours along with the system load, percent of CELT forecast peak and the Total Heat Index (THI) for Hartford, CT.

Table 6-20. 2018 Summer Seasonal Peak Hours and System Load

Date	Hour Ending	System Load (MW)	Percent of Peak	Hartford, CT THI
7/3/2018	17	23,992	90%	82.1
7/3/2018	18	23,904	90%	80.2
7/5/2018	17	23,992	90%	81.8
7/5/2018	18	24,188	91%	80.8
7/5/2018	19	23,966	90%	80.1
8/6/2018	17	24,300	92%	81.7
8/6/2018	18	24,685	93%	81.0
8/6/2018	19	24,555	93%	79.7
8/6/2018	20	23,983	90%	78.5
8/7/2018	14	23,873	90%	82.3
8/7/2018	15	24,236	91%	82.2
8/7/2018	16	24,335	92%	81.8
8/7/2018	17	24,334	92%	81.4
8/7/2018	18	24,202	91%	76.0
8/28/2018	15	24,311	92%	83.6
8/28/2018	16	24,683	93%	82.8
8/28/2018	17	25,086	95%	82.3
8/28/2018	18	25,365	96%	82.1
8/28/2018	19	25,125	95%	80.9
8/28/2018	20	24,814	94%	79.9
8/28/2018	21	24,289	92%	79.4
8/29/2018	13	23,968	90%	83.4
8/29/2018	14	24,720	93%	83.0
8/29/2018	15	25,025	94%	83.5
8/29/2018	16	25,232	95%	83.5
8/29/2018	17	25,573	96%	82.8
8/29/2018	18	25,763	97%	81.5
8/29/2018	19	25,317	95%	81.1
8/29/2018	20	24,931	94%	79.3
8/29/2018	21	24,308	92%	78.3

ISO-NE also uses a variable called a Weighted Heat Index (WHI) which is a three-day weighted average of the THI and is calculated as follows;

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

WHI = Weighted Heat Index

$THI_{di\ hi}$= Total Heat Index for the current day and hour

$THI_{d(i-1)\ hi}$= Total Heat Index for previous day and same hour

$THI_{d(i-2)\ hi}$= Total Heat Index for two days prior and same hour

The peak load data and the weighted THI and WHI data for 2018 were used to create linear regressions of peak system load as a function of THI and WHI. The analysis focused on non-holiday weekdays from June through August during hours ending 13 through 21. Evaluators used the time window of hours ending 13 to 21 based on the above observed peaks in the 2018 season.

The following THI & WHI cutoff points were the result of the regression analyses. These represent the selection points at which both the THI and WHI from a Hartford, CT TMY3 weather file must be greater than in order to trigger a summer seasonal peak hour.

THI Cutoff Point: 80.9

WHI Cutoff Point: 80.5

Table 6-21 provides a list of all hours from the Hartford, CT TMY3 weather file that met the above criteria of exceeding both the THI and WHI thresholds. There are a total of 27 TMY3 hours applied to the 2018 evaluation year that meet the criteria for being selected as a summer seasonal peak hour.

Table 6-21. Summary of Summer Seasonal Hours for Hartford, CT TMY3 File

Date	Hour Ending	THI	WHI
7/10/2018	14	82.2	81.0
7/10/2018	15	82.7	81.4
7/11/2018	13	81.3	81.4
7/11/2018	14	82.1	82.0
7/11/2018	15	82.1	82.2
7/11/2018	17	81.6	80.6
7/12/2018	13	81.4	81.3
7/12/2018	14	82.2	82.1
7/12/2018	15	81.4	81.7
7/13/2018	15	80.9	81.2
7/24/2018	13	82.9	81.3
7/24/2018	14	83.6	82.3
7/24/2018	15	83.6	82.3
7/24/2018	16	82.6	81.9
7/24/2018	17	82.2	81.4
7/25/2018	13	81.4	81.5
7/25/2018	14	82.5	82.6
7/25/2018	15	82.9	82.7
7/25/2018	16	82.1	82.0
7/25/2018	17	82.1	81.8
7/25/2018	18	80.9	80.7
8/6/2018	13	82.5	81.5
8/6/2018	14	82.4	82.1
8/6/2018	15	82.0	81.7
8/6/2018	16	81.5	81.5
8/6/2018	17	81.5	81.4
8/6/2018	18	81.3	80.6

The calculation of the winter seasonal peak demand reduction was based on the performance hours that were used to evaluate the Demand Reduction Values (DRV). Seasonal demand performance hours for ISO-NE FCM are defined as hours when the real time ISO-NE system load meets or exceeds 90% of the predicted seasonal peak from the most recent Capacity, Electricity, Load and Transmission Report (CELT report).

