FINAL REPORT

Impact Evaluation of PY2019 Rhode Island C&I Upstream Lighting Initiative

National Grid

Date: July 15, 2021

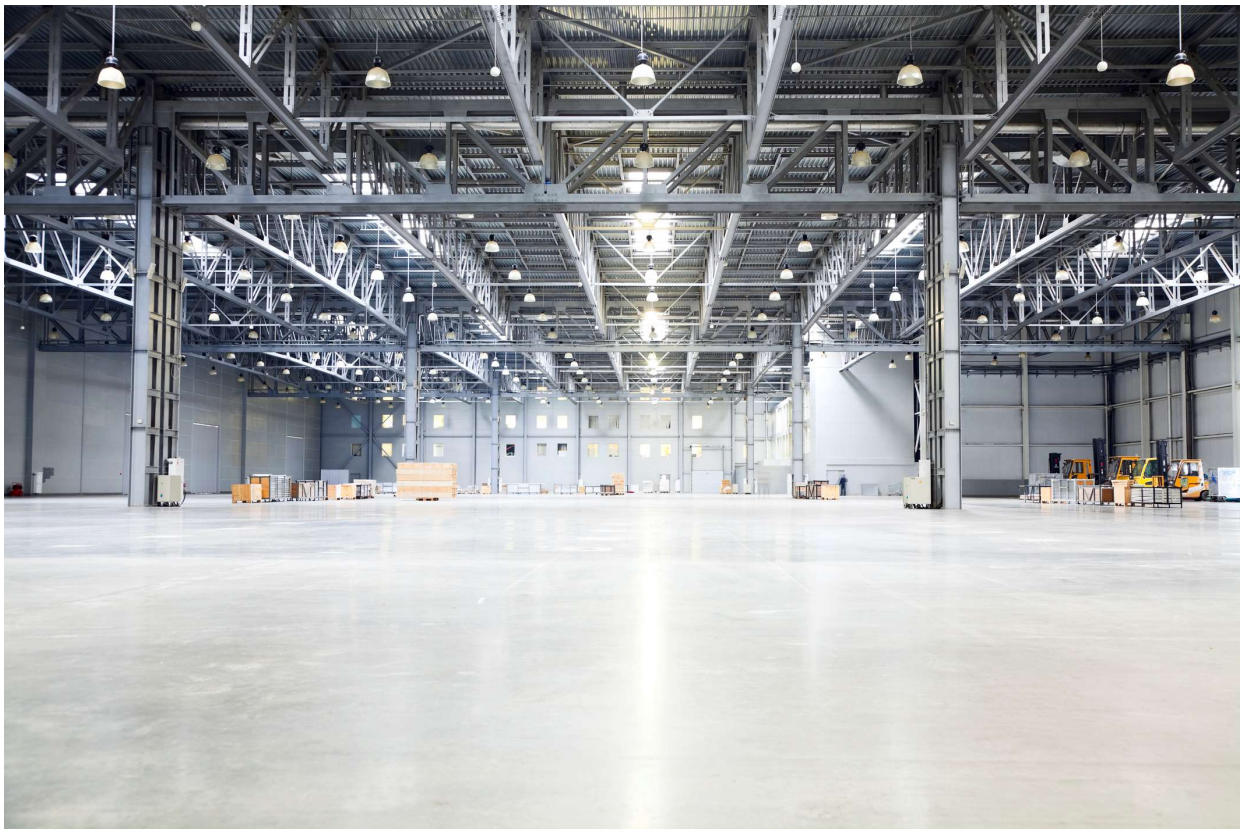


Table of contents

List of acronyms used in this report

BCR – benefit-cost ratio

C&I – commercial and industrial

CF – coincidence factor

CL – confidence level

EEAC – Energy Efficiency Advisory Council

ER – early replacement

HOU – hours of use

HVAC – heating, ventilation, and air conditioning

ISR – in-service rate

LED – light-emitting diode

NTG – net-to-gross

PAs – Program Administrators

PY – project year

QC – quality control

ROF – replace on failure

TLEDs – tubular LED

TRM – technical resource manual

1 CONSOLIDATED IMPACT FACTORS

1.1 Proposed new prospective energy savings factors[1]

For prospective application of results, we understand that National Grid has already locked in impact factors for the 2021 program but will be able to update impact factors for the 2022 program. Therefore, we provide two sets of prospective application results. For 2021, we provide realization rates that can be applied to existing program values. Since National Grid adopted the updated HOU values for 2021, the 2021 prospective realization rates exclude HOU adjustments. For 2022, we provide product-specific impact factors that can be applied. Given high variance in results, we have collapsed evaluation categories 1, 2, 3, 4, 5, and 6 and present screw-in LEDs separately. We elected to present screw-in LEDs separately due to the likely decrease in program activity for this evaluation category and eventual elimination from the initiative.

Table 1-1. 2021 prospective energy realization rates for the initiative[2]

Evaluation Category	TRM Realization Rate Assumption	Evaluation Energy Realization Rate	Precision at 90% CL
Category 1: TLEDs	78.0%	97.1%	±9.2
Category 2: LED Fixtures	78.0%	115.7%	±32.7%
Category 3: LED Fixtures w/Integrated Controls	78.0%	111.5%	±21.3%
Category 5: Exterior LEDs	68.0%	172.9%	±15.0%
Category 6: High/Low Bay LEDs	78.0%	52.8%	±24.0%
All Non-Screw-Ins	**77.2%**	**87.8%**	**±13.0%**
Category 4: Screw-In LEDs	78.0%	72.4%	±62.1%
Total	**77.3%**	**86.0%**	**±13.7%**

For prospective application of results (PY2022 and beyond), we recommend that National Grid replace tracking system factors with the evaluated system factors. The proposed new energy savings factors are provided in Table 1-2. Table 1-3 provides the energy and demand savings factors that were not updated as part of this study. It is our understanding that National Grid began using the updated HOU values provided in Table 1-4 for the 2021 program.

For fixtures with integrated controls, since metering is still taking place, we have not updated the controls savings factor. The control metering will be completed by July 2021 and we will recommend updated values for 2022 and beyond for that measure category at that time in a separate memo.

[1] Energy savings factors include energy realization rates, installation rates, kW saved per unit, hours of use, and HVAC interactive factors.

[2] Note: these realization rates exclude the HOU realization rates because National Grid has already adopted the proposed revised HOU values

Table 1-2. Proposed new energy savings factors

Product type	BCR Category	Evaluation Category	Short term Installation rate		kW Saved per Unit	
			Existing	Updated	Existing	Updated
PAR20	Screw-In LEDs	4	76%	49%	0.0281	0.0396
PAR30	Screw-In LEDs	4	76%	49%	0.0381	0.0537
PAR38	Screw-In LEDs	4	76%	49%	0.0442	0.0623
MR16	Screw-In LEDs	4	76%	49%	0.0221	0.0311
A-line, 75/100w	Screw-In LEDs	4	76%	49%	0.0305	0.0430
Decoratives	Screw-In LEDs	4	76%	49%	0.0136	0.0192
LED Retrofit kit, <25W	LED Fixtures	2	76%	98%	0.0384	0.0434
LED Retrofit kit, >25W	LED Fixtures	2	76%	98%	0.0496	0.0561
G24 LED	Screw-In LEDs	4	76%	49%	0.0153	0.0216
G23 LED	Screw-In LEDs	4	76%	49%	0.0084	0.0118
T8 TLED, 4ft	Linear LEDs	1	76%	96%	0.0138	0.0132
T8 TLED, 2ft	Linear LEDs	1	76%	96%	0.0069	0.0066
A-line, 40/60w	Screw-In LEDs	4	76%	49%	0.0217	0.0306
2x4 LED Fixture Standard	LED Fixtures	2	76%	98%	0.033	0.0373
2x4 LED Fixture Premium	LED Fixtures	2	76%	98%	0.037	0.0418
2x2 LED Fixture Standard	LED Fixtures	2	76%	98%	0.029	0.0328
2x2 LED Fixture Premium	LED Fixtures	2	76%	98%	0.033	0.0373
1x4 LED Fixture Standard	LED Fixtures	2	76%	98%	0.016	0.0181
1x4 LED Fixture Premium	LED Fixtures	2	76%	98%	0.02	0.0226
2x4 LED Fixture Standard w Controls	Linear LEDs w Controls	3	76%	97%	PENDING	PENDING
2x4 LED Fixture Premium w Controls	Linear LEDs w Controls	3	76%	97%	PENDING	PENDING
2x2 LED Fixture Standard w Controls	Linear LEDs w Controls	3	76%	97%	PENDING	PENDING
2x2 LED Fixture Premium w Controls	Linear LEDs w Controls	3	76%	97%	PENDING	PENDING

1x4 LED Fixture Standard w Controls	Linear LEDs w Controls	3	76%	97%	PENDING	PENDING
1x4 LED Fixture Premium w Controls	Linear LEDs w Controls	3	76%	97%	PENDING	PENDING
T5 LED	Linear LEDs	1	76%	96%	0.02	0.0191
U-Bend LED	Linear LEDs	1	76%	96%	0.0234	0.0223
High/Low Bay 20-99W	High Bay / Low Bay	6	76%	91%	0.174	0.0966
High/Low Bay 100-199W	High Bay / Low Bay	6	76%	91%	0.229	0.1271
High/Low Bay >= 200W	High Bay / Low Bay	6	76%	91%	0.334	0.1854
Exterior LED 20-99W	Exterior LEDs	5	76%	95%	0.1015	0.1797
Exterior LED 100-199W	Exterior LEDs	5	76%	95%	0.1765	0.3124
Exterior LED >= 200W	Exterior LEDs	5	76%	95%	0.2315	0.4098
1x4 LED Troffer Retrofit Kit - Premium	LED Fixtures	2	76%	98%	0.0373	0.0422
1x4 LED Troffer Retrofit Kit - Standard	LED Fixtures	2	76%	98%	0.0295	0.0334
2x2 LED Troffer Retrofit Kit - Premium	LED Fixtures	2	76%	98%	0.0196	0.0222
2x2 LED Troffer Retrofit Kit - Standard	LED Fixtures	2	76%	98%	0.0181	0.0205
2x4 LED Troffer Retrofit Kit - Premium	LED Fixtures	2	76%	98%	0.0562	0.0636
2x4 LED Troffer Retrofit Kit - Standard	LED Fixtures	2	76%	98%	0.0535	0.0605
LED Strip/Wrap	Linear LEDs	1	76%	96%	0.0218	0.0208
Mogul High Bay	High Bay / Low Bay	6	76%	91%	0.2836	0.1574
Mogul Low Bay	High Bay / Low Bay	6	76%	91%	0.191	0.1060
Mogul Ext 175W	Exterior LEDs	5	76%	95%	0.1419	0.2512
Mogul Ext 250W	Exterior LEDs	5	76%	95%	0.1849	0.3273

Mogul Ext 400W	Exterior LEDs	5	76%	95%	0.2833	0.5014
Parking garage 20-99W Standard	Exterior LEDs	N/A	76%	#N/A	0.1229	#N/A
Parking garage 20-99W Premium	Exterior LEDs	N/A	76%	#N/A	0.1305	#N/A
Parking garage 100-199W Standard	Exterior LEDs	N/A	76%	#N/A	0.2494	#N/A

