DRAFT REPORT

Impact Evaluation of PY2015 Massachusetts Commercial and Industrial Upstream Lighting Program

Massachusetts Program Administrators and Energy Efficiency Advisory Council

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Table of contents

List of figures

List of tables

1 EXECUTIVE SUMMARY

This Executive Summary provides a high-level review of the findings of the Impact Evaluation of the 2015 program year of the Massachusetts Commercial and Industrial (C&I) Upstream Lighting Program, conducted by the DNV GL team for the Massachusetts Program Administrators (PAs) and Energy Efficiency Advisory Council (EEAC) Consultants. In this section, we state the study objectives, summarize the evaluation approach, and present key findings, conclusions, and recommendations.

1.1 Overview of objectives and approach

The primary goal of this impact evaluation is to quantify the electric energy savings and demand reduction attributable to the Massachusetts C&I Upstream Lighting Program. This enables the PAs to assess whether the program is achieving the expected savings, and to identify any recommendations for improvement.

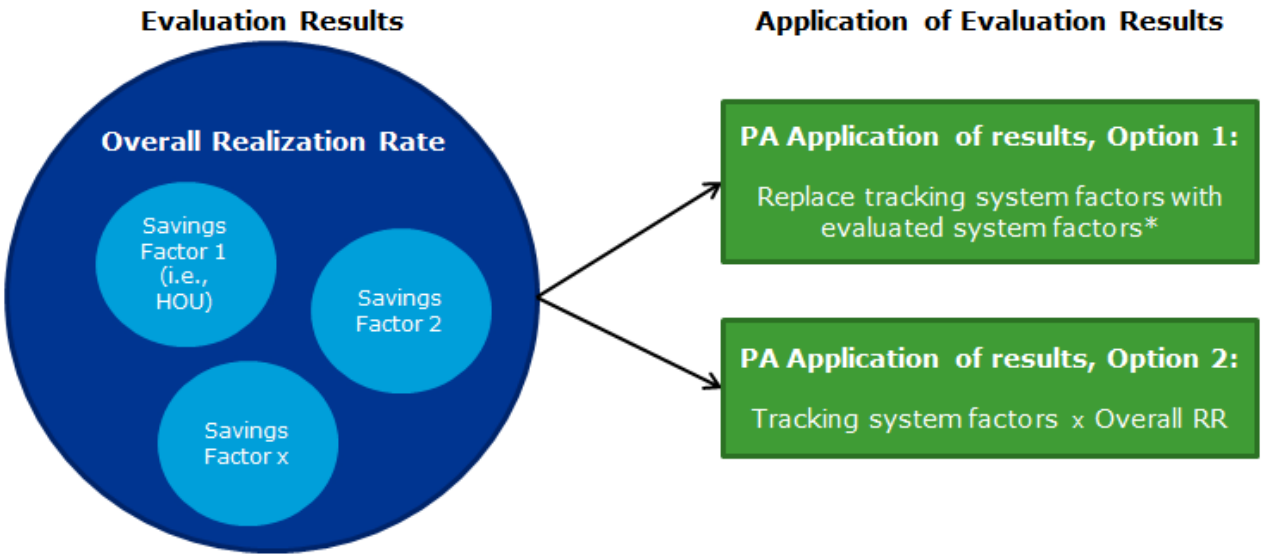
This study's research objectives include updating the following assumptions with Massachusetts-specific research:

- Deployment of purchased lamps by facility and space type
- Hours of use of purchased lamps—to inform both retrospective and prospective application
- Baseline replaced lamps for estimating delta watts—to inform both retrospective and prospective application
- Gross savings realization rates to be applied to 2016 results
- Estimates of summer and winter on-peak and seasonal peak coincidence factors
- Estimates of HVAC interactive effects
- Percent energy on-peak
- Non-electric HVAC interactive effect

The evaluation also seeks to address the potential issue of over or under-illumination by measuring foot-candle levels at the work surface and the general quality of the lighting.

This study provides results at the state-wide level using metered data collected from each site. We have developed savings factors that may be applied retrospectively and to future program assumption updates. Figure 1-1 shows the results we developed along with options for PA application.

Figure 1-1. Options for application of evaluation results



**Most PAs use Option 1 based on their tracking systems.*

In keeping with recent discussions about using evaluation, measurement, and verification (EM&V) to vet ex-ante baseline assumptions, the DNV GL team has determined whether the classification of upstream lighting measures as early replacement is valid.

1.2 Summary of approach

The DNV GL team's approach and methodology were consistent with the procedures and protocols developed during the previous upstream lighting impact evaluation conducted in 2012 (2012 evaluation). This study required on-site visits and metering of lighting hours of use for a randomly selected sample of measures[1] in locations which purchased bulbs or kits through the Upstream Lighting Program. In addition to on-site metering, our team investigated baseline issues. A high-level synopsis of the evaluation approach is as follows:

Error! Reference source not found.. Our team investigated program changes since the 2012 evaluation and determined the customer sample frame to develop a sample design that meets the desired statistical precision targets for key savings parameters such as energy and peak demand savings, as well as other factors such as peak coincidence factors and HVAC interactive effects.

Data collection and analysis. Data collection for this impact evaluation included a physical inspection and inventory, interviews with facility personnel, observation of site operating conditions and equipment, and short-term metering of lighting hours of use.

Error! Reference source not found.. In order to attempt to address the potential issue of over/under-illumination, the DNV GL team assessed lighting quality and any lost opportunities associated with light

1 The 2012 evaluation used a randomly selected sample of locations. The 2015 evaluation was based on a randomly selected sample of measures; more detail is provided in section 3.2.

measures, by measuring light levels, color rendering index and correlated color temperature reviews, lighting power densities, and an assessment of light quality in terms of light levels, light uniformity, and color rendering index.

1.3 Summary of findings

Table 1-1 shows the program's final realization rates by key product category. For measure categories 2, 3, and 4, realization rates were notably low. While category 1 had a high realization rate, this was driven in large part by PA installed case assumptions that were too high. For category 5, the high realization rate was driven by the observed hours of use being higher than the assumed hours of use.

Table 1-1. Final realization rates for the program by key product category

Savings Parameter	Energy - Category 1 TLEDs	Energy - Category 2 Stairwell kits	Energy - Category 3 Retrofit kits	Energy - Category 4 A-lines and Decoratives	Energy - Category 5 G24s	Energy - Categories 3, 4, 5 Combined
Gross Realization Rate (with in-storage adjustment)	195.20%	46.99%	51.38%	27.24%	111.87%	48.55%
Gross Realization Rate (without in-storage adj)	188.59%	45.72%	48.06%	25.92%	98.56%	44.84%

Table 1-2 shows the installation rates for all measure categories. We found these rates to be poor for all categories except category 1, TLEDs, which means that site auditors did not find a significant quantity of the products installed. Despite these poor installation rates, category 5 still saw some savings. Low installation rates occurred due to various factors including products still being in storage onsite, customers removing or returning defective products, products being sent to alternate locations, or customers exchanging products for which there was no associated tracking information.

Table 1-2. Installation rates for all measure categories

Savings Parameter	Energy - Category 1 TLEDs	Energy - Category 2 Stairwell kits	Energy - Category 3 Retrofit kits	Energy - Category 4 A-lines and Decoratives	Energy - Category 5 G24s	Energy - Categories 3, 4, 5 Combined
Installation Rate (with in-storage adjustment)	91.95%	69.77%	62.24%	66.63%	62.91%	63.81%
Installation Rate (without in-storage adj)	89.78%	65.94%	58.56%	62.42%	56.74%	59.54%

1.4 Conclusions

As shown in Table 1-1, for three LED categories, the MA C&I Upstream Lighting Program is delivering substantially lower savings than claimed by the PAs. Site auditors were unable to locate products claimed in tracking, despite extensive efforts to track down products that were not installed at the locations indicated in the tracking information. The on-site teams observed a complex market that may not always lend itself to a one-to-one correspondence between a distributor sale and a specific installation site. Contractors buy product to install at multiple locations and to have on-hand for future work. Franchisees buy product that is first centrally stored and then deployed to multiple locations. Customers may install a majority of the product, but keep the balance in storerooms.

These results were similar to the PY2012 results, even though PAs had taken steps to better identify product destinations. Data collection done for this study showed large and sweeping discrepancies between the program tracking data and what was observed onsite, with the tracking data claiming LED lighting that turned out not to be installed, for a variety of reasons. As the PAs are aware, these discrepancies arose in large part due to initial tracking system inadequacies, including an inability to link specific purchases with ongoing customer activity (such as returns, exchanges, etc.). Since being alerted to these inadequacies, the PAs have begun proactively making systematic program changes to address them. While such proactiveness is undoubtedly positive, it is possible that further program changes will be needed to avoid discrepancies of this nature in the future.

1.5 Recommendations and considerations

Overall, category-level results with the in-storage installation adjustment applied to in-storage sites resulted in a small increase beyond the category-level evaluation savings. Table 1-3 shows the increase in kWh realization rate for each LED category as a result of an assumed installation rate increase for sites with lamps found to be in-storage. The DNV GL team recommends using in-storage adjusted values when applying results from this study.

Table 1-3. Final realization rates for the program by key product category

Savings Parameter	Energy - Category 1 TLEDs	Energy - Category 2 Stairwell kits	Energy - Category 3 Retrofit kits	Energy - Category 4 A-lines and Decoratives	Energy - Category 5 G24s	Energy - Categories 3, 4, 5 Combined
Gross Realization Rate (with in-storage adjustment)	195.20%	46.99%	51.38%	27.24%	111.87%	48.55%
Gross Realization Rate (without in-storage adj)	188.59%	45.72%	48.06%	25.92%	98.56%	44.84%

1.5.1 Savings assumptions

For PAs who apply results of this study using *Option 1: Replace tracking system factors with system factors*, the proposed new energy savings factors are provided in Table 1-4 below. For each product type, multiply each factor in the table to derive the Annual Savings per Unit (kWh) value for that product type.

Table 1-5 provides the proposed new peak demand savings factors including the summer and winter coincidence factors and HVAC interactive effects factors. These can be multiplied by the Installation Rate and Watts Saved per Unit factors from Table 1-4 to produce summer and winter peak demand savings.