The peak load forecast for the winter 2017/2018 season was 20,714 MW, and 90% of which was 18,643 MW. There were a total of 54 hours during the winter 2017/2018 season when the load was 18,643 MW or greater. Table 6-22 provides a list of the winter seasonal peak hours along with the system load, the percentage of forecasted peak and the dry bulb temperature (DBT) for each hour for Hartford, CT.

Table 6-22. Winter 17/18 Seasonal Peak Hours and System Loads

Date	Hour Ending	System Load (MW)	Percent of Peak	Hartford, CT DBT		Date	Hour Ending	System Load (MW)	Percent of Peak	Hartford, CT DBT
12/13/2017	18	19,121	92%	23		1/2/2018	17	19,568	94%	21
12/13/2017	19	19,038	92%	22		1/2/2018	18	20,629	100%	20
12/13/2017	20	18,681	90%	21		1/2/2018	19	20,639	100%	19
12/14/2017	18	18,792	91%	21		1/2/2018	20	20,266	98%	16
12/14/2017	19	18,795	91%	19		1/2/2018	21	19,601	95%	15
12/15/2017	18	18,685	90%	23		1/3/2018	18	19,446	94%	22
12/27/2017	18	19,522	94%	16		1/3/2018	19	19,539	94%	22
12/27/2017	19	19,457	94%	14		1/3/2018	20	19,238	93%	19
12/27/2017	20	19,080	92%	13		1/3/2018	21	18,729	90%	19
12/28/2017	17	19,550	94%	10		1/4/2018	12	18,773	91%	21
12/28/2017	18	20,523	99%	9		1/4/2018	13	18,696	90%	23
12/28/2017	19	20,418	99%	7		1/4/2018	17	18,674	90%	24
12/28/2017	20	20,015	97%	7		1/4/2018	18	19,450	94%	23
12/28/2017	21	19,429	94%	7		1/4/2018	19	19,156	92%	23
12/29/2017	10	18,742	90%	4		1/5/2018	16	18,746	91%	12
12/29/2017	11	18,709	90%	8		1/5/2018	17	19,631	95%	10
12/29/2017	17	19,125	92%	16		1/5/2018	18	20,663	100%	8
12/29/2017	18	20,014	97%	13		1/5/2018	19	20,607	99%	7
12/29/2017	19	19,825	96%	12		1/5/2018	20	20,185	97%	7
12/29/2017	20	19,397	94%	12		1/5/2018	21	19,648	95%	7
12/29/2017	21	18,874	91%	11		1/5/2018	22	18,874	91%	7
1/2/2018	8	19,033	92%	3		1/8/2018	18	19,209	93%	27
1/2/2018	9	19,214	93%	3		1/8/2018	19	19,104	92%	26
1/2/2018	10	19,100	92%	7		1/15/2018	17	19,040	92%	21
1/2/2018	11	18,905	91%	11		1/15/2018	18	19,831	96%	21
1/2/2018	12	18,665	90%	15		1/15/2018	19	19,592	95%	21
1/2/2018	16	18,672	90%	20		1/15/2018	20	19,021	92%	21

The 2017/2018 peak load data and the Hartford, CT temperature data were used to create linear regressions of peak system load as a function of dry bulb temperature. The results of the regression were used to identify the seasonal peak hours using the Hartford, CT TMY3 weather data. The analysis focused on low temperature periods in December and January between hours ending 8 and 22. Evaluators included this hour range based on the observed peaks in the 2017/2018 season in the table above.

The following DBT cutoff point was the result of the regression analysis. This represents the selection point at which the DBT from the Hartford, CT TMY3 weather file must be less than in order to trigger a winter seasonal peak hour.

DBT Cutoff Point: 17.9°F

Table 6-23 provides a list of the winter seasonal peak hours from the Hartford, CT TMY3 that meet the criteria above. There is a total of 40 hours that qualify.