Table 1-3. Not updated energy and demand savings factors

Product type	BCR Category	Evaluation Category	ENERGY		Summer CF	Winter CF	DEMAND	
			HVAC Interactive Effect (kWh)	Non-Electric Heat Penalty (MMBtu/kWh)			Summer kW HVAC Interactive Effect	Winter kW HVAC Interactive Effect
PAR20	Screw-In LEDs	4	103%	-0.00033	59.00%	52.10%	118%	94%
PAR30	Screw-In LEDs	4	103%	-0.00033	59.00%	52.10%	118%	94%
PAR38	Screw-In LEDs	4	103%	-0.00033	59.00%	52.10%	118%	94%
MR16	Screw-In LEDs	4	103%	-0.00033	59.00%	52.10%	118%	94%
A-line, 75/100w	Screw-In LEDs	4	103%	-0.00033	59.00%	52.10%	118%	94%
Decoratives	Screw-In LEDs	4	103%	-0.00033	59.00%	52.10%	118%	94%
LED Retrofit kit, <25W	Linear LEDs	1	103%	-0.00033	59.00%	52.10%	118%	94%
LED Retrofit kit, >25W	Linear LEDs	1	103%	-0.00033	59.00%	52.10%	118%	94%
G24 LED	Screw-In LEDs	4	103%	-0.00033	59.00%	52.10%	118%	94%
G23 LED	Screw-In LEDs	4	103%	-0.00033	59.00%	52.10%	118%	94%
T8 TLED, 4ft	Linear LEDs	1	102%	-0.00016	72.10%	65.90%	115%	99%
T8 TLED, 2ft	Linear LEDs	1	102%	-0.00016	72.10%	65.90%	115%	99%
A-line, 40/60w	Screw-In LEDs	4	103%	-0.00033	59.00%	52.10%	118%	94%
2x4 LED Fixture Standard	LED Fixtures	2	102%	-0.00016	72.10%	65.90%	115%	99%
2x4 LED Fixture Premium	LED Fixtures	2	102%	-0.00016	72.10%	65.90%	115%	99%
2x2 LED Fixture Standard	LED Fixtures	2	102%	-0.00016	72.10%	65.90%	115%	99%
2x2 LED Fixture Premium	LED Fixtures	2	102%	-0.00016	72.10%	65.90%	115%	99%
1x4 LED Fixture Standard	LED Fixtures	2	102%	-0.00016	72.10%	65.90%	115%	99%
1x4 LED Fixture Premium	LED Fixtures	2	102%	-0.00016	72.10%	65.90%	115%	99%

2x4 LED Fixture Standard w Controls	Linear LEDs w Controls	3	Pending	Pending	Pending	Pending	Pending	Pending
2x4 LED Fixture Premium w Controls	Linear LEDs w Controls	3	Pending	Pending	Pending	Pending	Pending	Pending
2x2 LED Fixture Standard w Controls	Linear LEDs w Controls	3	Pending	Pending	Pending	Pending	Pending	Pending
2x2 LED Fixture Premium w Controls	Linear LEDs w Controls	3	Pending	Pending	Pending	Pending	Pending	Pending
1x4 LED Fixture Standard w Controls	Linear LEDs w Controls	3	Pending	Pending	Pending	Pending	Pending	Pending
1x4 LED Fixture Premium w Controls	Linear LEDs w Controls	3	Pending	Pending	Pending	Pending	Pending	Pending
T5 LED	Linear LEDs	1	102%	-0.00016	72.10%	65.90%	115%	99%
U-Bend LED	Linear LEDs	1	102%	-0.00016	72.10%	65.90%	115%	99%
High/Low Bay 20-99W	High Bay / Low Bay	6	102%	-0.00016	72.10%	65.90%	115%	99%
High/Low Bay 100-199W	High Bay / Low Bay	6	102%	-0.00016	72.10%	65.90%	115%	99%
High/Low Bay >= 200W	High Bay / Low Bay	6	102%	-0.00016	72.10%	65.90%	115%	99%
Exterior LED 20-99W	Exterior LEDs	5	100%	0	0.00%	100.00%	100%	100%
Exterior LED 100-199W	Exterior LEDs	5	100%	0	0.00%	100.00%	100%	100%
Exterior LED >= 200W	Exterior LEDs	5	100%	0	0.00%	100.00%	100%	100%
1x4 LED Troffer Retrofit Kit - Premium	LED Fixtures	2	102%	-0.00016	72.10%	65.90%	115%	99%
1x4 LED Troffer Retrofit Kit - Standard	LED Fixtures	2	102%	-0.00016	72.10%	65.90%	115%	99%
2x2 LED Troffer Retrofit Kit - Premium	LED Fixtures	2	102%	-0.00016	72.10%	65.90%	115%	99%
2x2 LED Troffer Retrofit Kit - Standard	LED Fixtures	2	102%	-0.00016	72.10%	65.90%	115%	99%
2x4 LED Troffer Retrofit Kit - Premium	LED Fixtures	2	102%	-0.00016	72.10%	65.90%	115%	99%
2x4 LED Troffer Retrofit Kit - Standard	LED Fixtures	2	102%	-0.00016	72.10%	65.90%	115%	99%
LED Strip/Wrap	Linear LEDs	1	102%	-0.00016	72.10%	65.90%	115%	99%
Mogul High Bay	High Bay / Low Bay	6	102%	-0.00016	72.10%	65.90%	115%	99%
Mogul Low Bay	High Bay / Low Bay	6	102%	-0.00016	72.10%	65.90%	115%	99%

Mogul Ext 175W	Exterior LEDs	5	100%	0	0.00%	100.00%	100%	100%
Mogul Ext 250W	Exterior LEDs	5	100%	0	0.00%	100.00%	100%	100%
Mogul Ext 400W	Exterior LEDs	5	100%	0	0.00%	100.00%	100%	100%
Parking garage 20-99W Standard	Exterior LEDs	N/A	100%	0	0.00%	100.00%	100%	100%
Parking garage 20-99W Premium	Exterior LEDs	N/A	100%	0	0.00%	100.00%	100%	100%
Parking garage 100-199W Standard	Exterior LEDs	N/A	100%	0	0.00%	100.00%	100%	100%

It is our understanding that the National Grid began using the updated HOU values provided in Table 1-4 for the 2021 program year.

Table 1-4. Proposed new hours of use by building type

Building Type	Existing	Updated
College & University	4,839	4,132
Grocery/Food Sales	5,468	5,920
Hospital	5,413	5,601
Industrial/Manufacturing	4,988	5,229
K-12 School	2,788	2,902
Lodging	4,026	4,194
Medical Office	3,673	3,673
Office Building	4,181	4,171
Other	4,336	4,141
Parking Garage	8,760	8,760
Restaurant/Food Service	5,018	4,891
Retail	4,939	4,957
Warehouse and Storage	6,512	6,512
Overall*	**4,583**	**4,569**

*To be used in cases of unknown building type.

2 INTRODUCTION

This report presents the results from the Impact Evaluation of the 2019 Program Year Rhode Island C&I Upstream Lighting Initiative. Lighting is an important energy end use in Rhode Island's efficiency portfolio, and the Initiative represents a significant share of C&I savings. Since the Initiative tracks estimated savings based on deemed savings values, it is essential that National Grid periodically evaluate the program to determine realization rates and update deemed values for future programs.

The Upstream Lighting Initiative endeavors to increase sales of select[3] energy-efficient lighting equipment in the C&I sector using an upstream program design. The Initiative reimburses participating lighting distributors for selling qualifying equipment to non-residential customers. Figure 2-1 shows how the upstream pathway compares to other C&I lighting program pathways sponsored by National Grid.

Figure 2-1. Rhode Island C&I lighting program pathways[4]

Pathway	Upstream	Downstream				
Approach	Point of Sale	Direct Install	Prescriptive		Custom (Incl. Performance Lighting)	
Project Type(s)	All	Retrofit	New Construction	Retrofit	New Construction	Retrofit
Scalability	High	Medium	Medium		Medium (PL – Low)	
Transaction Costs	Very Low	High	Medium		High	
Target Market	Small CI Customers Large DIY Customers with Small Projects	Small C&I Customers	Medium / Large C&I Customers		Large Customers and Projects, including New Construction and Major Renovation	
Target Lighting Types	Most lighting types from screw-based and TLEDs (smaller incentives) to fixtures with controls (higher incentives)	Focus on fixture replacements and controls (where appropriate). TLEDs are not generally included.	Most lighting types from screw-based and TLEDs (smaller incentives) to fixtures with controls (highest incentives.		All lighting types. Depends on situation / need / preferences. (PL – 3 tiers incl. fixtures only, fixtures + controls, fixtures + advanced controls on performance basis)	

As part of the Upstream Lighting Initiative, every month, the participating distributors submit their sales data to a third-party initiative manager via an online portal. The manager combines the sales data, allocates the energy savings and incentives to National Grid, and then issues a monthly invoice to National Grid.

The Initiative also conducts quality control (QC) inspections to verify on-site the lighting quantities and types claimed in the distributor sales reports. Results of these inspections are also entered into an online portal. Findings from QC sites[5] are not expanded to non-QC sites in the tracking data (i.e., any adjustments to non-QC sites are made outside of the tracking data via evaluation). In 2019, National Grid began using building type hours of use (HOU) as part of their savings calculations. Therefore, building type assignments were assessed as part of this study.

[3] To influence the market to install fixtures allowing for future controls implementation, the incentive amount for lamp replacement (TLEDs) was reduced in 2018. The best available option to customers, given expected future program offerings, would be to install fixtures or fixtures with controls.

[4] Source: Presentation by the PAs to EEAC Council on October 16, 2019, slide 49: http://ma-eeac.org/wordpress/wp-content/uploads/EEAC-Meeting-CI-10-16-2019.pdf

[5] Sites visited by the QC contractor which is the contractor retained by National Grid to perform inspections of incentivized products as part of the quality assurance (QA) and QC plan.

2.1 Study purpose, objectives, and research questions

DNV carried out the Impact Evaluation of the Project Year 2019 Rhode Island C&I Upstream Lighting Initiative for National Grid from December 2020 to June 2021. The study's overall purpose was to build on prior research to understand the extent to which program performance is meeting program and policy goals and objectives. Its objectives and their associated research activities are shown in Table 2-1.

Table 2-1. Research activities and objectives

Research activities	Research objectives
Assess the representativeness of QC inspection data (PY2019)	Gauge whether the program is adhering to its protocols for verifying installed equipment Gauge whether the program is meeting the 85% in-service rate target
Interview implementers and document QC inspection process and impact on evaluation	Increased understanding of how QC inspection data is incorporated into the tracking data and online portal Generate flow diagram with implementer input to record details of how QC inspection data is incorporated into the tracking data and online portal. This could inform potential future improvements for both implementation and evaluation. Document impact of QC process on evaluation and ability to leverage QC data for evaluation purposes
Building-type HOU update (performed in MA)	Update building-specific HOU values using recently completed site-specific lighting evaluations Establish process and schedule for future updates
Sample design	Review PY2019 program data to understand key measures contributing to savings Develop sample design that meets desired statistical precision targets for key measures and saving parameters
Customer surveys	Conduct surveys with customers to identify sites for on-site visits Leverage surveys of customers that received fixtures with integrated controls for NTG analysis Collect self-reported building type for comparison with tracking data
Verification of program-supported measures (all sites)	Collect detailed lighting inventory for program-supported lamps/fixtures Collect data to inform updates to select impact factors: delta watts and estimates of HVAC interactive effects (both heating and cooling) Identify building type for comparison to customer self-reported and program tracking data
Lighting control metering (sites that purchased LED fixtures with integrated controls) (Results pending; expected in June 2021)	Install metering equipment to record usage (CT loggers) for controlled fixtures/lamps Program controls (primary) Non-program controls (secondary) Document control settings and usage as described by site contact
Analysis and reporting	Calculation of savings and realization rates Produce draft, revised, and final reports

The study was designed to answer the following research questions in three categories:

Baseline information:

- Was the site new construction or a major renovation event?

- What type, wattage, and count of lamps/fixtures were replaced by measures supported by the initiative? This question includes the proportion of T12 systems or lamps replaced by program measures.

Savings factor results and their application:

- What are the updated savings factors for National Grid to use prospectively?
- How much savings can be attributed to controls induced by the initiative?
- How has the quantity of light fixtures/lamps increased or decreased since participating in the program? For example, where TLEDs were installed, were extra linear T8s installed to make up for the less than expected light output?