Table 1-4. Proposed new energy savings factors

Product type	Category	Installation Rate	Watts Saved per Unit	Hours of Use	HVAC Interactive Effect (kWh)	Annual Savings per Unit (kWh)
G24 LED	5	63%	15.3	5,673	102%	56
A-line, 40/60w	4	67%	21.7	2,400	103%	36
A-line, 75/100w	4	67%	30.5	2,400	103%	50
Decoratives	4	67%	13.6	2,400	103%	22
LED Retrofit kit, <25W	3	62%	38.4	3,281	104%	81
LED Retrofit kit, >25W	3	62%	56.6	3,281	104%	120
MR16	3	62%	22.1	3,281	104%	47
PAR20	3	62%	28.1	3,281	104%	60
PAR30	3	62%	38.1	3,281	104%	81
PAR38	3	62%	44.2	3,281	104%	94
Stairwell Kit, 2ft w/sensor	2	70%	41.3	7,633	100%	220
Stairwell Kit, 4ft w/sensor	2	70%	35.6	7,633	100%	189
TLED, 2ft	1	92%	6.9	4,426	101%	28
TLED, 4ft	1	92%	13.8	4,426	101%	57

Table 1-5. Proposed new peak demand savings factors

Product type	Category	Summer CF	Winter CF	Summer kW HVAC Interactive Effect	Winter kW HVAC Interactive Effect
G24 LED	5	81%	81%	113%	100%
A-line, 40/60w	4	38%	31%	119%	81%
A-line, 75/100w	4	38%	31%	119%	81%
Decoratives	4	38%	31%	119%	81%

Product type	Category	Summer CF	Winter CF	Summer kW HVAC Interactive Effect	Winter kW HVAC Interactive Effect
LED Retrofit kit, <25W	3	66%	56%	134%	88%
LED Retrofit kit, >25W	3	66%	56%	134%	88%
MR16	3	66%	56%	134%	88%
PAR20	3	66%	56%	134%	88%
PAR30	3	66%	56%	134%	88%
PAR38	3	66%	56%	134%	88%
Stairwell Kit, 2ft w/sensor	2	81%	82%	102%	100%
Stairwell Kit, 4ft w/sensor	2	81%	82%	102%	100%
TLED, 2ft	1	72%	66%	115%	97%
TLED, 4ft	1	72%	66%	115%	97%

1.5.2 Program process

- In their new address validation process, the PAs should include a flag for customers that have key account managers. This flag should direct those customers back to the PAs so that they don't go through the program. This would help close the gap between vendor-driven and key account-driven initiatives.[2]

- The PAs should record any customer follow-up activity relating to program products in the new inspection tracking system. This will help ensure that when the PAs are contacted by a customer directly and work with that customer to return or exchange any products received through the program, this activity gets tracked and saved, to be retrievable later.

1.6 Considerations

- Consider adding data validation to tracking data entries so that returns (negative entries) cannot be entered without linking sales to support the return. Program tracking data associated with a site can include a negative sales quantity which is typically from customer bulb returns. A negative sales quantity can also be a correction made to the tracking database if the third-party QC contractor could not find the bulbs at the site. In preparation of the sample frame for this study the DNV GL team worked with the third-party program manager to try and rectify sites that had more negative sales quantities than positive sales quantities; in several cases the purchases were made the previous year and returns were

[2] The evaluation team understands that the PAs have had a rule in place that if above a certain threshold of fixtures are purchased they should go through an account manager.

reflected in the 2015 data received by the evaluation team. However, for some customers, the third-party QC contractor was unable to locate the sales associated with the return. In order to more easily verify bulb returns made by customers and to avoid possible keying errors, negative sales entries should be linked to the sale in the tracking database.

- Consider engaging distributors in reporting practice trainings and tie reporting and verification to distributor. Several of the category 3 purchases were not found on site or in-storage but were associated with the customer installation address. There was at least one case where the customer information for a set of purchases (multiple line items in the tracking database) was the same but the customer only knew about a subset of the purchases. It is possible that if there are project changes, distributors are not going back and updating installation and purchase details in the tracking database. Distributors should be trained on how to accurately report sales, returns, and installations, and the program could consider a review of distributor reporting performance.
- In their new address validation process, the PAs may consider including a flag indicating that that customer has been served by another distributor in the past. This could help to inform distributor installation and performance thresholds. Additionally, consider making distributors who share the same customer share the installation rate if it cannot be clearly determined which products were installed by which distributor.
- In addition to linking distributor sales entries to account numbers, consider including distinct address fields to be auto-populated based on validation prompts. It's expected that large customers have separate addresses for billing, product delivery, and installation; the product delivery and installation addresses should be entered accurately by the distributor based on customer or contractor provided information.[3] Consider building in validation logic so that distributors don't have to enter the same address information multiple times for small customers/purchases.
- Consider adding a purchaser category field such as contractor, electrician, or end-use customer to help track performance progress by purchaser type. This can also help the QC vendor identify contractor projects to follow up with.
- In addition to training distributors on data entry, consider offering training and support communication materials that distributors can pass on to contractors and customers, to be able to communicate why they're getting discounts (PAs), what's needed from them in order to sell the products, and the rationale for the information requested.
- Consider including product literature about appropriate applications for each technology (i.e., "How to make your LEDs last their full measure life") and include this sort of information with a flier to purchasers that remind them about program rules, that the PAs are sponsoring the product, and that the PAs would like to hear from the customer if they experience any product issues.

1.7 Future research

- Consider further installation rate analysis. The program conducts quality control inspections for about 10 percent of the sites to make sure that they can verify on-site the lighting quantities and types claimed in the distributor sales reports. Part of the intention of the QC contractor visits is to establish that the installs are legitimate, and if not, provide a window for reconciliation after which, if not installed, the units would be backed out of the tracking data and appear as negative sales entries in the third-party

[3] The DNV GL team assumes that distributors enter account information provided by the customer and the billing address and customer name auto populate. This type of data entry would keep customer name and addresses standardized within the data with data entry quality potentially varying in other fields to be entered by the distributor. Having at least the customer and account number accurate and consistent allows the PAs to efficiently track customer activity relating to the upstream lighting program.

provided data for the year of the install. The PAs could consider supporting further research into the discrepancy between installation rate shown by the QC contractor visits and those found in this evaluation. Interviews with the third-party program manager could help to explain potential tracking challenges.

- Conduct a process evaluation after program changes are complete to assess areas of improvement due to the changes. The last process evaluation of the MA C&I Upstream Lighting Program was conducted as part of the Year 1 evaluation (2012-2013). The timing for a process evaluation of the program within the next 6 to 8 months is good to inform and assess program delivery.
- Consider assessing the quality of the program data in early 2017 following the rollout of program changes.
- Consider identifying purchaser thresholds by account number, distributor, purchaser, and/or customer installation address. The program uses a threshold to prompt follow-up; having multiple thresholds can help identify the individual to follow-up with.
- Consider exploring the extent to which customer installation addresses and associated installation fields have more than one distributor selling products to that address. It's expected that this would be a more problematic issue prior to program changes since program changes will now include an address validation process as well as require more detailed information be entered around the location for where products are being installed.
- Consider conducting another set of on-sites revisiting in-storage and product issue sites to assess any changes in installation rates since the initial site visit. In 2015, a follow-up study (known as the revisit study, or Project 49) was performed to revisit Year 1 (Project 17) sites that were found to have in-storage bulbs, and investigate whether and when those bulbs were eventually installed, as well as calculate savings from bulbs moved from storage to sockets. The revisit study found that some of the bulbs in storage were later installed (within three years of the first site visit). The DNV GL team used the revisit study to inform an adjustment which was applied to this study's category 3 results. The PAs could consider a revisit study in 2018 to revisit in-storage sites as well as sites with product issues that are part of this study, and calculate savings from lamps that were eventually installed.

2 INTRODUCTION

This document presents the final report for the Impact Evaluation of the Massachusetts Commercial and Industrial (C&I) Upstream Lighting Program (Upstream Lighting Program). DNV GL completed this study with the help of ERS and NMR (DNV GL team) for the Massachusetts electric Program Administrators (PAs) with the guidance of the Massachusetts Energy Efficiency Advisory Council (EEAC).

2.1 Background

The Massachusetts C&I Upstream Lighting Program attempts to increase the market penetration of energy-efficient lighting technologies in C&I buildings through the use of upstream incentives that are used to buy down the cost of these lighting technologies at the lighting distributor level. All four electric PAs in the state (Cape Light Compact, Eversource, National Grid, and Unitil) are participating in the program. The program began offering upstream incentives for linear fluorescent lighting technologies in August 2011, and for LED lighting technologies in October 2011. In the case of the LED lamp lighting technologies, the upstream incentives took the place of the downstream lamp incentives that the Massachusetts C&I programs had previously offered for these technologies.

The lighting distributors who participate in the program are obligated to collect sales data on the type and quantity of discounted products sold, as well as the name, location, and contact information of the customers to whom they sold the products. Every month the distributors submit their sales data to the PAs and to a third-party program manager (Program Manager), who combines the sales data from the various participating distributors and then allocates the energy savings and incentives to each participating PA. The Program Manager then issues invoices to each PA for that particular month.

The program also utilizes an independent third-party quality control (QC) contractor, who conducts on-site quality control inspections at about 10% of the facilities each month to verify the lighting quantities and types claimed in the distributor sales reports. The QC contractor performs inspections on a selection of the largest purchases, and a random selection of purchases from across the PA territories and distributors.

2.1.1 Key program changes following 2012 evaluation

The Upstream Lighting Program was last evaluated for program year 2012 through Project 17 (2012 evaluation)[4] with a follow-up study of in-storage lamps conducted in 2014 (Project 49).[5] Since the time of these prior evaluations, the program has grown and changed in ways that make it important to reassess program performance.

The DNV GL team spoke with PA program managers and reviewed the 2015 tracking data to understand program changes that had occurred since the first impact evaluation, which covered the 2012 program year. The Upstream Lighting Program has continued to grow since the 2012 evaluation, and now features a more diverse measure mix. Notably, however, as shown in Table 2-1, the LED product types included in category 3 were largely included in the Year 1 evaluation.