Table 6-23. Summary of Winter Seasonal Hours for Hartford, CT TMY3 File

Date	Hour Ending	DBT		Date	Hour Ending	DBT
1/4/2018	8	16		1/31/2018	22	16
1/24/2018	21	17		12/11/2018	8	16
1/24/2018	22	16		12/13/2018	8	8
1/25/2018	8	17		12/13/2018	9	14
1/30/2018	8	14		12/13/2018	10	15
1/30/2018	9	15		12/13/2018	11	17
1/30/2018	10	17		12/13/2018	19	17
1/30/2018	18	17		12/13/2018	20	15
1/30/2018	19	15		12/13/2018	21	13
1/30/2018	20	14		12/13/2018	22	12
1/30/2018	21	14		12/14/2018	8	3
1/30/2018	22	13		12/14/2018	9	8
1/31/2018	8	10		12/14/2018	10	11
1/31/2018	9	12		12/14/2018	11	15
1/31/2018	10	13		12/14/2018	18	15
1/31/2018	11	16		12/14/2018	19	14
1/31/2018	18	17		12/14/2018	20	15
1/31/2018	19	15		12/14/2018	21	12
1/31/2018	20	14		12/14/2018	22	13
1/31/2018	21	13		12/21/2018	8	15

APPENDIX B. DETAILED POPULATION SUMMARIES

This appendix provides summaries of the EO 2016/2017 electric and gas sample frames and the 2018 upstream lighting sample frame used in this study. These breakdowns include energy and peak savings tracking activity by end use or sample end use category and utility.

Table 6-24. 2016-2017 Electric Savings by End Use and Utility

Measure	# Projects	Annual MWh	Summer Seasonal Peak kW	Winter Seasonal Peak kW
Eversource				
Cooling	155	13,283.0	1,647.9	806.6
Heating	37	2,095.0	38.1	378.3
Lighting	2,052	175,111.0	21,418.3	19,334.7
Motor	68	7,073.0	565.4	554.3
Process	43	9,375.5	891.0	577.6
Refrigeration	83	11,239.0	591.3	1,108.2
Other	52	3,643.6	358.1	229.9
Subtotal	**2,176**	**221,821.0**	**25,510.0**	**22,990.0**
United Illuminating				
Cooling	7	1,310.0	17.3	-
Heating	4	68.5	-	5.1
HVAC	37	2,258.0	232.6	119.7
Lighting	519	56,979.0	6,470.7	6,151.7
VFD's	7	150.2	-	-
Process	11	7,111.0	332.2	199.0
Refrigeration	18	853.0	21.3	35.5
Custom	47	3,292.0	127.9	82.4
Subtotal	**567**	**72,021.7**	**7,202.1**	**6,593.4**
Grand Total	**2,743**	**293,842.7**	**32,712.0**	**29,583.4**

Table 6-25. 2016-2017 Electric Savings by Measure Category and Utility

Measure Category	Accounts	Annual Savings (MWh)	Summer Seasonal Peak Savings (kW)	Winter Seasonal Peak Savings (kW)
Eversource				
Lighting	2,053	175,111	21,418	19,335
HVAC & DHW	170	15,378	1,686	1,185
Everything Else	209	31,331	2,406	2,470
Eversource Total	2,176	221,821	25,510	22,990
United Illuminating				
Lighting	519	56,979	6,471	6,152
HVAC & DHW	47	3,636	250	125
Everything Else	75	11,406	481	317
Avangrid Total	567	72,022	7,202	6,593
Statewide				
Lighting	2,572	232,090	27,889	25,487
HVAC & DHW	217	19,015	1,936	1,310
Everything Else	284	42,738	2,887	2,787
Statewide Total	2,743	293,843	32,712	29,583

Table 6-26. 2016-2017 of Gas Savings by End Use and Utility

Measure	# Projects	CCF
Eversource		
DHW	7	37,982
Heating	91	1,245,386
Other	8	47,185
Process	19	778,180
Subtotal	**112**	**2,108,733**
AvanGrid		
Custom	35	154,028
DHW	7	982
Heating	43	376,495
HVAC	23	537,224
Process	7	776,718
Subtotal	**96**	**1,845,447**
Grand Total	**208**	**3,954,180**

Table 6-27. 2018 CT C&I Upstream Lighting program tracking savings summary by MA LED sample category[45]