2.2 Organization of report

The remainder of this report is organized as follows:

- Methodology and Approach
- Data Sources and Collection
- Analysis and Results
- Recommendations, Considerations, and Guidance
- Appendix A: Massachusetts Hours of Use Update Memo
- Appendix B: Quality Control Review
- Appendix C: State-Level Results

3 METHODOLOGY AND APPROACH

This section describes the methodologies that DNV used to guide data collection and analysis for this impact evaluation. Primary tasks and their associated subtasks are presented below in Figure 3-1. 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 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 3-1. Each stage in the figure is presented with more detail in following subsections.

Figure 3-1. Summary of key evaluation methods

Sample Design and Selection

Gather electric account and measure-level population data

Develop stratified sample designs by evaluation category and quality control category

File and Savings Reviews

Acquire files supporting savings claims for sampled sites

Perform file reviews with savings validation

On-Site Data Collection

On-site recruitment

Measure verification, operating condition, meter deployment

Site and Aggregate Savings Analysis

Measure-level engineering estimates of connected kW and kWh savings

Statistical expansion of results and realization rates with precisions

3.1 Sample design and selection

In May 2020, the DNV team received program tracking data that covered January 2019 through December 2019, which was consistent with the concurrent Massachusetts Upstream Lighting Study (P87). These data were used to determine the sample frame for this study.

3.1.1 Upstream lighting 2019 sample

Based on the Massachusetts study, prior evaluations in Rhode Island, and discussions with National Grid as part of the development of the work plan, DNV disaggregated the 2019 Upstream Lighting Program data into specific evaluation categories as shown below.

- TLEDs (includes 2-ft, 3-ft, and 4-ft TLEDs, U-bend LEDs, and LED strip/wrap)
- LED fixtures (includes LED troffers of various lengths and configurations)
- LED fixtures with integrated controls (includes LED troffers with integrated controls)
- Screw-in LEDs (includes a variety of screw-in LEDs ranging from PAR20 to MR16 to A-line)
- Exterior LEDs (includes exterior and parking garage LEDs)
- High/low bay LEDs (includes those with integrated controls)

The sample frame was defined as unique purchasers for each customer location and evaluation category. Table 3-1 presents a summary of the 2019 Upstream Lighting program purchases in Rhode Island based on these categories. Overall, the program served more than 3,700 customers and generated nearly 27,500 MWh of energy savings in 2019.

Table 3-1. Summary of 2019 Rhode Island Upstream Lighting Purchases

Evaluation Category	Quantity of Sites	Total kWh Savings
Category 1 – TLEDs	739	5,721,901
Category 2 – LED Fixtures	901	3,411,087
Category 3 – LED Fixtures w/Integrated Controls	14	73,959
Category 4 – Screw-In LEDs	724	4,392,938
Category 5 – Exterior LEDs	706	2,535,215
Category 6 – High/Low Bay LEDs	659	11,351,033
Total	**3,743**	**27,486,134**

Based on discussion with National Grid, DNV concluded that there is no significant difference in upstream lighting program implementation between the two states (MA and RI). Both states offer the same technologies using the same third-party program manager. Therefore, to be more cost effective, populations of both RI and MA (National Grid only) were combined to create a new sample frame (National Grid MA and RI). The sample design targeted an overall precision of 10%, at the 90% confidence level, based on the National Grid MA and RI population. The results were evaluated to target the precisions 90/10 at National Grid MA and RI level, not at an individual state level. National Grid MA sites used in the MA (P87) sample were incorporated into this sample design to be consistent. Using the existing National Grid MA sites, sample points were added in RI to achieve the overall targeted precision for the National Grid MA and RI population.

After placing the sites into qualitative strata, ratio estimation was used to optimally allocate sites into size strata based on the error ratios shown in Table 3-2[6]. The sample design in this study included 70 National Grid sites from the Massachusetts study and 25 sites in Rhode Island, where in-service rates, delta watts, and HVAC interaction were gathered and hours of use/power metering performed at the 11 LED fixtures with integrated controls sites. The proposed sample design included 95 total sites and was expected to achieve 9% relative precision.

Ultimately, 59 of the 70 planned site visits were performed at National Grid customer sites in Massachusetts and 25 site visits were performed in Rhode Island for a total of 84 sites (49 in-person and 35 virtual) were performed where in-service rates, delta watts, and HVAC interaction were gathered. Only two of the five completed integrated controls sites included metering. At two National Grid Massachusetts sites the customers would not allow the installation of metering equipment, and a third Massachusetts site would not allow an in-person visit due to the COVID-19 pandemic. All metering equipment was removed in late April/early May 2021, and the average metering period was 17.1 weeks or 3.9 months.

[6] Stratified ratio estimation is a technique that allows for efficient sampling of a population, based on known information about that population (tracked savings) and the assumed variability of the relationship (error ratio) between the known information and the unknown information (actual savings). See the 2004 California Evaluation Framework pages 327-339 for additional detail: http://www.calmac.org/publications/California_Evaluation_Framework_June_2004.pdf

Table 3-2. Summary of 2019 National Grid MA and RI Upstream Lighting Tracking Data and Sample

Evaluation Category	# Customers (N)	Annual kWh Savings	Assumed Error Ratio	Design Sample Size	Expected Relative Precision	Final Sample Size
Category 1 - Linear/TLEDs	3,051	22,075,503	0.27	14	16%	9
Category 2 – LED Fixtures	3,775	14,900,714	0.28	6	18%	14
Category 3 – LED Fixtures w/ Integrated Controls	62	869,013	0.48	11	57%	5
Category 4 – Screw-In LEDs	2,753	15,154,491	0.48	9	25%	10
Category 5 – Exterior LEDs	2,935	10,547,402	0.39	11	23%	12
Category 6 – High/Low Bay LEDs	2,993	63,032,333	0.34	44	16%	34
Total	**15,569**	**126,579,456**	**0.16**	**95**	**9%**	**84**

3.1.2 Recruitment disposition

The final response and refusal rates experienced in this study are provided in Table 3-3. Examining final dispositions of a sample in this way can help assess whether there may have been non-response error and why. Attempts were made to contact a total of 588 customers as part of the survey effort. Of these, 168 or 28.6% were unresponsive or had disconnected numbers. An internet search of these customers revealed that all but 13 unsuccessfully recruited sites were in business at the time of recruitment. The number of open small businesses in Rhode Island decreased by over 38% in 2020,[7] likely due to the COVID-19 pandemic. Given the expected impact of COVID-19 on business closures, a closed business adjustment to savings was not made in this study but should be explicitly studied in future such studies.

In total there were 90 completed surveys (with a response rate of 15%), which resulted in a total of 58 pre-recruited sites for the impact evaluation – an acceptance rate of 64%. Ultimately, we were able to convert 25 of these sites, for a conversion rate of 43.1%. The response rate calculated in the table below are based on these pre-recruited sites and 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.[8] The response and refusal rates are similar to those experienced in Massachusetts (48.9% and 15.5%, respectively), but poorer than those experienced in a recently completed upstream lighting study performed in Connecticut, likely due to COVID-19 concerns.[9]

[7] https://www.tracktherecovery.org/.
[8] https://www.aapor.org/Standards-Ethics/Standard-Definitions-(1).aspx.
[9] https://www.energizect.com/sites/default/files/C1635_FINAL%20Report_Energy%20Opportunities%20Impact%20Evaluation%2008272020.pdf, page 18 (Upstream Lighting), where the response rate was 66.2% and the refusal rate was 8.7%.

Table 3-3. Final on-site recruitment response and refusal rates

Disposition Description	Disposition Count
Complete	25
Refused – In business	9
Non-contact – In business	24
Total Contacts	58
Response Rate 1	43.1%
Refusal Rate 1	15.5%

4 DATA SOURCES AND COLLECTION

In May 2020, the DNV team received initiative tracking data directly from the initiative vendor. The tracking data covered the period from January 2019 through December 2019. We used these data to determine the sample frame discussed above and used the tracking data to identify customers to participate in a survey that collected data to assess net-to-gross (NTG) effects for LED fixtures with integrated controls and pre-recruited customers for the impact evaluation inspections. Based on the data collected through this survey, the NTG ratio for LED fixtures with integrated controls was estimated to be 80%, which means that 80% of the gross program savings for these measures can be claimed as net savings.

At each successfully recruited site, engineers verified the presence of the equipment received through the program as either installed and operating or in storage and not yet installed, to the extent possible. In a few cases, program products were not found to be installed or in storage, and the customer was unable to provide any information on if they were received or where they might be. Site engineers also had discussions with facility personnel to gather the baseline (e.g., pre-existing) characteristics of the measure (quantities, product types, and product wattages). The program does not differentiate between ROF or ER as all products receive the same delta watts. The realization rates provided by this study incorporate the impact of an ER/ROF adjustment.

During the CATI survey, the vast majority (72%) of the sample reported that program products replaced equipment in an existing building. Of the remaining sample, 16% were part of a renovation at an existing facility, 8% added equipment to an existing building, and 4% were installed in a newly constructed building.

4.1 Metering equipment used

DENT ELITEpro power loggers were deployed at the sites where LED fixtures with controls received through the program were found to be installed, except as noted above. These loggers monitor voltage, amperage, power factor, and kW over the monitoring period. The monitoring frequency was typically 15 minutes or less. The current transformers used were split-core current transformers manufactured by DENT to measure current ranging from 5 amps to 600 amps nominally.

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.

5 ANALYSIS AND RESULTS

Two savings values were calculated for each site in this study: connected demand savings (kW) and energy savings (kWh). Connected demand savings are calculated using in-service rate and delta watts, while energy savings are calculated by multiplying the connected demand savings by annual hours of use. As part of this study, DNV updated building-level hours of use estimates. A memo detailing the results of the hours of use update constitutes Appendix B. Since metering equipment was installed only on program fixtures with integrated controls and will not be removed until summer 2021, the updated hours of use estimates provided in the memo were applied by building type in the calculation of the program energy savings provided below. All results provided in this section are National Grid MA and RI combined results. Results are provided separately by state in Appendix C.

5.1 Baseline adjustment and outlier analysis

5.1.1 New construction and major renovation adjustment

As mentioned above, 12% of the sample reported that the program fixtures were installed as part of a renovation at an existing facility and 4% were installed in a newly constructed building. For the program fixtures installed in these facilities, the baseline was calculated by applying the 0.60 adjustment factor from the pending 2020 Code Compliance and Baseline Study to 2015 International Energy Conservation Code (IECC) lighting power density (LPD) values by building area type,[10] based on the square footage of the areas where program fixtures were installed.

5.1.2 Early replacement and replace on failure adjustment

As part of the 2019 C&I Lighting Inventory and Market Model Study performed in Massachusetts[11], the DNV team developed an algorithm to determine the share of lighting installations that are ER and ROF. Based on the outcome of participant responses to a CATI survey, we determined the ROF fraction was 29%. This is also the value that was used in the recently completed Upstream Lighting evaluation performed in Massachusetts.

The delta watts calculated for this study, excluding renovations and new construction, were calculated based on comparing pre-installation conditions to program installed equipment. This is equivalent to an ER baseline per the Massachusetts C&I Baseline Framework.[12] To account for ROF event type and adjust savings, we turned to the current market characterization study being performed in Massachusetts. The 2020 AML spreadsheet includes assumptions regarding ER and ROF delta watts calculated in accordance with the baseline framework. We used these values to calculate adjustment factors for the impact evaluation. Rather than apply evaluation category specific adjustment factors, we used the values provided in Table 5-1 to calculate a savings weighted average adjustment factor. Given the relatively high adjustment factor for screw-in LEDs and the understanding that screw-in LEDs were expected to be a much smaller portion of program moving forward, we calculated the weighted average excluding the screw-in LED values.[13] The results of this calculation is 6% (rounded to nearest whole percent). To adjust delta watts by this value we multiplied observed delta watts by 1.06.

[10] https://codes.iccsafe.org/content/IECC2015/chapter-4-ce-commercial-energy-efficiency, Table C405.4.2(1).