[4] *Impact Evaluation of the Massachusetts Upstream Lighting Program*, Final Report; prepared by KEMA, Inc. for Massachusetts Energy Efficiency Program Administrators and Massachusetts Energy Efficiency Advisory Council; February 19, 2014. http://ma-eeac.org/wordpress/wp-content/uploads/Upstream-Lighting-Impact-Evaluation-Final-Report.pdf

[5] *Massachusetts Commercial and Industrial Upstream Lighting Program: "In Storage" Lamps Follow-up Study*, Final Report; prepared by DNV GL for Massachusetts Energy Efficiency Program Administrators and Massachusetts Energy Efficiency Advisory Council; March 27, 2015. http://ma-eeac.org/wordpress/wp-content/uploads/CI-Upstream-Lighting-Program-In-Storage-Lamps-Follow-up-Study.pdf

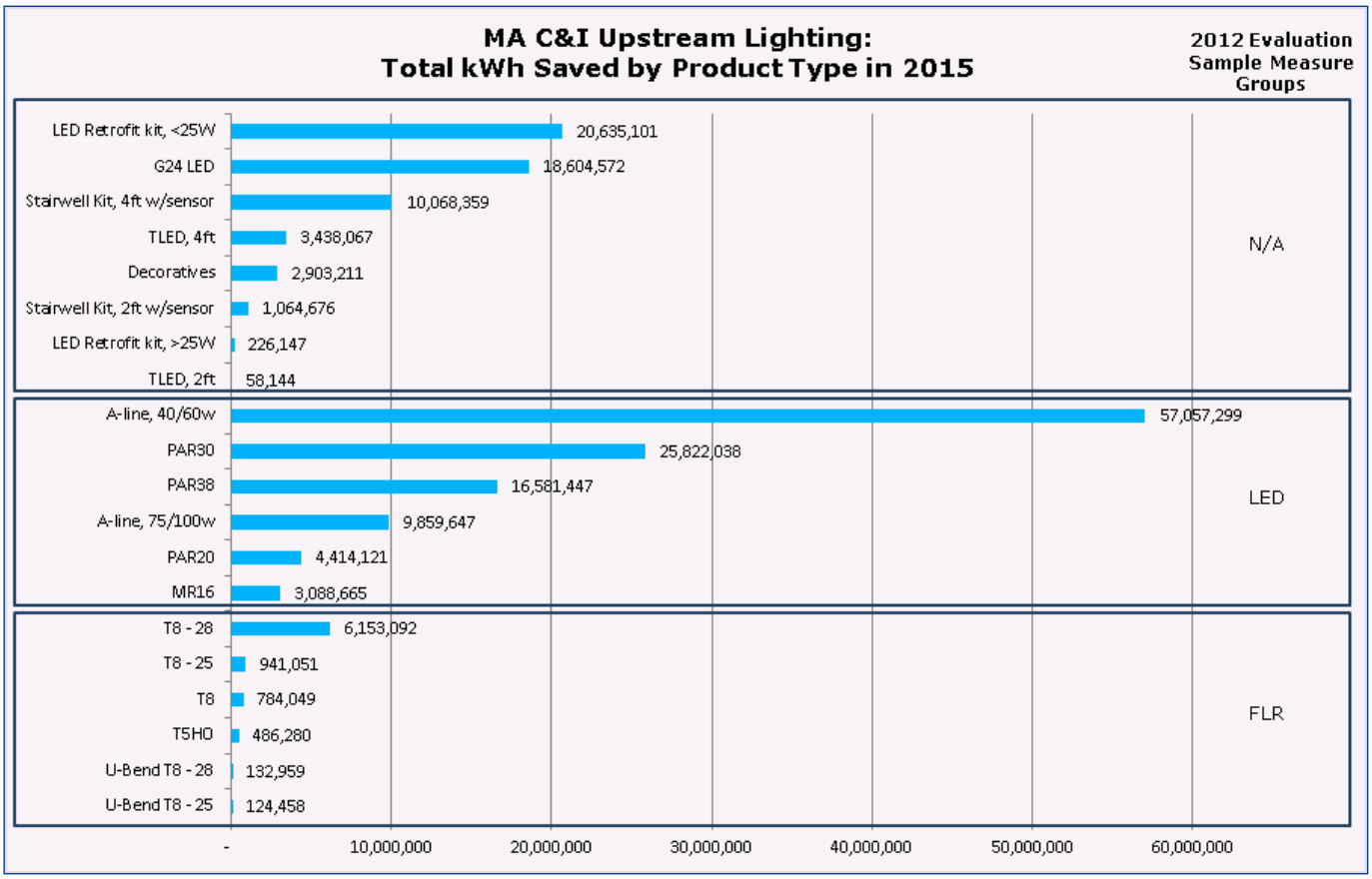
The 2015 program largely consisted of LED lighting technologies. It is expected that linear fluorescents will no longer be offered as part of the Upstream Lighting Program after 2016; thus, the focus of this evaluation was on LED lighting technologies. LED product descriptions are provided in APPENDIX A.

Table 2-1. 2015 Upstream lighting program LED product type timing

Sample design category	Product type name	Introduction into program/updated	Included in 2012 evaluation
1	TLED, 2ft and 4ft	January 2015	
2	Stairwell Kit w/	June 2014	
3	LED retrofit kit, <25W	April 2013	
3	LED retrofit kit, >25W	April 2013	
3	MR16	October 2011	X
3	PAR20	October 2011	X
3	PAR30	October 2011	X
3	PAR38	October 2011	X
4	A-line, 40/60w	January 2015	X
4	A-line, 75/100w	January 2015	X
4	Decoratives	April 2012	
5	G24 LED	July 2015	

Figure 2-1 provides a summary of 2015 upstream lighting savings by product type and by 2012 evaluation sample measure groups (LED versus fluorescent); the top grouping shows products added since the first evaluation.

Figure 2-1. Summary of 2015 MA C&I upstream lighting data with 2012 evaluation sample measure groups[6]



The PAs have made (and plan to make further) process improvements in response to ongoing third-party QC results. These improvements and their implementation dates are listed in Table 2-2. Note that all of these changes have occurred since the program year evaluated in this report.

Table 2-2. Past and planned process improvements to the MA C&I Upstream Lighting Initiative

Number	Date	Name	Description
1	June 2016	Begin program QC review and redesign	PAs reviewed program inspection results and began a concerted effort to redesign and address issues
2	June 2016	Distributor action	Distributor/s responsible for poor results were suspended, pending correction
3	Fall 2016	Inspection tracking in Salesforce	Used Excel to track and communicate inspection results; created logistic and accuracy issues
4	Jan 2017	Improved inspection follow-up	Third-party program manager began more concerted inspection follow-up requiring a return or corrected

[6] Savings are based on the final 2015 lighting assumptions spreadsheet provided by the PAs.

Number	Date	Name	Description
			install on all inspections with rebates >$500
5	April 2017	Phase 1 return tracking	Less manual return process to deduct returns from sales
6	July 2017	Address validation	Improved customer eligibility verification at the point of sale to check for account numbers
7	Sept 2017	Automated inspection result exchange	Fully automated data transfer into Salesforce of inspection results, reducing human error and inconsistent delivery and content
8	Oct 2017	Phase II return tracking	Automated return tracking, improved auditing and accounting process
9	Oct 2017	Distributor dashboard	View of inspection results, performance metrics, suspension thresholds, status tracking of corrections
10	Dec 2017	Performance thresholds active	Inspection results and all changes are active and functional

Also since the first evaluation, the PAs have made baseline adjustments to account for Energy Independence and Security Act (EISA) legislation through adjustments to measure life. The first impact evaluation showed that a large percentage of incandescent bulbs were being replaced; eventually this trend will not continue, as incandescent bulbs are completely phased out.

The PAs have also updated their hours of use (HOU) assumptions based on the first impact evaluation. To the extent possible, this information was leveraged to help determine the error ratios to be used in the sample design for this study. It was expected that since prior evaluation results were directly applied to the savings estimates used by the PAs, the evaluation results would be less variable than they were in the first evaluation, justifying lower error ratios.

After the first evaluation, the PAs ran promotions on LED fixtures between June 2015 and November 2015. These promotional LED fixtures were not included in the Upstream Lighting Program in 2015, but were added in 2016.

2.2 Study objectives

The primary goal of this impact evaluation is to quantify the electric energy savings and demand reduction attributable to the Massachusetts C&I Upstream Lighting Program. This enables our team to assess whether the program is achieving the expected savings, and to identify any recommendations for improvement.

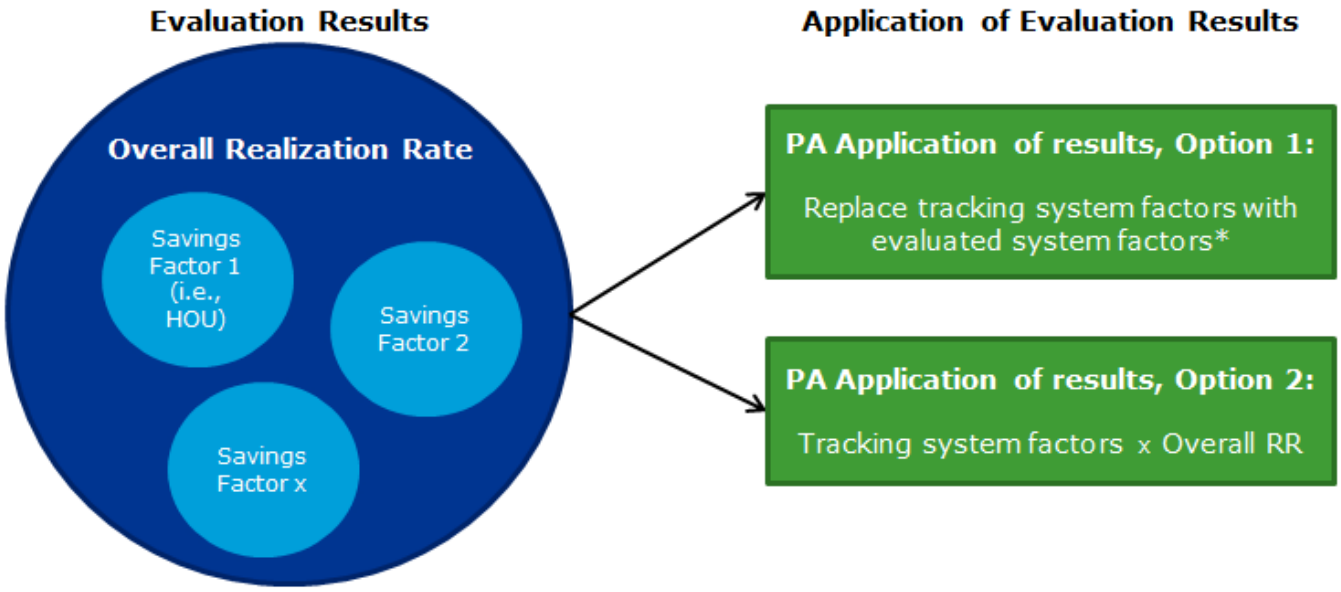
This study's research objectives include updating the following assumptions with Massachusetts-specific research:

- Application of purchased lamps by facility and space type
- Hours of use of purchased lamps—to inform both retrospective and prospective application

- Baseline replaced lamps for estimating delta watts—to inform both retrospective and prospective application
- Gross savings realization rates to be applied to 2016 results
- Estimates of summer and winter on-peak and seasonal peak coincidence factors
- Estimates of HVAC interactive effects
- Percent energy on-peak
- Non-electric HVAC interactive effect

This study will provide results at the state-wide level using metered data collected from each site. A listing of all realization rates and savings factors with descriptions and algorithms is presented in APPENDIX E. The savings factors will be developed so that they may be applied retrospectively and to future program assumption updates. Figure 2-2 shows the results to be developed and options for application by the PAs.

Figure 2-2. Options for application of evaluation results



**Most PAs use Option 1 based on their tracking systems.*

In keeping with recent discussions about using evaluation, measurement, and verification (EM&V) to vet ex-ante baseline assumptions, the DNV GL team has attempted to determine whether the classification of upstream lighting measures as early replacement is valid.