MA Upstream Lighting Category	Description	Eversource			UI			Total			
		Custom-ers	Qty	kWh Savings	Custom-ers	Qty	kWh Savings	Custom-ers	Qty	kWh Savings	% of Total
Category 1	Linear LEDs	2,525	237,767	13,210,894	275	40,792	2,097,431	2,800	278,559	15,308,325	47.5%
Category 2	LED Stairwell Kits	8	51	22,574	0	0	0	8	51	22,574	0.1%
Category 3	LED Downlights	1,068	25,519	4,299,059	89	4,234	555,528	1,157	29,753	4,854,587	15.1%
Category 4	LED A-Line/Deco	429	16,713	2,457,531	64	5,548	703,041	493	22,261	3,160,573	9.8%
Category 5	GU24 LEDs	86	5,993	304,839	6	1,096	52,580	92	7,089	357,419	1.1%
Category 6	LED Exterior Wall-packs	153	685	315,401	8	48	24,647	161	733	340,048	1.1%
Category 7	High/Low Bay LEDs	456	9,588	7,732,974	11	372	301,763	467	9,960	8,034,737	25.0%
N/A	Linear Fluorescents	96	8,424	116,253	0	0	0	96	8,424	116,253	0.4%
	Total	**3,907**	**304,740**	**28,459,526**	**365**	**52,090**	**3,734,990**	**4,272**	**356,830**	**32,194,516**	**100.0%**

45 The MA Upstream Lighting Categories are based on the most recent impact evaluation work conducted in Massachusetts of the MA C&I Upstream Lighting Initiative.

APPENDIX C. DETAILED SAMPLE SUMMARIES

This appendix provides summaries of the EO 2016/2017 electric and gas final sample and the 2018 upstream lighting final sample frame used in this study. These breakdowns show the various strata cut points used for each measure category and population, sample points in each, and case weights.

Table 6-28. Final EO Electric Sample by measure group and strata

Measure	Stratum	Maximum (kWh)	Population Count	Total Annual Savings (kWh)	Sample Size	Case Weight
Lighting	1	51,118	1,742	27,652,204	13	134.0
	2	141,930	426	37,084,821	13	32.8
	3	269,468	229	43,090,036	13	17.6
	4	619,778	122	50,506,276	13	9.4
	5	4,927,788	52	65,210,000	12	4.3
	6	8,546,989	1	8,546,989	1	1.0
HVAC	1	86,493	154	4,557,773	9	17.1
	2	204,727	43	5,835,312	8	5.4
	3	733,383	19	7,469,099	8	2.4
	4	1,152,514	1	1,152,514	1	1.0
Other	1	153,098	203	9,774,119	9	22.6
	2	336,636	57	12,739,274	8	7.1
	3	1,543,121	23	16,264,766	8	2.9
	4	3,959,715	1	3,959,715	1	1.0

Table 6-29. EO Gas Sample by measure group and strata

End Use	Stratum	Maximum (CCF)	Population Count	Total Annual Savings (CCF)	Sample Size	Case Weight
HVAC/DHW	1	8,263	98	236,292	6	16.3
	2	18,710	24	307,718	6	4.0
	3	29,522	14	360,684	6	2.3
	4	47,326	11	394,355	5	2.2
	5	72,582	7	443,267	5	1.4
	6	301,998	2	454,770	2	1.0
Other	1	14,302	56	193,055	5	11.2
	2	45,462	11	271,508	4	2.8
	3	79,163	6	355,718	4	1.5
	4	557,029	3	936,812	3	1.0

APPENDIX D. METERING EQUIPMENT USED

This study used the metering devices itemized below. Individual reports developed for each site visited contain information on the meters deployed, the data gathered, and how it was used to develop the savings estimates.

DENT ELITEpro power loggers that monitor voltage, amperage, power factor, and kW over the monitoring period. The monitoring frequency was typically 15-minutes or less. ELITEpro power loggers were installed on variable load equipment including fans pumps, compressors, packaged equipment, lighting projects, and process equipment. The current transformers used with these loggers include:

1. Split-core current transformers manufactured by DENT and Magnelab to measure current ranging from 5 amps to 600 amps nominally.
2. Rogowski coil current transformers manufactured by DENT. These current transformers measure between 5 amps and 5,000 amps.

Continental Control Systems Wattnode Pulse energy meters that measure kWh. The monitoring period was typically 15-minutes or less. Wattnode loggers were installed in similar applications where DENT ELITEPro power loggers were installed. The data from these meters was typically logged in either a HOBO H-21-002 logger, or a HOBO UX-90-001 state data logger. The current transformers were split-core units manufactured by DENT or Magnelab.