[11] https://ma-eeac.org/wp-content/uploads/MA19C14-E-LGHTMKT_2019-CI-Lighting-Inventory-and-Market-Model-Report_Final_2020.04.06.pdf

[12] https://ma-eeac.org/wp-content/uploads/MA-Commercial-and-Industrial-Baseline-Framework-1.pdf

[13] As agreed to on March 3, 2021 with Massachusetts EEAC Consultants and PA representatives.

Table 5-1. Market characterization ER and ROF Delta Watts[14]

Parameter	TLED	LED Fixture	Screw-in LEDs	Exterior LEDs	High/Low Bay LEDs
Delta Watts ROF	46.0	50.0	35.2	151.9	117.7
Delta Watts ER First Period	34.6	38.6	5.7	126.2	103.2
Difference	11.4	11.4	29.5	25.7	14.5
% Difference	25%	23%	84%	17%	12%
% Difference times 29%	7%	7%	24%	5%	4%
Evaluated Savings Prior to Adjustment	49,171	29,934	Excluded	18,004	36,787
Weighted Average Adjustment	**6%**				

5.1.3 Outlier analysis

The project team conducted the outlier analysis following a procedure that the neighboring MA PAs worked through and documented in the MA Gross Impact Framework to determine if there were any observations that might warrant downweighting.[15]

Generally, in conducting an outlier analysis, we are trying to assess whether any observations are exerting unexpectedly high leverage on the analysis (accounting for too large a portion of the analysis result) and then whether any of these high-leverage observations have very different results from other, similar observations. We don't want to exclude or reduce the weight of certain observations just because they have high leverage, since some observations represent a large portion of population savings and should be expected to have a larger influence on results. Given this, we only consider reweighting observations if:

1. They are highly influential, and
2. We have reason to believe the observations results are anomalous (more extreme) than similar tyes of observations (i.e. TLEDs compared to other TLEDs or Exterior LEDs compared to other Exterior LEDs).

Given those criteria, the outlier analysis did not identify any outliers that required downweighting.

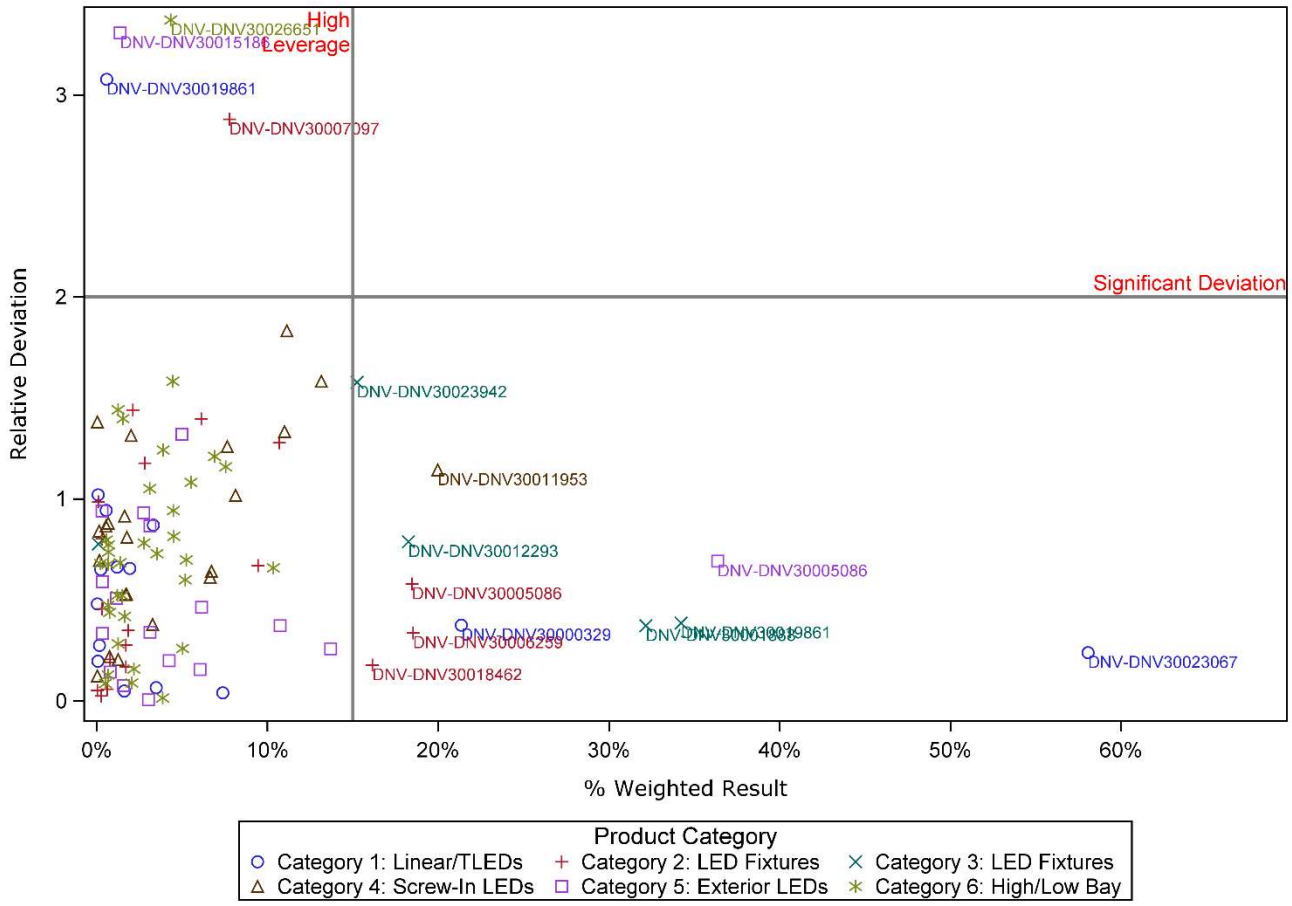
More specifically, to understand how extreme or anomalous a value is, we compare the residual of an observation yj – R̂xj with the typical residual. An outlier is one that is large given the magnitude of xj. A value is identified as an outlier based on a sample t-test. We calculate the mean m and standard deviation SD of the relative residuals u, then look for values that are more than t standard deviations from the mean. That is, we test for: |uj -m| > t SD, where t is the t-statistic we want to use as a criterion for extreme. For the 2019 RI Upstream Lighting Evaluation, we chose a t-statistic of 2.

Figure 5-1 shows the relative deviation of each sampled site within each product analysis category, plotted against the percent of weighted results each site represents within the product category. Sites right of the vertical reference line alone represent >15% of the weighted result within a category, while sites above the horizontal reference line have a relative deviation greater than our critical value of 2. Sites that are candidates for reweighting would appear in the upper right quadrant of the graph.

[14] Based on the MA19C14-E-LGHTMKT AML spreadsheet provided on March 3, 2021.

[15] https://ma-eeac.org/wp-content/uploads/MA20C06-B-GIF-InterimMemo-Final_2021.01.20.pdf

Figure 5-1. Outlier and leverage analysis



5.2 Combined MA & RI Results

Table 5-2 provides the prospective energy savings results. The overall realization rate is 86.0% with a precision of ±13.7% at the 90% confidence level (CL). Recall that metering results for integrated controls are still pending and are expected prior to August 2021. Meters were installed only on LED fixtures with integrated controls that were installed through the program. Therefore, to calculate energy savings, the hours of use from the Hours of Use Memo in Appendix A were used along with the ISRs and delta watts collected in this study. The largest drivers of the 86.0% realization rate are differences in delta watts for high/low bay LEDs and differences in ISR for screw-in LEDs. The key savings parameters for upstream lighting are provided in the remainder of this section.

Table 5-2. Energy savings results (MA+RI)

Evaluation Category	Tracking Annual Energy Savings (MWh)	Evaluation Annual Energy Savings (MWh)	Realization Rate	Precision at 90% CL	TRM Realization Rate Assumption[16]
Category 1: Linear/TLEDs	5,722	5,555	97.1%	±9.2%	78.0%
Category 2: LED Fixtures	3,411	3,947	115.7%	±32.7%	78.0%
Category 3: LED Fixtures w/ Integrated Controls	74	82	111.5%	±21.3%	78.0%
Category 5: Exterior LEDs	2,535	4,383	172.9%	±15.0%	68.0%
Category 6: High/Low Bay LEDs	11,351	5,992	52.8%	±24.0%	78.0%
All Non-Screw-In LEDs	**23,093**	**20,285**	**87.8%**	**±13.0%**	**77.2%[17]**
Category 4: Screw-In LEDs	4,393	3,181	72.4%	±62.1%	78.0%
Overall	**27,486**	**23,651**	**86.0%**	**±13.7%**	**77.3%[18]**

[16] https://etrm.anbetrack.com/#/workarea/trm/MADPU/COM-L-LS/2019-2021%20Plan%20TRM/version/1?measureName=Lighting%20-%20System, Energy Realization Rates from 'Impact Factors for Calculating Adjusted Gross Savings' Table.

[17] TRM RR assumptions of 78% for linear/TLEDs, LED fixtures, LED fixtures with integrated controls, and high/low bay LEDs and 68% for exterior LEDs weighted by the tracking savings for each of these evaluation categories.

[18] TRM RR assumptions of 78% for linear/TLEDs, LED fixtures, LED fixtures with integrated controls, screw-in LEDs, and high/low bay LEDs and 68% for exterior LEDs weighted by the tracking savings for each of these evaluation categories.

Table 5-3 summarizes the in-service rate (ISR) results. 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 88.1% with a precision of ±6.7% at the 90% confidence level.

Since the ISR 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% from the two-stage study performed in Massachusetts[19] that examined the installation rate of C&I upstream lighting over a year. In applying this multiplier, 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. Products that could not be accounted for during the site visits were not included in calculating long term ISRs. The overall long-term ISR of 88.8% (with ±6.5% precision at the 90% confidence level) can be applied one year after upstream lighting measures are installed.

Table 5-3. In-service rate results (MA+RI)

Evaluation Category	Tracking System In-Service Rate[20]	Evaluation Short-Term In-Service Rate	Precision at 90% CL	Evaluation Long Term In-Service Rate	Precision at 90% CL
Category 1: Linear/TLEDs	100.0%	96.0%	±6.7%	96.0%	±6.7%
Category 2: LED Fixtures	100.0%	97.5%	±3.5%	98.5%	±1.7%
Category 3: LED Fixtures w/ Integrated Controls	100.0%	97.2%	±4.5%	97.2%	±4.5%
Category 5: Exterior LEDs	100.0%	94.6%	±8.0%	94.6%	±8.0%
Category 6: High/Low Bay LEDs	100.0%	90.6%	±7.4%	91.7%	±7.2%
All-Non-Screw-In LEDs	**100.0%**	**93.3%**	**±4.5%**	**93.9%**	**±4.3%**
Category 4: Screw-In LEDs	100.0%	48.7%	±45.3%	50.0%	±46.0%
Overall	**100.0%**	**88.1%**	**±6.7%**	**88.8%**	**±6.5%**

Table 5-4 compares the short-term in-service rates for quality control (QC) sites and non-QC sites. Overall, the QC ISR was 94.4%, while the non-QC ISR was 87.1%. As detailed in 0, participating distributors are required to a *maintain a rolling average of more than 85% ISR and a verification correction threshold of less than $20,000 for all incentivized sales throughout the current initiative year.* Verification results are presented to distributors, who choose how to respond. When the verification vendor reports that products are not installed, there are three possible actions distributors may take: 1) return incentives, 2) re-inspect, or 3) do nothing. While the evaluation found lower in-service rates at a subset of QC categories (linear/TLEDs and LED fixtures with controls), the overall in-service rate for QC sites was in line with program standards at 85%. As noted in 0, the overall reported ISR for QC site was approximately 87%.

[19] https://ma-eeac.org/wp-content/uploads/Upstream-Lighting-Initiative-Impact-Evaluation-PY2015.pdf, Page D-3.

[20] https://etrm.anbetrack.com/#/workarea/trm/MADPU/COM-L-LS/2019-2021%20Plan%20TRM/version/1?measureName=Lighting%20-%20System. All upstream ISRs are incorporated into the realization rates so the ISR is set to 100% to avoid double counting.