A final objective of this evaluation, which was proposed as an optional task in this study's work plan, is to attempt to address the potential issue of over or under-illumination by measuring foot-candle levels at the work surface; more detail on this will be provided in the next iteration of this report.

2.3 Summary of approach

The DNV GL team's approach and methodology were consistent with the procedures and protocols developed during the previous round of upstream lighting impact evaluation conducted in 2012. This study

required on-site visits and metering of lighting hours of use for a randomly selected sample of measures[7] in locations which purchased bulbs through the Upstream Lighting Program. In addition to on-site metering, our team investigated baseline issues.

7 The 2012 evaluation used a randomly selected sample of locations. The 2015 evaluation was based on a randomly selected sample of measures; more detail is provided in section 3.2.

3 METHODOLOGY

3.1 Determining the customer sample frame

In January 2016, the DNV GL team received program tracking data that covered the period from January 2015 through December 2015. We used these data to determine the sample frame discussed in this subsection. Based on PA Program Manager feedback, the DNV GL team considered December 2014 data we had previously received for the frame, but concluded that the measure mix beginning in January 2015 more closely matched future program offerings (e.g., it included TLEDs). This study thus covers the period from January 2015 through December 2015.

Table 3-1 presents a summary of the 2015 Upstream Lighting Program purchases, including quantity and estimated savings. The "Count of Rows" column represents the number of lines in the 2015 tracking data for which each product type appeared. It is roughly equivalent to the number of purchases of each lamp type at a unique site, but not the number of unique sites. It is important to note that the per-lamp savings estimates were drawn from the final 2015 lighting assumptions spreadsheet provided by the PAs, which incorporated the hours of operation determined in the prior evaluation. The DNV GL team applied actual program savings to the whole year, rather than applying the total kW and kWh savings estimates provided by the third-party program manager. We confirmed that the savings assumptions were being accounted for by the third-party program manager in the December 2015 program data, and that we expect these savings assumptions to be used in 2016 across all purchases. Notably, the bold lines in Table 3-1 represent the lamp types that were part of the previous impact evaluation. The A-line lamps were added to the program toward the end of the period covered by the prior impact evaluation, and did not end up with many lamps represented in the 2012 evaluation.

Table 3-1. Summary of 2015 upstream lighting purchases (Jan-Dec)

Product Type	Count of Rows	Quantity of Lamps	Watts Saved per Lamp	kWh Saved per Lamp	Total kW Saved	Total kWh Saved	2012 Evaluation Sample Measure Groups
A-line, 40/60w	**7,459**	**436,156**	**33.53**	**130.82**	**14,626**	**57,057,299**	**LED**
A-line, 75/100w	**821**	**53,652**	**47.11**	**183.77**	**2,527**	**9,859,647**	**LED**
Decoratives	1,169	35,327	21.07	82.18	744	2,903,211	N/A
G24 LED	2,014	371,658	12.83	50.06	4,769	18,604,572	N/A
LED Retrofit kit, <25W	7,929	130,098	40.66	158.61	5,290	20,635,101	N/A
LED Retrofit kit, >25W	59	967	59.95	233.86	58	226,147	N/A
MR16	**1,434**	**33,836**	**23.40**	**91.28**	**792**	**3,088,665**	**LED**
PAR20	**2,227**	**37,971**	**29.80**	**116.25**	**1,132**	**4,414,121**	**LED**
PAR30	**6,929**	**163,845**	**40.40**	**157.60**	**6,619**	**25,822,038**	**LED**
PAR38	**5,220**	**90,824**	**46.80**	**182.57**	**4,251**	**16,581,447**	**LED**
Stairwell Kit, 2ft w/sensor	58	2,276	53.40	467.78	122	1,064,676	N/A
Stairwell Kit, 4ft w/sensor	532	24,986	46.00	402.96	1,149	10,068,359	N/A
T5HO	**299**	**35,651**	**4.00**	**13.64**	**143**	**486,280**	**FLR**
T8	**725**	**65,320**	**3.52**	**12.00**	**230**	**784,049**	**FLR**
T8 - 25	**362**	**44,800**	**6.16**	**21.01**	**276**	**941,051**	**FLR**
T8 - 28	**5,113**	**512,621**	**3.52**	**12.00**	**1,804**	**6,153,092**	**FLR**
TLED, 2ft	102	4,012	4.25	14.49	17	58,144	N/A
TLED, 4ft	1,200	118,476	8.51	29.02	1,008	3,438,067	N/A
U-Bend T8 - 25	**188**	**5,925**	**6.16**	**21.01**	**36**	**124,458**	**FLR**
U-Bend T8 - 28	**334**	**11,077**	**3.52**	**12.00**	**39**	**132,959**	**FLR**
Total	**44,174**	**2,179,478**	**494.59**	**2,392.92**	**45,633**	**182,443,382**	

The sample frame for the impact evaluation was defined as unique rows for each customer location and LED product type. The DNV GL team identified several sites where a net negative sales quantity and savings value were being rolled up into standardized[8] customer installation addresses.[9] We performed a manual review of these "net negative savings" sites and were able to rectify some records by locating purchases that should have been rolled into one site. Manually searching the data for different spellings of an address found that, for example, "Rodgers Street" and "Rogers Street" were listed for the same business (based on customer installation name and address), and the team confirmed that the product type description associated with the negative sales quantities matched the product type description for the purchases found. There were several records, however, that we could not reconcile after a manual review. We reached out to the PAs to discuss this issue and identify next steps.

We took the following steps to resolve the "net negative savings" sites to arrive at the current population:

- We performed a manual review, correcting some sites and identifying outstanding sites that we provided to the PAs.
- The PAs engaged the third-party program manager to attempt to locate purchases for outstanding sites.
- With support from the third-party program manager, PAs provided updates to the DNV GL team; we incorporated these updates to finalize the population.
- Presently, based on investigation so far, purchases for several sites were made prior to 2015; sites that do not have 2015 purchases were removed from the population.[10]

The DNV GL team worked with the PAs to finalize the population, rerun the proposed sample design with the final population, and share any large changes with the PAs and EEAC Consultants for final approval before proceeding with pulling the final sample and commencing on-site visits. We also worked with the QC contractor to identify facilities that were previously visited as part of the QC process. We kept those sites in the sample but decided to move to backup more quickly than normal if these customers express any reluctance to the additional follow-up visits.

3.2 Sample design

The DNV GL team developed a sample design that meets the desired statistical precision targets for key savings parameters such as energy and peak demand savings, as well as other factors such as peak coincidence factors and HVAC interactive effects. The 2012 evaluation included a stratified sample of LED lamps (66 sites) and fluorescent lamps (15 sites), with a focus on LEDs. The achieved precision on energy savings for LEDs and fluorescent lamps at 90% confidence were 18% and 27%, respectively.

Given the program growth, planned program offerings, and that the program now features a measure mix than it did at the time of the 2012 evaluation, the DNV GL team worked with the consultants to disaggregate the 2015 LED data into specific measure categories for sampling.

Table 3-2 shows the disaggregation for each LED product type.

8 The MA C&I database team ran the raw Upstream Lighting data through a SAS geocoder in order to standardize installation address (i.e., changing "St." to "Street," etc.).
9 A negative sales quantity can result from customer bulb returns when a purchase was made in a previous year or the third-party QC contractor could not find the bulbs at the site and so they were removed from the tracking database.
10 The savings associated with the sites removed from the population are 206,781 kWh.

Table 3-2. Proposed 2015 evaluation measure groups, LEDs only

Product type	Proposed 2015 evaluation sample measure groups	2012 evaluation sample measure groups
G24 LED	5	N/A
A-line, 40/60w	**4**	**LED**
A-line, 75/100w	**4**	**LED**
Decoratives	4	N/A
LED retrofit kit, <25W	3	N/A
LED retrofit kit, >25W	3	N/A
MR16	**3**	**LED**
PAR20	**3**	**LED**
PAR30	**3**	**LED**
PAR38	**3**	**LED**
Stairwell kit, 2ft w/sensor	2	N/A
Stairwell kit, 4ft w/sensor	2	N/A
TLED, 2ft	1	N/A
TLED, 4ft	1	N/A

Disaggregation was based on a product type's similarity to other LED products when reviewing assumptions (i.e., delta watts, hours of use, measure life, etc.). To the extent possible, the DNV used historical information to inform proposed error ratios. As
Table 3-2 shows, the first evaluation largely informs category groups 3 and 4. Based on the first study, we began with an error ratio of 0.9 for these categories but ratcheted down to an error ratio of 0.7, since the 2012 evaluation showed large uncertainty in HOU, and based on that evaluation, the PAs updated the hours component of tracking assumptions. The error ratios used for categories 1, 2 and 5 are informed by the expected variability in what the technology could replace; we expected that there would be more variability in what G24s could replace (category 5) compared to TLEDs (category 1) and stairwell kits with sensors (category 2).

Based on discussions with the PAs and EEAC consultants, we proceeded with the sample design shown in Table 3-3.

Table 3-3. Sample design, confidence level at 90%

Category	Accounts	kWh savings	Error ratio	Sample	Expected relative precision
1 – TLEDs, 2ft and 4ft	753	3,498,271	0.50	20	18.72%
2 – Stairwell kits w/ sensors, 2ft and 4ft	420	11,136,259	0.50	20	17.59%
3 – Retrofit kits, MR16s, PARs (20, 30, 38)	10,112	70,963,745	0.70	50	17.54%
4 – A-lines, Decoratives	5,080	69,825,127	0.70	50	17.24%

5 – G24	830	18,604,872	0.60	30	18.58%
Total	**17,195**	**174,028,274**	**0.67**	**170**	**10.22%**

A sample size of 20 for both TLEDs and stairwell kits with sensors represents an oversampling for both groups; although these groups have relatively low savings in 2015, we expect that they will contribute to higher savings in future program years.

3.3 Data collection and analysis

Data collection for the impact work included physical inspection and inventory, interviews with facility personnel, observation of site operating conditions and equipment, and short-term metering of lighting hours of use. Evaluators attempted to determine pre-existing lamps from interviews with facility staff while performing the on-site data collection. Our data collection instrument is included in APPENDIX F. We retained several components from 2012 evaluation, and added additional questions to address baseline issues we had identified (i.e., confirm or refute classification of upstream lighting measures as early replacement). Judging that advance letters would be more beneficial than participation incentives, we sent an advance letter of introduction[11] prior to recruitment, and did not budget for incentives.