Amprobe 220 power meters that spot measure voltage, amperage, power factor, and kW during a short period during the site visits. This meter data was used to measure power factor in situations where a DENT ELITEpro meter could not be installed.

HOBO H-21-002, H-22-001 data loggers that record amperage, kWh, temperature, humidity and pressure, depending on what sensors are connected. The monitoring frequency was 15-minutes or less. HOBO H-21-002 loggers are waterproof loggers and were used in applications where outdoor air temperature/humidity measurements were taken. HOBO H-22-001 loggers were used in indoor applications. The sensors that were typically installed with these loggers are as follows:

1. Split-core current transformers manufactured by DENT and Magnelab to measure current ranging from 5 amps to 600 amps nominally.
2. Wattnode energy meters that monitor kWh. These kWh meters used current transformers described above. Used for various types of projects.
3. HOBO S-THB-M002 sensors to measure temperature/humidity. These measure air temperatures between -40 and 167°F, and humidity between 10% and 90% RH. Typically used for HVAC projects.
4. HOBO S-TMB-M0xx sensors to measure temperature only. These measure temperatures between -40 and 212° F. Typically used for HVAC projects.
5. Ashcroft G2 gauge pressure transducers. Gauges used include pressure 0-50 psig, 0-100 psig, and 0-200 psig. Typically used for pumping applications, especially involving VFDs.
6. Veris differential air pressure transducer. Measures differential pressure from 0-0.1" W.C. to 0-10" W.C. Typically used for building shell weatherization projects.

DENT time of use (TOU) loggers measure the percent of time that equipment was on during the monitoring period, in increments as small as 1-minute to up to 1-day. The following DENT TOU loggers were used in this study.

1. DENT TOUL-4G Lighting logger to measure the operating hours for lighting projects. This logger uses a photosensor to determine if lighting equipment is on.
2. DENT TOUM-4G Motor logger to measure the operating hours of any motor-driven system. This logger responds to the electromagnetic field generated when a motor is on in motors that generate more than 40 mGauss of electric field
3. DENT TOUCT-4G CT logger to measure the operating hours equipment for any electric system using more than 0.25 amps. These were used in smaller motor applications, such as evaporator fan motors in refrigeration systems.

HOBO UX-100-003 temperature/humidity loggers that monitor temperature and humidity. The monitoring frequency was typically 5-minutes. These loggers were installed to monitor supply, return, mixed, and exhaust temperatures in HVAC upgrade projects such as those involving scheduling upgrades, demand control ventilation, or temperature resets or setbacks.

HOBO UX120-014M and UX100-014M thermocouple temperature loggers. The monitoring frequency was typically 5-minutes. HOBO UX120-14M and UX100-014M loggers with type-K thermocouples were installed as a primary option to monitor high temperature surfaces in applications such as pipe/fitting insulation projects, and steam trap upgrade projects. The UX120-14M loggers are 4-channel loggers, whereas the UX100-014M loggers are 1-channel.

HOBO MX1102A CO_2, temperature and humidity loggers. The monitoring frequency was 15-minutes or less. These loggers were used in projects that involved demand-controlled ventilation.

Pace Scientific XR440 Pocket Logger. This logger was also used in applications where gauge pressure was being measured and logged, typically for pumping applications. Pace Scientific P1600 pressure transducers were used with this logger. These pressure transducers come in ranges of 0-50 psig, 0-100 psig, and 0-200 psig.

Etekcity Infrared Thermometer Lasergrip 749. This infrared thermometer was used to take spot measurements of hot surfaces, including the bare surface temperature of pipes and fittings that had insulation added, and the inlets and outlets of steam traps.

UE Systems ultrasonic probe that identifies ultrasonic frequencies from steam traps and air leaks for compressed air systems. The meter is used for spot measurements during a site visit. UE Systems Ultraprobe 9000 was used as a primary option to identify steam trap operation and detect air leaks in compressed air systems.

Testo 340 combustion analyzer that monitors combustion efficiency and combustion fuel ratios. The meter is used for spot measurements during a site visit. Testo 340 Combustion Analyzer was used as a primary option to evaluate combustion efficiency.

APPENDIX E. SITE REPORTS (UNDER SEPARATE COVER)

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