Table 5-4. Short-term in-service rate results – QC vs. non-QC (MA+RI)

Evaluation Category	Tracking System ISR	Evaluation QC Short-Term ISR	QC Short-Term Precision at 90% CL	Evaluation Non-QC Short-Term ISR	Non-QC Short-Term Precision at 90% CL
Category 1: Linear/TLEDs	100.0%	67.4%	±99.0%	99.3%	±1.3%
Category 2: LED Fixtures	100.0%	100.0%	N/A	96.7%	±4.6%
Category 3: LED Fixtures w/ Integrated Controls	100.0%	N/A	N/A	97.2%	±4.5%
Category 5: Exterior LEDs	100.0%	100.0%	N/A	90.8%	±13.0%
Category 6: High/Low Bay LEDs	100.0%	100.0%	N/A	89.5%	±8.4%
All-Non-Screw-In LEDs	**100.0%**	**94.4%**	**±10.2%**	**93.1%**	**±5.0%**
Category 4: Screw-In LEDs	100.0%	47.9%	N/A	47.9%	±46.5%
Overall	**100.0%**	**94.4%**	**±7.6%**	**87.1%**	**±5.9%**

Table 5-5 presents the delta watts results compared to the 2019 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 delta watts realization rates for evaluation categories 1-5 are all over 100%. For high/low bay LEDs the delta watts realization rate is 58.3%, which produces an overall realization rate of 97.6% with ±12.0% precision at the 90% confidence level.

Table 5-5. Delta watts results (MA+RI)

Evaluation Category	Tracking Delta Watts	Evaluation Delta Watts	Realization Rate	Precision at 90% CL
Category 1: Linear/TLEDs	14.73	14.90	101.1%	±7.7%
Category 2: LED Fixtures	32.09	38.10	118.7%	±32.3%
Category 3: LED Fixtures w/ Integrated Controls	40.50	46.44	114.6%	±25.1%
Category 5: Exterior LEDs	141.39	258.39	182.7%	±14.1%
Category 6: High/Low Bay LEDs	203.64	118.68	58.3%	±26.9%
All Non-Screw-In LEDs	**44.29**	**41.70**	**94.1%**	**±12.8%**
Category 4: Screw-In LEDs	29.68	44.09	148.5%	±35.1%
Overall	**38.77**	**37.85**	**97.6%**	**±12.0%**

During recruitment we sought to speak with a site contact who is most knowledgeable about the facility's lighting. Typically, these contacts are responsible for building maintenance. For determining the baseline, we asked the site contact to provide as much detail as possible on the replaced equipment. In some cases, customers are able to show other fixtures/lamps in the building that have not been replaced. In other cases, all the pre-existing equipment has been replaced and the baseline is based on their recollection of this equipment. Table 5-6 shows the site contact-reported fixture types and average wattages that replaced the high/low bay LEDs installed through the program. In nearly all cases, the site visit delta watts are much lower than was assumed in the tracking savings calculation due to incorrect assumptions about pre-existing

technology. It is important to note that the overall site visit and tracking average delta watts shown in Table 5-6 are simple averages, which is why they are slightly different from the weighted averages shown for high/low bay LEDs in Table 5-5.

Table 5-6. Customer-reported high/low bay LED baseline fixture types and wattages (MA+RI)

Baseline Fixture Type	Proportion of High/Low Bay LED Baseline Fixtures	Average Baseline Wattage	Average Installed Wattage	Sample Site Visit Simple Average Delta Watts	Sample Tracking Simple Average Delta Watts
High bay/low bay	97.7%	227.0	107.6	119.4	206.5
Linear - troffer	0.9%	64.0	40.0	24.0	174.0
Pendant	0.9%	1,000.0	215.7	784.3	334.0
Linear - flush mount	0.6%	123.0	72.5	50.5	201.5
Overall	**100.0%**	**231.8**	**107.8**	**124.0**	**208.9**

Table 5-7 compares the tracking system hours of use and evaluation hours of use from the update memo in 0 by evaluation category. Except for the linear/TLED and exterior LEDs, the updated hours of use are very close to the tracking assumptions. The overall realization rate for HOU is 92.5%.

Table 5-7. Hours of Use Results by Evaluation Category (MA+RI)

Category	Tracking Hours of Use	Evaluation Hours of Use	Realization Rate	Precision at 90% CI
Category 1: Linear/TLEDs	4,575	3,546	77.5%	±15.4%
Category 2: LED Fixtures	4,505	4,455	98.9%	±0.9%
Category 3: LED Fixtures w/ Integrated Controls	4,001	4,020	100.5%	±1.1%
Category 5: Exterior LEDs	4,711	4,350	92.3%	±6.8%
Category 6: High/Low Bay LEDs	4,936	5,122	103.8%	±5.5%
All Non-Screw-In LEDs Sub-Total	**4,603**	**4,245**	**92.2%**	**±8.5%**
Category 4: Screw-In LEDs	4,446	4,228	95.1%	±3.4%
Overall	**4,543**	**4,203**	**92.5%**	**±7.9%**

Table 5-8 compares the tracking system hours of use and evaluation hours of use from the Massachusetts update memo in 0 by building type. Except for college & university sites and grocery/food sales sites, all updated hours of use by building type are also very close to the tracking assumptions.

Table 5-8. Hours of use results by building type

Building Type	Tracking Hours of Use	Evaluation Hours of Use	Realization Rate	Precision at 90% CL
College & University	4,839	4,132	85.4%	±29.6%
Grocery/Food Sales	5,468	5,920	108.3%	±8.1%
Hospital	5,413	5,601	103.5%	±12.2%
Industrial/Manufacturing	4,988	5,229	104.8%	±16.0%
K-12 School	2,788	2,902	104.1%	±11.6%
Lodging	4,026	4,194	104.2%	±21.8%
Medical Office	3,673	3,673	100.0%	±6.8%
Office Building	4,181	4,171	99.8%	±11.0%
Other	4,336	4,141	95.5%	±16.8%
Parking Garage*	8,760	8,760	100.0%	±3.7%
Restaurant/Food Service	5,018	4,891	97.5%	±22.0%
Retail	4,939	4,957	100.4%	±10.1%
Warehouse and Storage	6,512	6,512	100.0%	±16.3%
Overall	**4,583**	**4,569**	**99.7%**	**±7.0%**

*Note that, as detailed in 0, we recommend that the PAs continue to use a value of 8,760 for parking garages.

Although there were 84 sites in the sample, there were nine instances where the tracking data reported two different building types for a single site and one instance where it reported three different building types for a single site. Figure 5-2 shows the consistency of the 95-total site/building type combinations in the tracking system for the sample with what was found during the site visit. Over two-thirds (71%) were found to be correctly classified. Retail, restaurants, and warehouses were found to be misclassified most frequently.

Figure 5-2. Building types found to be correctly classified most frequently (MA+RI)

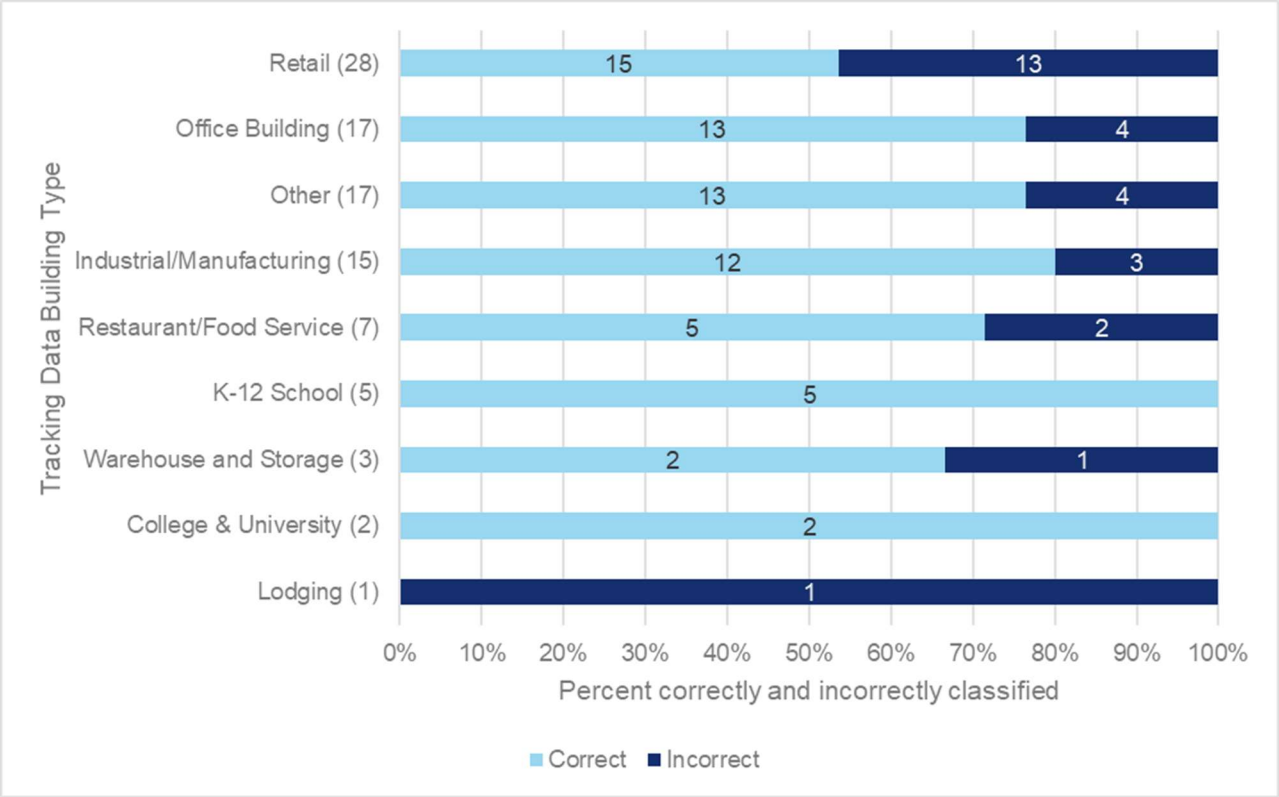


Table 5-9 shows how the 28 incorrectly classified site/building type combinations in the tracking system were reclassified in calculating the evaluation energy savings results provided in Table 5-2**Error! Reference source not found.**. The actual observed building type is shown on the far left of the table with the tracking classification shown across the top of the table. The count of number of misclassified buildings are shown in the columns corresponding to the misclassified building type. For example, five warehouse and storage buildings were misclassified retail (2), office building (1), other (1), and industrial/manufacturing (1). This reclassification of building types had minimal impact on the overall results.

Table 5-9. Classification of incorrectly classified buildings (MA+RI)

	Tracking Building Type							
Site Visit Building Type	**Lodging**	**Warehouse and Storage**	**Restaurant/ Food Service**	**Industrial/ Manufacturing**	**Other**	**Office Building**	**Retail**	**Grand Total**
Warehouse and Storage				1	1	1	2	**5**
Industrial/Manufacturing			1		1	1	2	**5**
Other-Auto Repair							5	**5**
Office Building			1	1			2	**4**
Other-Shop Facilities		1				1		**2**
Other-Recreational							2	**2**
Other-Multifamily Residential	1							**1**
College & University				1				**1**
K-12 School					1			**1**
Retail					1			**1**
Other-Mechanic Garage						1		**1**
Grand Total	**1**	**1**	**2**	**3**	**4**	**4**	**13**	**28**

Table 5-10 presents the connected demand savings results without accounting for interactive effects. The overall realization rate is 95.2% with a precision of ±15.0% at the 90% confidence level. The poor realization rate for Category 6 high/low bay LEDs is due to a tracking savings delta watts assumption of 208.9 watts, while the evaluation found the weighted average delta watts to be 124.0 watts for these products (as shown in Table 5-6).