The DNV GL team combined the data gathered during the site visit with the tracking data provided by the PAs to estimate gross savings realization rates for annual kWh. We also used the combined data to estimate gross savings results for other relevant savings factors, including HVAC interactive effects, and summer and winter peak coincidence factors. The study also strove to produce new estimates of delta watts and annual hours of use that can be applied by the PAs retroactively and going forward. All reporting at this level was sample weighted and statistically representative of the population or appropriate population sub-groups; post-stratification was performed based on our sample design.

Our overall measurement and evaluation plan is detailed below.

3.3.1 Measurement, verification, and analysis methodology

A key task in the on-site engineering assessment was the installation of measurement equipment to aid in the development of independent savings estimates. The type of measure influences the measurement strategy used.

In the context of an energy analysis, most efficiency measures can be characterized as either time-dependent or load-dependent. Time-dependent equipment typically runs at constant load according to a time-of-day operating schedule. Mathematically, hour-of-day and day-of-week are usually the most relevant variables in the energy savings analysis of these measures. Lighting is the most prevalent time-dependent measure.

3.3.2 Verification

Each site visit consisted of the verification of installed equipment, a discussion with facility personnel regarding the baseline characteristics of the measure,[12] and the collection and analysis of monitored data. Once on site, we collected data for calculating savings estimates for all LED products[13] that were purchased through the program, including an inventory of the measures installed. If measures were removed, we

11 Since some customers were already contacted by the third-party QC contractor, the DNV GL team referenced the third-party QC contractor in the advance letter.
12 Additional questions since the 2012 evaluation will be added to the 2015 data collection instrument in order to better assess baseline issues raised during PA/EEAC discussions.
13 This will include primary sample between LED categories and any backup sample, also between LED categories.

gathered the reasons for removal. If measures had not yet been installed, we explored the planned date of installation.[14] The DNV GL team used the Upstream Lighting Impact Revisits Study (P49) to inform the installation rate, and worked with the PAs and EEAC Consultants to determine how the revisit study would be applied to this study.

We also gathered program measure operating characteristics and general building operation characteristics, including information on heating and cooling systems, to assess interactive effects. We collected information on the pre-existing or baseline conditions to increase the accuracy of savings calculations. To gather this, the field auditor identified the person who was most knowledgeable about the lighting at each facility to ask questions such as:

- For retrofit:
  - What type and wattage fixtures were replaced by the program fixtures?
  - Do you have any of these old bulbs/fixtures in storage for us to look at?
  - Is there a part of your facility that still has similar old bulbs/fixtures in place? [Auditor confirming bulbs/wattage]
  - Is there an untreated space that's similar to the upgraded space we've looked at together? [Auditor confirming connected wattage (whether more bulbs were installed in upgraded space compared to untreated space)].
- For burnout or new construction:
  - What type and wattage fixture would you have installed as typical practice?

If the site contact was unable to answer the untreated space question listed above, the field auditor attempted to talk with the contractor or installer to try and understand whether more lamps were installed than were replaced.

In order to capture whether cases were appropriately classified as early replacement, field auditors indicated whether the installation was part of a major renovation (i.e., ceiling grid removed, terminal AC units replaced, studs exposed, etc.), triggering code. In addition, field auditors asked about the reason for the LED installation, seeking to determine if there were any other site-specific reasons (i.e., systematic failure or incipient failure of overall lighting systems) why a project may not have constituted early replacement. Posed questions can be found in APPENDIX F.

For new installations that did not prove to be early replacement (code triggering or a reason that might not have constituted early replacement), the on-site protocol was to ask what the customer would have installed as typical practice.

In anticipation of future study needs, field auditors asked about the age of the pre-existing equipment when it was replaced. The question below was asked and is included in the data collection instrument in APPENDIX F.

- What was the age of the replaced equipment?

A summary of this information for category 1, TLEDs, is included in Table 4-3. While this information helps to inform measure life moving forward, we suggest that that PAs consider additional research in order to support the move to a dual baseline approach for early replacement measures.

14 In the first evaluation, measures that were not installed at the time of the visit did not receive any credit for being installed. The revisit study found that some of the bulbs in storage were later installed (within three years of the first site visit).

3.3.3 Monitoring

Time-dependent measures typically call for the installation of time-of-use (TOU) lighting loggers to measure hours of use. These small devices use specialized sensors—photocells in the case of lighting measures—to sense and record the dates and times that a device turns on and off. These TOU data were used to support the evaluation in two key ways:

1. To develop peak coincidence factors
2. To develop annual hours of use

The measure scope influences the appropriate number of loggers and systems monitored for each site. Factors that drive the number of installed loggers include the number of unique usage areas at the site, expected energy savings for each usage area, and the anticipated level of variation among the schedules within a particular usage area. For this study, most sites included a minimum of 3 months of data collection.

The DNV GL team used amp or power loggers for lamps controlled to provide variable output (dimming). In this case, occupancy and/or other factors (e.g., daylight) can be the primary variable used to estimate savings. The DNV GL team monitored and calculated control savings for all stairwell fixtures since that measure includes sensors.

For measures other than stairwell fixtures with sensors, we surmised that the type of technology installed could have prompted the installation of controls. Site auditors sought to monitor controls for which the customer did not receive an incentive for (i.e., went through the downstream program) and which were installed after the pre-existing lighting at around the same time as the upstream program installation. Site recruiters asked the following types of questions to inform the type of monitoring equipment to be brought on site.

- Does your facility have any lighting controls?
- Were those lighting controls installed in 2015 or around the time of the program fixtures?
- Why were controls added?
- Did you receive an incentive for these controls?

3.3.4 Site analysis

The DNV GL team used data collected from TOU lighting loggers to develop time-of-use load profiles and estimate total run times during the monitoring period. The typical 3-month data collection period of this study gathers short-term metered data, which is difficult to accurately expand to a typical year or to specific periods of interest that do not coincide with the monitoring period (e.g., estimating summer peak demand if the metering is not done in summer). In determining lighting schedules from time-of-use data, we accommodated annual trends such as seasonal effects (e.g., daylight savings), production, and occupancy swings (such as vacations, business cycles, etc.) to the extent supported by the data. As a general rule, visual inspection of time-of-use data should reveal explicable patterns that agree with other data sources, such as the information gathered from on-site interviews. Each site visit included an interview with the site contact to gather information that could help in the expansion of short-term metered data.

We compiled the data gathered from the on-sites into spreadsheets for analysis. We calculated the savings as line-by-line comparisons of pre- and post-retrofit electrical use. We developed pre- and post-retrofit energy estimates for each line item within each measure. We also calculated interactive cooling and heating effects of the installed measures utilizing engineering algorithms where applicable. This component of the savings is described in further detail in the following section.

We performed all so as to identify discrepancies between the tracked and gross savings according to each adjustment phase, including technology, quantity, operation, and HVAC interaction.

In addition to these adjustments, the DNV GL team provided measure-specific estimates for the following savings input parameters, based on the data collected on site:

- Installation rate
- Delta watts
- Annual hours of use

For new construction-type installations we used the following method, detailed further in APPENDIX B.

The code compliance team processed the baseline compliance data to produce an average code-to-installed ratio that could be used in this study to "de-rate" the code baseline for new construction. In the past compliance data collection, the auditor calculated installed lighting power densities (LPDs) for sample spaces that were extrapolated to whole-building LPDs. The auditor also determined the code LPD for the sampled spaces. For this study, the code compliance team revisited the aforementioned data and re-weighted that ratio for a population LPD ratio.

The field auditor determines the code and installed LPD for a sample of spaces. The savings for the measures are calculated as:

*Savings kW = LPD Code * 0.75 – Installed LPD*

Once we had processed the code compliance data, the code compliance team summarized and documented these data in a short memo for the PAs and EEAC Consultants.

3.3.5 HVAC interactive effects

When lighting equipment converts electrical energy to light, a significant amount of that energy dissipates in the form of heat. Energy efficient lighting measures convert more electrical energy to light and less to heat. This serves to reduce the heat gain to a given space and accordingly reduce the load on cooling equipment. However, this reduced heat gain has the added consequence of increasing the load on the heating system. A complete estimation of energy savings considers the associated impacts on the space's heating and cooling systems, or the "HVAC interactive effects."

As part of the on-site methodology, evaluators interviewed facility personnel to ascertain the cooling and heating fuel, system type, and other information with which to approximate the efficiency of the HVAC equipment serving the space of each lighting installation. The DNV GL team expressed HVAC system efficiency in dimensionless units of coefficient of performance (COP), which reflects the ratio of work performed by the system to the work input of the system. Table 3-4 details the COP assumptions for general heating and cooling equipment types expected to be encountered in this study. Where site-specific information yields improved estimates of system efficiency, these were used in place of the general assumptions below.

Table 3-4. General heating and cooling COP assumptions

Cooling system type	COP
Packaged DX	2.9
Window DX	2.7
Chiller <200 ton	4.7
Chiller >200 ton	5.5
Air to air heat pump	3.9
Water to air heat pump	4.4
Refrigerated area (high temp)	1.4
Refrigerated cases (low temp)	1.9

Heating system type	COP
Air to air heat pump	1.5
Electric resistance	1
Water to air heat pump	2.8

We calculated HVAC interactive effects at all sites where heating or cooling systems were in use. Leveraging the 8,760 profile of hourly demand impacts, we computed electric interactive effects during the hours that lighting and HVAC are assumed to operate in unison.

The DNV GL team utilized the Typical Meteorological Year 3 (TMY3) hourly dry-bulb temperatures for Worcester, Massachusetts as the balance point criteria in this analysis. For each hour in a typical year, we computed HVAC interactive effects according to the following equations:

*Cooling kW Effects = 80% * Lighting kW Savings / Cooling System COP*
*Heating kW Effects = -80% * Lighting kW Savings / Heating System COP*

The 80% values represent the assumed percentage of the lighting energy that translates to heat, which either must be removed from the space by the air conditioning system or added to the space by the heating system during the aforementioned HVAC hours. This assumption is consistent with those established and employed in previous impact evaluations of custom lighting measures and in the 2012 evaluation. Also, heating factors are negative because electric heating interaction decreases gross lighting savings, while cooling interactive increases it.

3.3.5.1 HVAC interaction assumption investigation

The DNV GL team performed a brief review of the literature to investigate whether the 80% value used in calculating HVAC interactive effects should be updated since this study includes only LED lighting. Our findings are included in APPENDIX C for the PAs and EEAC Consultants to review.

4 FINDINGS

The results presented in the following subsections include statewide-level realization rates (and associated precision levels) for annual kWh savings, percent on-peak kWh savings, and on-peak demand (kW) coincidence factors at the times of the winter and summer peaks, as defined by the ISO New England Forward Capacity Market (FCM). All coincident summer and winter peak reductions were calculated using the following FCM definitions:

- **Coincident summer on-peak kW reduction** is the average demand reduction that occurs during all hours between 1 p.m. and 5 p.m. on non-holiday weekdays in June, July, and August.