Table 5-10. Connected demand savings results without interactive effects (MA+RI)

Evaluation Category	Tracking Connected Demand Savings (kW)	Evaluation Connected Demand Savings (kW)	Realization Rate	Precision at 90% CL
Category 1: Linear/TLEDs	885	890	100.7%	±11.2%
Category 2: LED Fixtures	623	756	121.3%	±33.1%
Category 3: LED Fixtures w/ Integrated Controls	11	16	143.5%	±23.6%
Category 5: Exterior LEDs	730	1,424	195.1%	±20.8%
Category 6: High/Low Bay LEDs	1,932	1,115	57.7%	±25.8%
All Non-Screw-In LEDs	**4,181**	**4,019**	**96.1%**	**±15.0%**
Category 4: Screw-In LEDs	1,704	1,510	88.6%	±62.7%
Total	**5,885**	**5,604**	**95.2%**	**±15.0%**

5.3 Study error ratios

Table 5-11 presents the final study energy error ratios by evaluation category. Three categories (LED Fixtures, Screw-in LEDs, and High/Low Bay LEDs) are inconsistent with those assumed in the sample design for each sample in this study. These final observed error ratios can be used to inform future sample designs for similar studies of Upstream Lighting programs in Massachusetts. The end uses with the higher error ratios should expect to have larger sample sizes in future studies.

Table 5-11. Study kWh error ratios (MA+RI)

Evaluation Category	Study Error Ratio	Assumed Error Ratio
Category 1: Linear/TLEDs	0.49	0.4
Category 2: LED Fixtures	0.63	0.4
Category 3: LED Fixtures w/ Integrated Controls	0.50	0.6
Category 4: Screw-In LEDs	1.33	0.9
Category 5: Exterior LEDs	0.49	0.6
Category 6: High/Low Bay LEDs	0.97	0.6

6 RECOMMENDATIONS, CONSIDERATIONS, AND GUIDANCE

6.1 Recommendations

Recommendation 1. In 2021 the initiative should use the realization rates included in Table 1-1, which exclude the impact of HOU updates which the PAs already adopted in 2021. Beginning in 2022, the PAs should use the updated impact factors provided in Table 1-2, Table 1-3, and Table 1-4.

Recommendation 2. In line with prior guidance, if a building type is unknown, National Grid should use the "Overall" result from Table 1-4 for upstream lighting, which represents the average operating hours of all building types combined. The "other" category should only be used if the building type is known but it does not fall into one of the existing categories.

6.2 Considerations

Consideration 1. Given the changes for the College & University and Grocery/Food Sales building type MA HOU estimates, consider a review of the underlying data to determine if some of the older study results should be removed from the analysis. Some of the buildings included in this analysis date back to 2010, which could indicate that the programs are targeting lamps/fixtures that operate differently today than in 2010. However, the removal of older data could also result in worse precision for some of the building type hours of use.

Consideration 2. The verification and implementation vendors should consider making actions taken as a result of verification results more transparent by tracking distributor actions with more detail. When a QC inspection reveals products are not installed, distributors may return the products (incentives), do nothing, or request a re-inspection. All returns, regardless of reason, are listed as negative sales values and include a return date. Including a variable stating the reason for returns, in the vendor tracking system, would increase the transparency of negative sales within the tracking system. The current return notes field is not consistently populated. It should also be noted that if a distributor chooses to "do nothing," it can impact their participation in the initiative.

Consideration 3. The verification vendor should consider adopting a more robust sampling approach in coordination with the evaluation team. The current sampling process allows for an element of convenience in selection of sites. In addition, by sampling monthly with no correction for changes in participation over the course of a year, it is possible to exclude distributors (seven distributors received no inspections in PY2019). A mid-year check on sampled sites might reveal opportunities to improve sampling for end of year.

6.3 Guidance for future studies

Guidance 1. Future hours of use updates may consider RI-specific values using historical metering data collected through previous evaluations of upstream lighting and custom electric lighting in Rhode Island.

Guidance 2. Consider adding RI-specific space type HOU estimates using historical metering data collected through previous lighting evaluations performed in Rhode Island.

Guidance 3. Given the lack of historic data on business closures in upstream lighting program studies, closed businesses should be explicitly studied in future upstream lighting evaluations as was done as part of this evaluation.

APPENDIX A. HOURS OF USE MEMO

DNV initially presented results of the hours of use update to the Massachusetts PAs in a memo dated July 24, 2020. The content of that memo has been incorporated into this appendix.

Introduction

This document presents building hours of use (HOU) updates to the results of the "Quick Hit" Massachusetts C&I Project 86 (Lighting Hours of Use Study)[21] developed for the Massachusetts Program Administrators (PAs) with guidance from the MA Energy Efficiency Advisory Council (EEAC). In addition to this update, space type hours of use were developed to assist in future planning and development of the upstream program pertaining to potential controls savings. The primary objectives of this project were to update hours of use (HOU) by building type and begin to develop a database of HOU by space type.

The PAs and the upstream subcommittee began using building hours of use estimates in 2019 to develop upstream lighting program savings per the recommendation from the prior P86 HOU study. This memo is the first time we have calculated space type HOU estimates for consideration of incorporation into the upstream lighting controls energy savings estimation process.

The previous evaluation (MA Project 86) developed building-level HOU estimates by using the site-level results from previous Massachusetts C&I lighting evaluations. In total, 406 of the 458 unique sites with metered data were used by the DNV team for the previous version of this analysis, which are as follows:

- P12 – 2010 Custom Lighting (45 sites)
- P12 – 2010 Prescriptive Lighting (57 sites, including 12 months of metering)
- P17 – 2012 Upstream Lighting (81 sites)
- P58 – 2016 Upstream Lighting (170 sites)
- P69 – 2016 Small Business Lighting (105 sites)

This study updates the previous building-level HOU estimates by adding site-level data from the most recent custom lighting impact evaluations listed below:

- P80 – 2016 Custom Lighting (43 sites)
- P88 – 2017-2018 Custom Lighting (24 sites)

There are three study caveats:

1. All of the hours of use estimates are based on metered profiles (with the exception of exterior lighting on timers), however only those from the P12 Prescriptive Lighting evaluation are based on a full year of metered data. For all other sites, the metering period was typically 8-12 weeks, and was extrapolated to the rest of the year using knowledge of the individual building annual operating schedules as reported by each customer.
2. The profiles have been selected opportunistically, as available from past study efforts, and therefore cannot be guaranteed to be representative of a population. The profiles were examined for anomalies which may have warranted exclusion or special handling in the aggregated result.
3. The space type hours estimates were created using site-level HOU data solely from Massachusetts C&I Project 80 and Project 88. These are the same 67 sites that were used to update the building type hours of use.

Objectives

The study's overall objectives are as follows:

[21] DNV GL, Lighting Hours of Use Study, April 12, 2019. http://ma-eeac.org/wordpress/wp-content/uploads/MA-CIEC-stage-5-report-P86-Lighting-HOU-Study-FINAL.pdf

Objective 1: Add building-specific HOU estimates from P80 and P88 custom lighting impact evaluations to the prior set of building-specific HOU estimates to produce updated building type HOU estimates for use in estimating Upstream Lighting savings beginning in 2021.

Objective 2: Review the custom electric site data to begin to compile a database of space-specific HOU estimates. Analyze applicable space type categorization in site-level data from recent custom lighting projects and apply the corresponding ASHRAE space type. By using ASHRAE space type classification, this database could be expanded to include additional results from studies as they are completed. While the application of space type HOU is not practical for the Upstream Lighting program since sales are tracked by building type, it would be beneficial for future exploration of potential for control savings, which may vary by space type.

Summary of approach

The following summarizes the approach the DNV team used for updating the building type HOU estimates and for creating space type HOU estimates. The team used data from previous evaluations, including the data used in the Lighting Hours of Use study (Project 86). The space type analysis utilized data only from P80 and P88.

Task 1: Update building HOU estimates

The DNV team collected all of the site-level savings spreadsheets compiled by evaluators for P80 and P88. In total, we identified 67 new sites that were added to the site previously included in the P86 HOU study. Table 6-1 details the total number of sites included in the updated analysis.

Table 6-1. Completed MA C&I lighting studies

MA Study	Program Year	Number of Sites	Typical Metering Length	HOU Study Added To
P12 Custom Lighting	2010	45	8-12 weeks	Project 86
P12 Prescriptive Lighting	2010	57	52 weeks	Project 86
P17 Upstream Lighting	2010	81	8-12 weeks	Project 86
P58 Upstream Lighting	2016	170	8-12 weeks	Project 86
P69 Small Business Lighting	2016	105	8-12 weeks	Project 86
P80 Custom Lighting	2016	43	8-12 weeks	MA19C06
P88 Custom Lighting	2017/2018	24	8-12 weeks	MA19C06
Total		525		

The DNV team extracted copies of all applicable site spreadsheets that were used in the analysis. We reviewed all sites and processed them into a common format for use in the analysis. Impacts from lighting controls were not included. The format included the following information for each site:

- PA sponsor
- Study name
- Site ID
- Program year studied
- Year of metering
- Building type

- ASHRAE space type (as assigned by MA19C06 Upstream Lighting study team)
- Connected kW savings (fixtures only)
- Annual kWh savings (fixtures only)
- Annual lighting hours of use

Annual lighting hours of use

Average annual hours of use for each site were calculated by dividing the total site evaluated annual kWh savings by the site evaluated connected kW savings to ensure a consistent approach across sites. Therefore, the weighting of each site is based on connected kW savings. Only fixture savings were used in this calculation, since fixture savings are derived from the lighting annual operating hours. Lighting controls savings were not factored into the calculation of annual operating hours.

Building type definitions

The site-level HOU estimates were aggregated by building type according to those listed in Table 6-2. This list was provided by the upstream subcommittee based on three different sources, including their two upstream vendors and CBECS. Per the recommendations in the P86 HOU study, this list includes the following changes to the original: Government Buildings were moved into the Office Building category, and Multi-family was moved into Lodging due to small sample sizes. In addition, Parking Garage was added following the addition of this category in the Upstream Lighting program offering.

Table 6-2. Building type and description

Building Type	Description	Includes
College and University	Buildings used for academic or technical classroom instruction such as classroom buildings on college or university campuses. Buildings on education campuses for which the main use is not classroom are included in the category relating to their use. For example, administration buildings are part of "Office," dormitories are "Lodging," and libraries are "Other."	College or university, junior or community college
Grocery/Food Sales	Buildings used for retail or wholesale of food.	Grocery store or food market, gas station with convenience store, convenience store
Hospital	Buildings used as diagnostic and treatment facilities for inpatient care.	Hospital, inpatient rehabilitation, nursing homes
Industrial/Manufacturing	Facilities where mechanical or chemical transformations of materials or substances into new products take place. Range from steel mills, to small farms, to companies assembling electronic components.	Plants, factories, or mills
K-12 School	Buildings used for academic or technical classroom instruction, such as elementary, middle, or high schools.	Elementary and high schools, preschool or daycare, adult education, care or vocational training, religious education
Lodging	Buildings used to offer multiple accommodations for short-term or long-term residents, including skilled nursing and other residential care buildings.	Motel or inn, hotel, dormitory, retirement home, nursing home, assisted living
Medical Office	Buildings used as diagnostic and treatment facilities for outpatient care. Medical offices are included here if they use any type of diagnostic medical equipment (if they do not, they are categorized as an office building).	Medical office, clinic or other outpatient health care, veterinarian
Office Building	Buildings used for general office space, professional office, or administrative offices excluding government. Medical offices are	Administrative or professional office, government buildings, federal, state, or local government office, city hall, city center,

	included here if they do not use any type of diagnostic medical equipment (if they do, they are categorized as an outpatient health care building).	bank or other financial institution, mixed-use office, sales office, call center.
Parking Garage	Structure used for parking vehicles, multi-level garages.	Parking spaces, ramps, entrances and exits, ticket booth.
Restaurant/Food Service	Buildings used for preparation and sale of food and beverages for consumption.	Fast food, restaurant or cafeteria, bar, coffee, bagel or doughnut shop, ice cream or frozen yogurt shop
Retail	Buildings used for the sale and display of goods other than food.	Retail store, beer, wine or liquor store, auto dealership or showroom, enclosed mall, strip shopping center
Warehouse and Storage	Buildings used to store goods, manufactured products, merchandise, raw materials, or personal belongings (such as self-storage).	Refrigerated warehouse, non-refrigerated warehouse, distribution or shipping center
Other	All other non-residential buildings not otherwise defined in this list.	A wide variety of buildings, including recreational and entertainment facilities such as health clubs, ice rinks, museums, theaters, casinos; service-oriented facilities such as auto repair shops, dry cleaners, car washes, post offices, libraries, etc.; religious facilities such as churches, mosques, synagogues; municipal buildings such as government offices, police and fire stations, etc.