- **Coincident winter on-peak kW reduction** is the average demand reduction that occurs during all hours between 5 p.m. and 7 p.m. on non-holiday weekdays in December and January.

The adjusted gross energy savings and connected kW demand reduction are presented with their associated realization rate and relative precision for each lighting measure. These tables present results as adjustments to tracking savings. Each of these adjustments is described below:

- **Technology adjustment:** This adjustment reflects the change in savings due to the identification of a lighting technology (fixture type and wattage) at the site that is different than the technology represented in the program tracking system estimate of savings.
- **Quantity adjustment:** This adjustment reflects the change in savings due to the identification of a quantity of lighting fixtures at the site that is different than presented in the program tracking system estimate of savings.
- **Operational adjustment:** This adjustment reflects the change in savings due to the observation or monitoring of lighting operation hours at the site that is different than represented in the tracking system estimate of savings.
- **HVAC interaction adjustment:** This adjustment reflects changes in savings due to interaction between the lighting and HVAC systems among the sampled sites. Generally, these impacts cause a heating penalty and a cooling credit. This adjustment reflects impacts from electric heating and/or cooling, not other fuels.

Also included in the results are savings factors for summer and winter on-peak coincidence factors, summer and winter kW HVAC interactive effect factors, a kWh HVAC interactive effect factor, the percent of energy savings during on-peak periods, and a non-electric heating HVAC interactive effect, which is presented in MMBtu/kWh saved. Relative precision levels and error bounds are calculated at the 80% and 90% confidence level for demand savings factors and values. For all kWh realization rates, the standard 90% confidence level is used.

4.1 Category 1, TLED findings

This section summarizes the study's findings for category 1: TLEDs, 2-ft and 4-ft.

4.1.1 Statewide results

Table 4-1 presents the category 1 statewide results with the in-storage installation adjustment applied to in-storage sites from this study based on previous study (P49) findings. The realization rate for category 1 was 195% with HVAC interaction effects and in-storage factor included. The relative precision for this estimate

was ±28.1% at the 90% level of confidence. Note that the gross tracking savings did not include HVAC interactive effects. The error ratio was 0.73, which was higher than the estimated error ratio of 0.50.

Table 4-1. Summary of category 1 energy realization rate

Savings Parameter	Energy - Category 1	
	kWh	% Gross
Gross Savings (Tracking)	3,495,514	
Technology Adjustment	2,153,288	62%
Quantity Adjustment with in-storage adj	(454,585)	-13%
Quantity Adjustment without in-storage adj	*(571,305)*	
In-storage Adjustment	*116,720*	
Operational Adjustment	1,547,273	44%
HVAC Interactive Adjustment	81,780	2%
Adjusted Gross Savings	6,823,270	195%
Gross Realization Rate	195.20%	
Relative Precision	±28.1%	
Confidence Interval	90%	
Error Ratio	73%	

The category 1 installation rate is approximately 90%, and 92% with the in-storage installation adjustment. The P49 study demonstrated an increase in in-storage installation for LEDs from 82% in Year 1 to 85% after the revisit study.

Table 4-2 presents the statewide savings factors resulting from this analysis. All relative precisions were calculated at the 90% confidence level for energy and at 80% for demand. The summer on-peak coincidence factor was 72.1%, with a relative precision of ±11.1% at the 80% level of confidence. The on-peak winter coincidence factor was 65.9%, with a relative precision of ±13.1% at the 80% level of confidence. The table also provides savings factors for on-peak summer and winter kW HVAC interactive effects, kWh HVAC interactive effect, hours of use realization rate and percent on-peak kWh.

Table 4-2. Summary of category 1 savings factors

Savings Parameter	Category 1		
	Value	Precision at 90% Confidence	Precision at 80% Confidence
Installation Rate (Quantity Adjustment - kW) - with in-storage adj	92.0%	±5.9%	±4.6%
Installation Rate (Quantity Adjustment - kW) - without in-storage adj	89.8%	±6.6%	±5.1%
In-storage Adjustment	2.2%	-	-
Delta Watts (Technology Adjustment - kW)	161.6%	±9.5%	±7.4%
Connected kW Realization Rate	148.6%	±13.5%	±10.5%
Hours of Use estimate	4,426	-	-
Summer Coincidence Factor			

Savings Parameter	Category 1		
	Value	Precision at 90% Confidence	Precision at 80% Confidence
On Peak Hours	72.1%	±14.3%	±11.1%
Winter Coincidence Factor			
On Peak Hours	65.9%	±16.9%	±13.1%
Summer kW HVAC Interactive Effect			
On Peak Hours	115.4%	±4.8%	±3.7%
Winter kW HVAC Interactive Effect			
On Peak Hours	97.5%	±4.4%	±3.4%
kWh Factors			
kWh HVAC Interactive Effect	101.2%	±2.1%	±1.6%
Hours of Use Realization Rate	129.8%	±21.0%	±16.4%
% On Peak kWh	77.8%	±5.2%	±4.1%
Non-Electric			
Heating HVAC Interaction Effect (MMBtu/kWh)	-0.000162279		

4.1.2 Key drivers

The most important finding in category 1 is the adjusted gross savings value of 195%—an excellent result that is largely driven by a very positive technology adjustment number (161.6%). This large technology adjustment number is a result of our frequently finding that 15-watt TLEDs had been installed instead of the assumed 19-watt TLEDs. Since the tracking savings assumed an 8.5-watt delta, this 4-watt difference has a major impact on the delta watts factor. An additional driver, though to a lesser extent, is that for a majority of sites 32-watt lamps were being replaced with TLEDs instead of the assumed 28-watt lamps. Table 4-3 summarizes the baseline information from each site, including reported age of replaced equipment by the site contact.

Table 4-3. Category 1 on-site baseline information

Site ID	Facility Type	Space type	Replaced Equipment type (rated watts)	Age of replaced equipment (per site contact)
046241	School/University	TLED: library, classroom	28W T8	Not sure, mostly different ages
058351	School/University	TLED: classrooms, dorm common room, gym, library	32W T8	-
098011	School/University	TLED: labs, mechanical rooms, hallways, offices, bathrooms	28W T8	Lamps were being replaced every three months on average
045761	Office	TLED: office, conference rooms	17W T8 (2' lamps)	4 years
082831	Office	TLED: offices, hallways, conference rooms	28W T8	17 years (In 2000 renovated, from T12 to T8)
004051	Parking Garage	TLED: garage	31W T8	T8s were burning out annually
085511	Parking Garage	TLED: garage and stairs	32W T8	1 year

Site ID	Facility Type	Space type	Replaced Equipment type (rated watts)	Age of replaced equipment (per site contact)
063241	Manufacturing Facility	TLED: general manufacturing and non-manufacturing traffic area, admin office	28W T8	~7 years
088541	Manufacturing Facility	TLED: general building (pre-press room), nurses office, unused wing (offices), 24-7 area entrance lobby	28W T8	8 years
076011	Retail	TLED: product floor, warehouse	32W T8	About 3 months, existing occupancy sensor made replaced equipment burnout so decided to upgrade to TLEDs
126431	Retail	TLED: warehouse, sales floor	32W T8	Don't know
007631	Hotel	TLED: restroom, kitchen	32W T8	Unsure
048981	Hospital	TLED: mechanical room, hallways (24-7), offices, operating room/labs, break room, medical records room, restrooms, main lobby	30W T8	5 years
053451	Police/Fire Station	TLED: conference room, stairwell, garage	32W T8	8 years
058601	Dining: Bar Lounge/Leisure	TLED: restaurant - dining area	17W T8 (2' lamps)	5 years
111721	Dining: Cafeteria/Fast Food	TLED: kitchen/office, seating area, restrooms	32W T8	4 years
065921	Library	TLED: archives, office, hallways, restrooms	25W T8	Unsure
082271	Sports Arena	TLED: elevator lobby, restrooms, boiler room, concession stands, electric station, grounds keeping storage	32W T8	15 years
120081	Motion Picture Theatre	TLED: N/A	N/A	N/A
030201	Workshop [contractor]	TLED: N/A	32W T8	3 years

4.1.3 Quantity discrepancies

Site auditors generally found program TLEDs to be installed; this LED category had the highest installation rate (89.8%, excluding the in-storage adjustment) when compared to the other four LED categories. Just over 75% of the lamps that were found not installed were verified as in storage, with the customer planning to install them in the future. An in-storage adjustment was applied to these sites, which assumes that a subset of these products will move from storage to socket. Three sites had a subset of lamps that were found neither onsite nor in storage; one site contact reported never having received the program TLEDs but instead receiving and installing other program lamps that were not included in tracking. The number of lamp sales included in the tracking data for visited sites is included in Table 4-4 along with the number of lamps not found to be installed for various reasons (i.e., in storage, missing, or burnout).

Table 4-4. Quantity discrepancy for category 1 products

	Category 1	% of tracking
Quantity discrepancy *(lamps not installed at time of site visit)*	**3,393**	**17%**
Confirmed as in-storage, to be installed over time	2,605	13%
Missing*	768	4%
Burned out	20	0%
Tracking sales quantity total (visited sites, n=20)	**20,376**	**100%**

*420 lamps were associated with a high school, this customer appeared in the 2016 program data but no negative sales entries in the program data exist indicting a product return or correction. 300 lamps were associated with a movie theatre, the location listed in the 2015 program data did not appear in the 2016 data but the customer name did (movie theatre chain); for all movie theatre locations in the 2016 data, there were no negative sales entries in the program data indicating a product return or correction.

4.2 Category 2, stairwell kit findings

This section summarizes the study's findings for category 2: stairwell kits with sensors, 2-ft and 4-ft.

4.2.1 Statewide results

Table 4-5 presents the category 2 statewide results with the in-storage installation adjustment applied to in-storage sites from this study based on previous study (P49) findings. The realization rate for category 2 was 46.9% with HVAC interaction effects and in-storage factor included. The relative precision for this estimate was ±20.2% at the 90% level of confidence. Note that the gross tracking savings did not include HVAC interactive effects. The error ratio was 0.74, which was higher than the estimated error ratio of 0.50.

Table 4-5. Summary of category 2 energy realization rate

Savings Parameter	Energy - Category 2	
	kWh	% Gross
Gross Savings (Tracking)	11,136,259	
Technology Adjustment	(2,529,205)	-23%
Quantity Adjustment with in-storage adj	(2,601,736)	-23%
Quantity Adjustment without in-storage adj	(3,000,318)	
In-storage Adjustment	398,582	
Operational Adjustment	(772,816)	-7%
HVAC Interactive Adjustment	-	0%
Adjusted Gross Savings	5,232,502	47%
Gross Realization Rate	46.99%	
Relative Precision	±20.2%	
Confidence Interval	90%	
Error Ratio	74%	

The category 2 installation rate is approximately 65.9%, and 69.8% with the in-storage installation adjustment.

Table 4-6 presents the statewide savings factors resulting from this analysis. All relative precisions were calculated at the 90% confidence level for energy and at 80% for demand. The summer on-peak coincidence factor was 81.0%, with a relative precision of ±7.5% at the 80% level of confidence. The on-peak winter coincidence factor was 82.3%, with a relative precision of ±7.7% at the 80% level of confidence. The table also provides savings factors for on-peak summer and winter kW HVAC interactive effects, kWh HVAC interactive effect, hours of use realization rate and percent on-peak kWh.

Table 4-6. Summary of category 2 savings factors

Savings Parameter	Category 2		
	Value	Precision at 90% Confidence	Precision at 80% Confidence
Installation Rate (Quantity Adjustment - kW) - with in-storage adj	69.8%	±12.1%	±9.4%
Installation Rate (Quantity Adjustment - kW) - without in-storage adj	65.9%	±13.6%	±10.6%
In-storage Adjustment	3.8%	-	-
Delta Watts (Technology Adjustment - kW)	77.3%	±11.9%	±9.3%
Connected kW Realization Rate	53.9%	±16.2%	±12.6%
Hours of Use estimate	7,633		
Summer Coincidence Factor			
On Peak Hours	81.0%	±9.7%	±7.5%
Winter Coincidence Factor			
On Peak Hours	82.3%	±9.9%	±7.7%
Summer kW HVAC Interactive Effect			
On Peak Hours	101.6%	±1.6%	±1.2%
Winter kW HVAC Interactive Effect			
On Peak Hours	100.0%	±0.0%	±0.0%
kWh Factors			
kWh HVAC Interactive Effect	100.0%	±0.0%	±0.0%
Hours of Use Realization Rate	87.1%	±9.2%	±7.2%
% On Peak kWh	64.0%	±1.6%	±1.3%
Non-Electric			
Heating HVAC Interaction Effect (MMBtu/kWh)	0.0000000000		

4.2.2 Key drivers

The evaluation of the stairwell kits found several factors that led to the overall realization rate of 47%. The lower than expected installation rate of 66% was one of the primary drivers of this finding. The next section discusses this result in more detail.

In addition to the low installation rate, the evaluation found a reduction in savings due to differences in the delta watts factor. In order to understand the differences between the PA estimate and the evaluated delta watts, it is important to know how the PA estimate was derived. A stairwell fixture purchased through this program includes both the linear LED (2- or 4-foot variety) and the integrated bi-level dimming control. The dimming control allows the fixture to step down to a reduced light level when the location is unoccupied.

When the sensor picks up activity, the fixture returns to 100% on. The dimmed level is set once at the individual fixture by the user. Generally, these can be set in 10% increments of power, but some varieties allow for finer settings. Once set, the fixture operates at the two levels, full and low-level, depending upon occupancy.

Tracking savings assume the proposed LED fixtures operate at full power 20% of the time and at 3/8 power 80% of the time. This equates to 50% of the proposed lamp full wattage across all 8,760 hours per year. The 8,760 hours assumptions is based on these being intended for stairwells, which requires 24/7 illumination by code.

The delta watts, or technology adjustment, in the evaluated results represents the difference between the tracking estimates of delta watts (66-watt baseline fixture – 50% full rated watts of proposed fixture) and the evaluation estimate of delta watts (baseline watts – [full rated watts of proposed fixture x [logged % lumen/logged total operating hours]]).

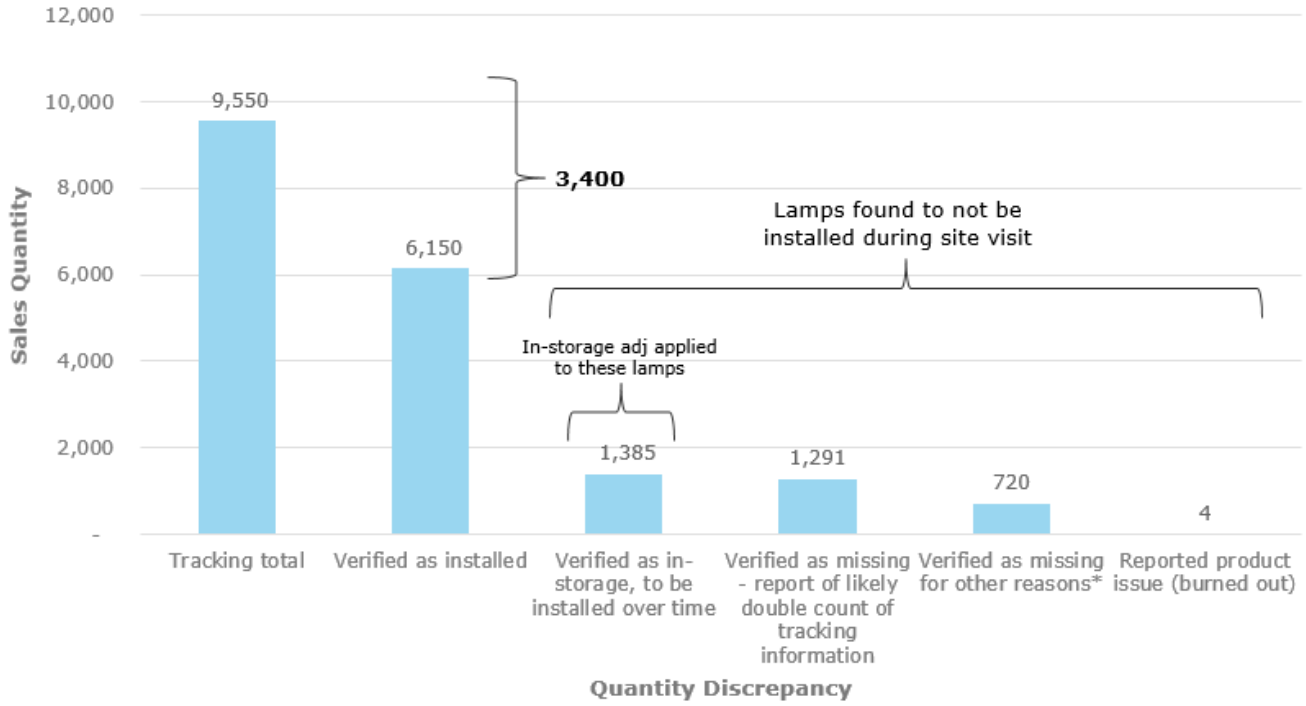
As noted in the methodology section above, the evaluated baseline wattages were established through site contact interview and/or observation of untreated, but similar spaces. In many cases, the evaluated baseline wattages were slightly different than the tracking estimates. Therefore, the delta watts differences were made up of both lower baseline wattages and different installed lamp wattages operating at levels other than 50% across all operating hours.

The third and final discrepancy in this category, the operational adjustment, is also important to understand. This adjustment represents the difference between the tracking savings estimate of 8,760 total operating hours and the evaluation's estimate of total operating hours. The evaluation found that in some cases, the stairwell kits were installed in areas other than stairwells, including hallways, storage, and mechanical rooms. Additionally, these locations as well as some actual stairwells were being controlled by wall switch. This means that the baseline hours of operation were not always 8,760 hours, but something less. The evaluation used the 0% readings from the light level loggers to estimate when the lights would have been off in the pre-condition. This led to an overall reduction of about 7% of the total savings.

4.2.3 Quantity discrepancies

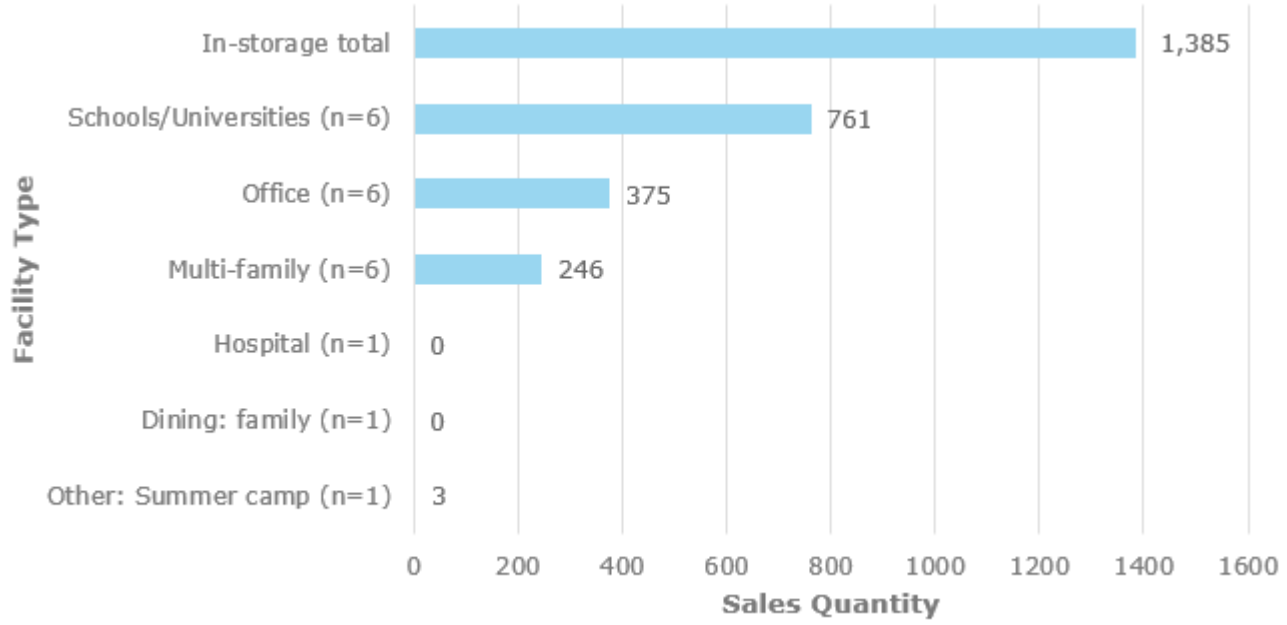
The quantity reduction is being mostly driven by missing fixtures not found on-site during the time of the evaluation. Figure 4-1 provides a breakdown of all program fixtures in the sample and their final disposition. Evaluators reviewed 2015 and 2016 program tracking data for returns associated with the missing fixtures, but no returns or corrections were identified. One site contact who was very knowledgeable and had tracked where each of the purchased fixtures were installed was confident that there was a duplicate entry in the tracking data. This duplication, identified in the chart below, represents 38% (1,291) of the (3,400) non-installed fixtures for this category. In addition to the missing fixtures, there was a high number (1,385) of fixtures having been found in-storage and are planned to be installed over time. About half (761) of these storage fixtures were associated with schools/universities as shown in Figure 4-2.