Task 2: Space type hours of use

Space type hours of use were developed exactly the same way as the building type hours of use, calculating the annual hours of use for each unique space type within each site by dividing the total space type annual kWh savings by the space type connected kW savings. Therefore, a site could include different hours of use estimates for each space type included in the building.

Only data from the two most recent custom lighting impact evaluations (P80 and P88) were used for this analysis. In order to standardize space types, evaluators reviewed each analysis spreadsheet and assigned each line a space type that most closely matched those from ASHRAE 90.1 based on the space type descriptions given in the analysis spreadsheet. In total, evaluators identified 43 unique ASHRAE space types in the 67 sites that were reviewed.

Results

Building type hours of use

Table 6-3 presents the results of this analysis as well as the absolute and relative precision estimates for each building type. All precisions were calculated at the 90% confidence interval.

Table 6-3. Building type hours of use

Building Type	Count of Buildings	Hours of Use	Standard Error	Absolute Precision (t-value)	Relative Precision (t-value)
College & University	27	4,132	717	1,223	±29.6%
Grocery/Food Sales	35	5,920	283	479	±8.1%
Hospital	17	5,601	392	684	±12.2%
Industrial/Manufacturing	24	5,229	489	838	±16.0%
K-12 School	42	2,902	201	338	±11.6%
Lodging	36	4,194	541	913	±21.8%
Medical Office	10	3,673	136	248	±6.8%
Office Building	73	4,171	275	458	±11.0%
Other	113	4,141	419	695	±16.8%
Parking Garage	3	8,263	104	305	±3.7%
Restaurant/Food Service	23	4,891	628	1,078	±22.0%
Retail	50	4,957	298	500	±10.1%
Warehouse and Storage	10	6,512	642	1,177	±18.1%
Overall	463	4,569	193	319	±7.0%

Space type hours of use

Table 6-4 presents the results of the space type hours of use analysis. This table does not provide errors and precision estimates due to the small sample sizes for most space type categories. These results are provided for guidance and may be used in the future when developing a savings factor for lighting controls as part of the current Upstream Lighting impact evaluation.

Table 6-4. Space type results

Space Type	Count of Spaces	Hours of Use
Audience/Seating Area - Permanent: For Auditorium	2	1,926
Banking Activity Area	1	5,268
Classroom/Lecture/Training	10	1,985
Conference/Meeting/Multipurpose	10	1,804
Corridor/Transition	30	4,802
Dining Area	6	4,860
Dormitory: Living Quarters	4	2,375
Electrical/Mechanical	21	5,572
Elevator	2	7,715
Exam/Treatment	1	5,818
Exterior	14	5,547
Fire Station: Engine Room	1	8,760
Food Preparation	17	4,688
Grow Room	1	4,018
Gymnasium/Fitness Center: Fitness Area	6	4,244
Laboratory: For Classrooms	3	7,719
Laboratory: For Medical/Industrial/Research	3	5,115
Laundry/Washing	6	2,438
Library: Stacks	5	2,190

Lobby	21	5,119
Locker Room	8	5,540
Lounge/Leisure Dining	2	4,636
Lounge/Recreation	12	4,493
Manufacturing: Detailed Manufacturing	2	7,615
Nurses Station	2	7,075
Office: Enclosed	30	2,164
Office: Open Plan	17	2,947
Operating Room	1	5,382
Other	19	1,567
Outdoor Sign	3	1,638
Parking Garage: Garage Area	4	8,760
Patient Room	2	5,666
Pharmacy	3	6,000
Radiology/Imaging	1	5,691
Refrigerated Case	7	8,508
Religious Buildings: Audience Seating	2	1,295
Restroom	23	4,800
Sales Area	16	5,998
Stairway	14	7,228
Storage	24	1,810
Waiting Area	3	5,356
Warehouse	4	7,134
Workshop	1	1,675

Conclusions and recommendations

This section presents conclusions, recommendations, considerations, and guidance for future research.

Conclusions

- Overall, the updated building type hours of use were within ±5% of those from the P86 HOU study with the following exceptions:

    1. College & University hours decreased by about 15% from the P86 HOU study. It is unclear why this changed so much, but one reason could be fewer common areas being covered by the program in the two most recent custom lighting study periods. The precision of ±29.6% is a small improvement over the P86 HOU study (±32%) but remains relatively poor. Until more College & University results can be included, this HOU estimate will carry more uncertainty than others.

    2. Grocery/Food Sales hours increased by 8%. This was the result of the grocery stores in the most recent custom lighting impact evaluations operating at near 8,760 hours prior to controls being added.

- The parking garage building type was added to this evaluation as a result of the Upstream Lighting initiative adding this category since the prior study was conducted. Currently, the Upstream Lighting initiative assumes 8,760 hours for parking garage lamps. We found the hours of use for parking garages to be 8,263. A deeper look at the three parking

garages in this study found that most of the lamps associated with the parking areas of the garage were 8,760. However, the parking garages in our sample also included some storage and office space with less than 8,760 hours.

- For the space type results, there aren't enough sample points to produce reasonable estimates at this time. Of the 43 space types in the table above, only 11 of these had precision estimates better than ±25%, while only four of these 11 had a sample size of 10 or more.

Recommendations

Recommendation 1. The initiative should begin to use the updated building type hours of use estimates provided in Table 6-3 for upstream lighting with the exception of parking garages.

Recommendation 2. For the Parking Garage Upstream Lighting category, the PAs should continue to assume 8,760 hours for all lamps being installed in main parking areas of the building.

Recommendation 3. As with the prior HOU study, if a building type is unknown, use the "Overall" result from Table 6-3 for upstream lighting, which represents the average operating hours of all building types combined.

Considerations

Consideration 1. Given the changes for the College & University and Grocery/Food Sales building type HOU estimates, consider a review of the underlying data to determine if some of the older study results should be removed from the analysis. Some of the buildings included in this analysis date back to 2010, which could indicate that the programs are targeting lamps/fixtures that operate differently today as compared to 2010. However, the removal of older data could also result in worse precision for some of the building type hours of use.

Consideration 2. The current Upstream Lighting impact evaluation should consider how the space type hours of use estimates can influence the lighting controls savings estimates. Currently, the LED Fixtures w/ Controls Upstream Lighting category assume a 30% percent savings applied to fixtures with controls. The impact evaluation is planning to meter power and hours of controlled upstream fixtures in RI and MA. These results will be supplemented with the results from a current controls study being performed in Connecticut. However, baseline hours will need to be assumed based on data gathered from the site, metering of similar spaces that don't have controls, and interviews. The space type hours of use data may be a valuable data point in helping derive baseline hours in order to develop a new program-level lighting controls savings factor.

Consideration 3. If there is interest in adding to the space type analysis to include more data, consider expanding the scope of this or a future effort to bring in more space type data. This task is fairly time-intensive given the close review and standardization of existing space type descriptions, which is why the scope was limited to the new data only. However, if the PAs find value in this analysis, there is more historical data that can be mined.

Guidance

Guidance 1. Future hours of use updates may consider other weighting schemes. Currently, the building type hours of use estimates are weighted based on the connected kW savings of each sample point. While this weighting scheme is reasonable, it could be over-weighting larger sample points. It also assumes the older data points are no different than the newer data points. Additional weighting options could consider program size and/or recency, which could be an alternative solution to Consideration 1 above.

Guidance 2. The DNV Team decided to present the space type results at their most granular level as these are not intended to be used directly in the savings estimation process. However, there may be some opportunities to collapse some categories to improve sample sizes and statistical results. This exercise should be revisited when developing the lighting controls savings factor as part of the impact evaluation.

APPENDIX B. QUALITY CONTROL REVIEW

DNV initially presented results of the quality control review in a memo dated April 13, 2021. The content of that memo has been incorporated into this appendix. Our review of the distributor handbook; PY2019 tracking data; PY2019 QA/QC data; and interviews with program staff, the implementer, and the verification vendor showed that the program is adhering to its protocols for verifying installation of equipment. According to the PY2019 QC data, 11% of unique transactions were inspected, and the in-service rate was approximately 87%. However, the QC process diverges from evaluation practices in some key areas, presenting some opportunities for improvement to data tracking.

Divergence from general evaluation practices:

- The QC process classifies sites as large and small for sampling purposes based on incentive amounts instead of expected savings.
- Sampling is done manually, and there is an element of convenience included in site selection.
- QC results apply only to sites selected and are not rolled up to the program level.
- If products are found not installed during a QC inspection, a distributor may request a re-inspection after customers have installed the products. About 7.5% of inspected sites were re-inspected in PY2019. Re-inspections are only available for sites with incentive values above $250.

Considerations for improvements in the QC process are:

Consideration 1. The verification and implementation vendors should consider making actions taken as a result of verification results more transparent by tracking distributor actions with more detail.

Rationale: When a QC inspection reveals products are not installed, distributors may return the products (incentives), do nothing, or request a re-inspection. All returns, regardless of reason, are listed as negative sales values and include a return date. Including a variable stating the reason for returns, in the vendor tracking system, would increase the transparency of negative sales within the tracking system. The current return notes field is not consistently populated.

Consideration 2. The verification vendor should consider adopting a more robust sampling approach.

Rationale: The current sampling process allows for an element of convenience in selection of sites. In addition, by sampling monthly with no correction for changes in participation over the course of a year, it is possible to exclude distributors (four distributors out of 33 received no inspections in PY2019). A mid-year check on sampled sites might reveal opportunities to improve sampling for end of year.

Review of quality control procedures

The Upstream Lighting Initiative includes integrated quality assurance and control (QA/QC) data review activities and field verification. As part of the PY2019 impact evaluation, DNV conducted a review of the field verification QA/QC activities. This examination included a review of the distributor handbook, a review of PY2019 QA/QC data, and interviews with program staff, the implementer, and the verification vendor.

QC site sampling

According to the distributor manual, field verification consists of visiting 5% of sites each month to verify installation of products distributed as part of the initiative. Sites are sampled monthly and are stratified by project size and distributor.

- **Project size.** Based on incentive amount, sites are divided into quartiles. The bottom two quartiles are considered small and the top two quartiles are considered large. The verification vendor selects 70% of sites from large and 30% of sites from small. Note: the QC tracking data does not indicate if a site was sampled as a large or small site.
- **Distributor.** At least one site from each distributor (on a statewide basis) each month, assuming such a site exists.

According to the handbook, and confirmed in interviews, National Grid reserves the right to adjust sampling methodology and National Grid and the implementation vendor reserve the right to inspect any site for any reason. Based on interviews, the verification vendor selects sites manually within the above criteria and attempts to geographically coordinate visits for Upstream Lighting with other programs for which they are conducting verification visits.

While on-site, the verification vendor attempts to access and inspect all products purchased. However, at some sites where inspecting all installations is not feasible (ex., dormitories, hotels, and secure laboratories), the verification vendor will inspect 10% of the product installed and credit the unobserved quantity at the same rate of installation. Unobserved product credited based on this method is tracked as installed partial access. For PY2019, less than 9% of products were listed as installed partial access.

Highlights and takeaways:

- Classification of sites as small and large for verification is based on incentive amounts. This is a departure from sampling done for evaluation purposes, which is based on expected savings.
- The QC data does not identify whether a site was classified as large or small for sampling purposes at the time of sample selection.
- Sampling is done manually, and an element of convenience is included in site selection to align with staffing resources across a variety of program verification activities.

Verification process

According to the initiative handbook, participating distributors are required *maintain a rolling average of more than 85% and a verification correction threshold of less than $20,000 for all incentivized sales throughout the current initiative year.* Verification results are presented to distributors, who choose how to respond. When the verification vendor reports that products are not installed, there are three possible actions distributors may take:

1. **Return incentives.** Distributors can return the entire project or a portion of the project and pay back the incentive that was paid out to them. This appears as a negative quantity, negative incentive, and negative savings in the tracking system. Note: customer returns appear the same way in the system.
2. **Re-inspect.** If the incentive value for the site exceeds $250, distributors may request a re-inspection of the site and updates to the inspection results. This is most often done when a QC vendor visits a site before a customer has finished installation of measures. The program has tried to reduce occurrence of this type of re-inspection by asking the QC vendor to ask about project status when scheduling the appointment. If measures are still found not installed upon re-inspection, the distributor may return the missing portion of the measures to the program.
3. **Do nothing.** If a distributor's rolling average is 85% or higher, they may choose to take no action. Implementation staff indicated that it is rare for distributors to take no action, as they strive to have high inspection rates. However, the implementation vendor indicated that distributors often take no action for sites with an incentive amount below $250.

The data tracking system provides details on inspection results, including if a site was re-inspected. However, the application of the results is not as transparent as it could be. All returns are listed as negative sales values and include a return date. In some cases, a comment field contains details on the reason for the return, but this field is not always populated, and when it is, the entries are not uniform. We suggest that including a variable stating the reason for returns would increase the transparency of negative sales within the tracking system. The new variable could include pre-coded fields that list the actions, for example, customer return, duplicate entry, and return based on verification.

This would be especially helpful since the QC data itself also does not list what action, if any, distributors took based on verification results, though the QC data does link to the tracking data based on invoice number. QC data indicates if an inspection was an original inspection, if it was a re-inspection (requested by distributor), and if follow-up action is required.

Highlights and takeaways:

- Re-inspections are only available for sites with incentives values above $250.
- Actions taken as a result of verification results are not transparent in the program tracking data.
- We recommend including a variable that indicates the reasons for returns to add clarity to the data.

PY2019 verification activity

As Table 6-5 shows, based on the tracking data, in 2019 there were 6,448 unique (non-negative) point-of-sale transactions covering 151,807 total unit sales. The verification vendor conducted 478 inspections and 55 re-inspections. These inspections accounted for 88% of all distributors, 17% of all unique sites, 11% of transactions, and 22% of unit sales (by volume). Based on the QC data provided, at these sites, the in-service rate (ISR) was approximately 87%. These results are comparable to those experienced recently in Massachusetts as shown below.

The results of verification visits, and actions taken by distributors as a result, only apply to sites inspected. No global changes in tracking are made based on QC results at a sample of sites. The verification vendor recently began to track product that customers said was on hand as spare separately. Based on PY2019 verification visits, less than 1% of product sold (5% of product found not installed) is kept on hand as spares. The largest categories of not installed units are refusals (57%), not found (12%), and to be installed (9%). See Table 6-6 for additional details and descriptions of categories.

Table 6-5. Verification data

Category	All	QC visits	QC coverage/result	MA QC coverage/result
Distributors	33	29	88%	88%
Unique sites	2,842	478	17%	12%
Unique transactions	6,448	729	11%	10%
Sales quantity	151,807	33,714	22%	16%
Installed	Unknown	29,308	87%	90%
Returned Products	Unknown	1,301	4%	<1%
Spare product	Unknown	204	<1%	1%

Table 6-6. Disposition for product not installed

Category	Percent	Description	MA Percent
Refusal not installed	57%	Refused the inspection and reported product was not installed.	23%
Not found	12%	Product not found during inspection.	20%
To be installed	9%	Customer reported product was scheduled to be installed.	13%
Product redistribution	6%	Product redistributed to another location.	3%
Refusal – not received	6%	Customer reported product had not been received.	2%
Spare	5%	Customer reported product kept on hand as spare.	10%
Refusal	3%	Refused to participate in inspection did not specify installation.	18%
To be returned	2%	Customer reported intention to return product.	1%
Product mismatch	1%	Product did not match sales records.	2%
Damage not confirmed	<1%	Customer reported product was damaged.	<1%
Damage confirmed	<1%	QC vendor confirmed damage to product.	<1%
Ineligible sale	0%	Customer ineligible for product.	<1%

Highlights and takeaways:

- Verification results are only applied to the sites visited as part of verification activities.
- Sites for seven distributors did not include any inspection activity for PY2019.

APPENDIX C. STATE-LEVEL RESULTS

Table 6-7 shows the study sample sizes by evaluation category and state. A total of 59 National Grid Massachusetts and 25 Rhode Island sites were included in this study.

Table 6-7. Study sample sizes by state

Evaluation Category	MA Sample Size	RI Sample Size	Combined Sample Size
Category 1 - Linear/TLEDs	6	3	9
Category 2 – LED Fixtures	10	4	14
Category 3 – LED Fixtures w/ Integrated Controls	4	1	5
Category 4 – Screw-In LEDs	4	6	10
Category 5 – Exterior LEDs	9	3	12
Category 6 – High/Low Bay LEDs	26	8	34
Total	**59**	**25**	**84**

Table 6-8 provides the energy savings results by state. The overall Massachusetts realization rate is 78.1% with a precision of ±15.5% at the 90% confidence level, while the overall Rhode Island realization rate is 87.4% with a precision of ±26.7% at the 90% confidence level.

Table 6-8. Energy savings realization rates by state

Evaluation Category	MA Realization Rate	RI Realization Rate	Combined Realization Rate	TRM Realization Rate Assumption[22]
Category 1: Linear/TLEDs	75.9%	73.3%	75.3%	78.0%
Category 2: LED Fixtures	115.3%	66.6%	114.4%	78.0%
Category 3: LED Fixtures w/ Integrated Controls	112.1%	26.6%	112.0%	78.0%
Category 5: Exterior LEDs	157.2%	175.3%	159.6%	68.0%
Category 6: High/Low Bay LEDs	56.9%	38.3%	54.8%	78.0%
All Non-Screw-In LEDs	**82.3%**	**73.1%**	**81.0%**	**77.2%[23]**
Category 4: Screw-In LEDs	39.1%	136.9%	68.9%	78.0%
Overall	**78.1%**	**87.4%**	**79.6%**	**77.3%[24]**

[22] https://etrm.anbetrack.com/#/workarea/trm/MADPU/COM-L-LS/2019-2021%20Plan%20TRM/version/1?measureName=Lighting%20-%20System, Energy Realization Rates from 'Impact Factors for Calculating Adjusted Gross Savings' Table.

[23] TRM RR assumptions of 78% for linear/TLEDs, LED fixtures, LED fixtures with integrated controls, and high/low bay LEDs and 68% for exterior LEDs weighted by the tracking savings for each of these evaluation categories.

[24] TRM RR assumptions of 78% for linear/TLEDs, LED fixtures, LED fixtures with integrated controls, screw-in LEDs, and high/low bay LEDs and 68% for exterior LEDs weighted by the tracking savings for each of these evaluation categories.

Table 6-9 summarizes the short-term in-service rate (ISR) results by state. The overall Massachusetts short-term ISR is 86.8% with a precision of ±8.0% at the 90% confidence level, while the overall Rhode Island short-term ISR is 95.3% with a precision of ±5.6% at the 90% confidence level.

Table 6-9. In-service rates by state

Evaluation Category	Tracking System In-Service Rate[25]	MA Short-Term In-Service Rate	RI Short-Term In-Service Rate	Combined Short-Term In-Service Rate
Category 1: Linear/TLEDs	100.0%	95.1%	98.9%	96.0%
Category 2: LED Fixtures	100.0%	98.1%	63.6%	97.5%
Category 3: LED Fixtures w/ Integrated Controls	100.0%	97.2%	100.0%	97.2%
Category 5: Exterior LEDs	100.0%	93.8%	100.0%	94.6%
Category 6: High/Low Bay LEDs	100.0%	90.9%	88.5%	90.6%
All-Non-Screw-In LEDs	**100.0%**	**93.1%**	**94.5%**	**93.3%**
Category 4: Screw-In LEDs	100.0%	27.0%	98.4%	48.7%
Overall	**100.0%**	**86.8%**	**95.3%**	**88.1%**

Table 6-10 presents the delta watts realization rates by state. The overall Massachusetts delta watts realization rate is 98.0% with a precision of ±13.5% at the 90% confidence level, while the overall Rhode Island delta watts realization rate is 96.1% with a precision of ±26.8% at the 90% confidence level.

Table 6-10. Delta watts realization rates by state

Evaluation Category	MA Realization Rate	RI Realization Rate	Combined Realization Rate
Category 1: Linear/TLEDs	105.7%	86.7%	101.1%
Category 2: LED Fixtures	118.9%	108.1%	118.7%
Category 3: LED Fixtures w/ Integrated Controls	114.8%	31.2%	114.7%
Category 5: Exterior LEDs	184.4%	172.8%	182.8%
Category 6: High/Low Bay LEDs	61.0%	35.8%	58.3%
All Non-Screw-In LEDs	**92.1%**	**75.8%**	**89.8%**
Category 4: Screw-In LEDs	148.8%	148.4%	148.5%
Overall	**98.0%**	**96.1%**	**97.6%**

Table 6-11 shows the hours of use realization rates by state based on the hours of use from the update memo in 0 by evaluation category. The overall Massachusetts HOU realization rate is 91.9% with a precision of ±9.2% at the 90% confidence level, while the overall Rhode Island HOU realization rate is 95.4% with a precision of ±9.0% at the 90% confidence level.

[25] https://etrm.anbetrack.com/#/workarea/trm/MADPU/COM-L-LS/2019-2021%20Plan%20TRM/version/1?measureName=Lighting%20-%20System. All upstream ISRs are incorporated into the realization rates so the ISR is set to 100% to avoid double counting.

Table 6-11. Hours of use realization rates by state

Category	MA Realization Rate	RI Realization Rate	Combined Realization Rate
Category 1: Linear/TLEDs	75.4%	85.4%	77.5%
Category 2: LED Fixtures	98.9%	96.9%	98.9%
Category 3: LED Fixtures w/ Integrated Controls	100.5%	85.4%	100.5%
Category 5: Exterior LEDs	90.9%	101.5%	92.3%
Category 6: High/Low Bay LEDs	102.6%	120.8%	103.8%
All Non-Screw-In LEDs Sub-Total	**91.7%**	**96.4%**	**92.2%**
Category 4: Screw-In LEDs	97.3%	93.7%	95.1%
Overall	**91.9%**	**95.4%**	**92.5%**

Table 6-12 presents the connected demand realization rates without interactive effects by state. The overall Massachusetts connected demand realization rate is 93.7% with a precision of ±16.9% at the 90% confidence level, while the overall Rhode Island connected demand realization rate is 103.5% with a precision of ±34.4% at the 90% confidence level.

Table 6-12. Connected demand savings realization rates without interactive effects by state

Evaluation Category	MA Realization Rate	RI Realization Rate	Combined Realization Rate
Category 1: Linear/TLEDs	104.8%	85.8%	100.7%
Category 2: LED Fixtures	121.9%	89.7%	121.3%
Category 3: LED Fixtures w/ Integrated Controls	143.6%	31.2%	143.5%
Category 5: Exterior LEDs	194.0%	202.8%	195.1%
Category 6: High/Low Bay LEDs	61.0%	31.3%	57.7%
All Non-Screw-In LEDs	**98.5%**	**80.5%**	**96.1%**
Category 4: Screw-In LEDs	50.8%	176.6%	88.6%
Total	**93.7%**	**103.5%**	**95.2%**

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