Figure 4-1. Category 2 quantity discrepancies



*For these lamps, the auditor could not locate on-site (installed or in-storage) and the site contact was generally unable to report details around why there were differences between the tracking quantities and the quantities on-site. For one site, the contact stated that (7) lamps could be under repair but they weren't certain of this. For another site, the site contact thinks there was an order mix-up and there were (8) fewer lamps purchased/received according to the site contact. One site stated that they did not receive one of the purchased lamps; documentation of a return or correction was not found in the 2015 nor 2016 data.

Figure 4-2. Category 2 in-storage lamps by facility type



4.3 Category 3, retrofit kit findings

This section summarizes the study's findings for category 3. Category 3 lights consist of LED point source recessed can retrofit kits, MR16 pin-based (often seen in track lighting), and PAR fixtures screw-in Edison base lamps. Category 3 program product type descriptions are also included in APPENDIX A. This category accounted for about half of the upstream lighting in 2015. The site auditors found that about half of the observed products provided general illumination, while the other half provided architectural accents, wall-wash, and retail spotlighting.

4.3.1 Statewide results

Table 4-7 presents the category 3 statewide results with the in-storage installation adjustment applied to in-storage sites from this study based on previous study (P49) findings. The realization rate for category 3 was 51.4% with HVAC interaction effects and in-storage factor included. The relative precision for this estimate was ±31.4% at the 90% level of confidence. Note that the gross tracking savings did not include HVAC interactive effects. The error ratio was 1.33, which was higher than the estimated error ratio of 0.70.

Table 4-7. Summary of category 3 energy realization rate

Savings Parameter	Energy - Category 3	
	kWh	% Gross
Gross Savings (Tracking)	70,969,666	
Technology Adjustment	(3,980,705)	-6%
Quantity Adjustment with in-storage adj	(25,296,434)	-36%
Quantity Adjustment without in-storage adj	(27,725,618)	
In-storage Adjustment	2,429,184	
Operational Adjustment	(6,627,855)	-9%
HVAC Interactive Adjustment	1,389,051	2%
Adjusted Gross Savings	36,453,722	51%
Gross Realization Rate	51.38%	
Relative Precision	±31.4%	
Confidence Interval	90%	
Error Ratio	133%	

The category 3 installation rate is approximately 59%, and 62% with the in-storage installation adjustment. The P49 study demonstrated an increase in in-storage installation for LEDs from 82% in Year 1 to 85% after the revisit study.

Table 4-8 presents the statewide savings factors resulting from this analysis. All relative precisions were calculated at the 90% confidence level for energy and at 80% for demand. The summer on-peak coincidence factor was 66.2%, with a relative precision of ±11.5% at the 80% level of confidence. The on-peak winter coincidence factor was 56.4%, with a relative precision of ±13.6% at the 80% level of confidence. The table also provides savings factors for on-peak summer and winter kW HVAC interactive effects, kWh HVAC interactive effect, hours of use realization rate and percent on-peak kWh.

Table 4-8. Summary of category 3 savings factors

Savings Parameter	Category 3		
	Value	Precision at 90% Confidence	Precision at 80% Confidence
Installation rate (quantity adjustment - kW) – with in-storage adj	62.2%	±16.1%	±12.5%
Installation rate (quantity adjustment - kW) – without in-storage adj	58.6%	±16.7%	±13.0%
In-storage Adjustment	3.7%	-	-
Delta Watts (technology adjustment - kW)	94.4%	±10.6%	±8.3%
Connected kW realization rate[15]	58.7%	±21.9%	±17.1%
Hours of Use estimate	3,281	-	-
Summer coincidence factor			
On peak hours	66.2%	±14.7%	±11.5%
Winter coincidence factor			

[15] The Connected kW Realization Rate is the product of the Installation Rate and Delta Watts factors.

Savings Parameter	Category 3		
	Value	Precision at 90% Confidence	Precision at 80% Confidence
On peak hours	56.4%	±17.5%	±13.6%
Summer kW HVAC interactive effect			
On peak hours	134.0%	±15.9%	±12.4%
Winter kW HVAC interactive effect			
On peak hours	88.4%	±11.7%	±9.1%
kWh factors (precisions at 90% confidence)			
kWh HVAC interactive effect	58.7%	±21.9%	±17.1%
Hours of use realization rate	104.0%	±4.3%	±3.3%
% On peak kWh	84.1%	±19.5%	±15.2%
Non-electric			
Heating HVAC interaction effect (MMBtu/kWh)	-0.0005049520		

4.3.2 Key drivers

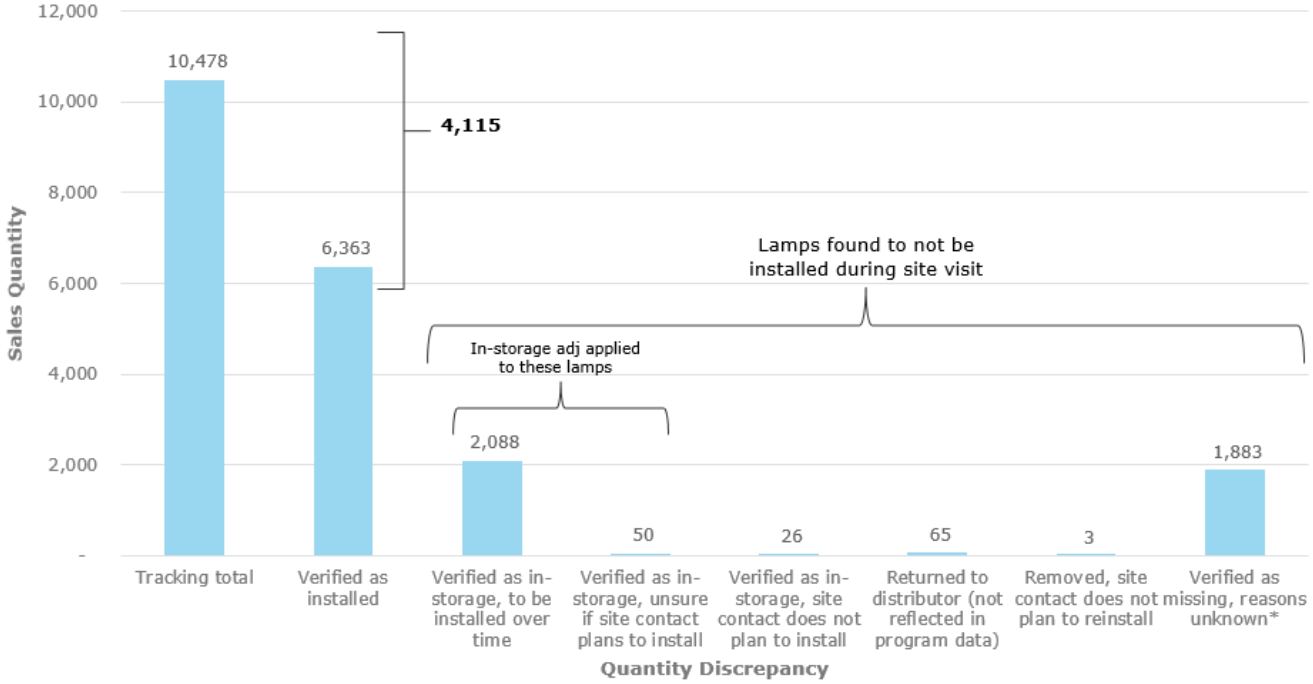
The driver for the poor adjusted gross savings (51%) in this category was the similarly poor installation rate (62%), which means that site auditors did not find a significant quantity of the products installed. Our onsite visits identified various reasons for this, including kits still being in storage, kits reportedly having been thrown away after breaking or proving defective, and kits with product issues being in the process of getting exchanged through the program; further details are covered in the next subsection.

4.3.3 Quantity discrepancies

The on-site protocols required the site auditors to account for all of the bulbs in the program tracking data. Site auditors found a significant number of category 3 bulbs to not be installed at the time of the site visit; this category had the second lowest installation rates (58.6%, excluding the in-storage adjustment) when compared to the other four LED categories. Just over half of the bulbs site auditors did not find installed were verified as in-storage, with the customer planning to install them over time or the site auditor had found the bulbs in-storage but the site contact was unsure if they were going to install. We applied an in-storage adjustment to these sites, which assumes that subset of these products will eventually move from storage to socket. Just over 45% of the bulbs not found installed were considered missing for reasons unknown or uncertain after speaking with the site contact. Over half of these (57%) were associated with one hotel, a multi-family property and dining establishment (cafeteria/fast food). Site contacts at these locations reported not knowing about a subset of the products listed in the program tracking data or claimed to not have purchased a subset of the products listed in the program tracking data. The DNV GL team checked the 2015 and 2016 program data for any returns or corrections, but did not find any to make adjustments to these or other sites including one where a site contact reporting having returned a subset of program products.

The number of bulb sales included in the tracking data for visited sites is included in Figure 4-3 along with the bulbs not found to be installed for various reasons (i.e., in-storage, missing, or removed/returned).

Figure 4-3. Category 3 quantity discrepancies



4.4 Category 4, A-line and decorative findings

This section summarizes the study's findings for category 4: A-lines and decoratives.

4.4.1 Statewide results

Table 4-9 presents the category 4 statewide results with the in-storage installation adjustment applied to in-storage sites from this study based on previous study (P49) findings. The realization rate for category 4 was 27.24% with HVAC interaction effects and in-storage factor included. The relative precision for this estimate was ±27% at the 90% level of confidence. Note that the gross tracking savings did not include HVAC interactive effects. The error ratio was 1.11, which was higher than the estimated error ratio of 0.70.

Table 4-9. Summary of category 4 energy realization rate

Savings Parameter	Energy - Category 4	
	kWh	% Gross
Gross Savings (Tracking)	69,831,407	
Technology Adjustment	(24,603,190)	-35%
Quantity Adjustment with in-storage adj	(15,094,586)	-22%
Quantity Adjustment without in-storage adj	*(17,225,443)*	
In-storage Adjustment	*2,130,856*	
Operational Adjustment	(11,595,992)	-17%
HVAC Interactive Adjustment	485,378	1%
Adjusted Gross Savings	19,023,016	27%

Savings Parameter	Energy - Category 4	
	kWh	% Gross
Gross Realization Rate	27.24%	
Relative Precision	±27.0%	
Confidence Interval	90%	
Error Ratio	111%	

The category 4 installation rate is approximately 62%, and 67% with the in-storage installation adjustment.

Table 4-10 presents the statewide savings factors resulting from this analysis. All relative precisions were calculated at the 90% confidence level for energy and at 80% for demand. The summer on-peak coincidence factor was 37.5%, with a relative precision of ±17.1% at the 80% level of confidence. The on-peak winter coincidence factor was 31.5%, with a relative precision of ±19.9% at the 80% level of confidence. The table also provides savings factors for on-peak summer and winter kW HVAC interactive effects, kWh HVAC interactive effect, hours of use realization rate and percent on-peak kWh.

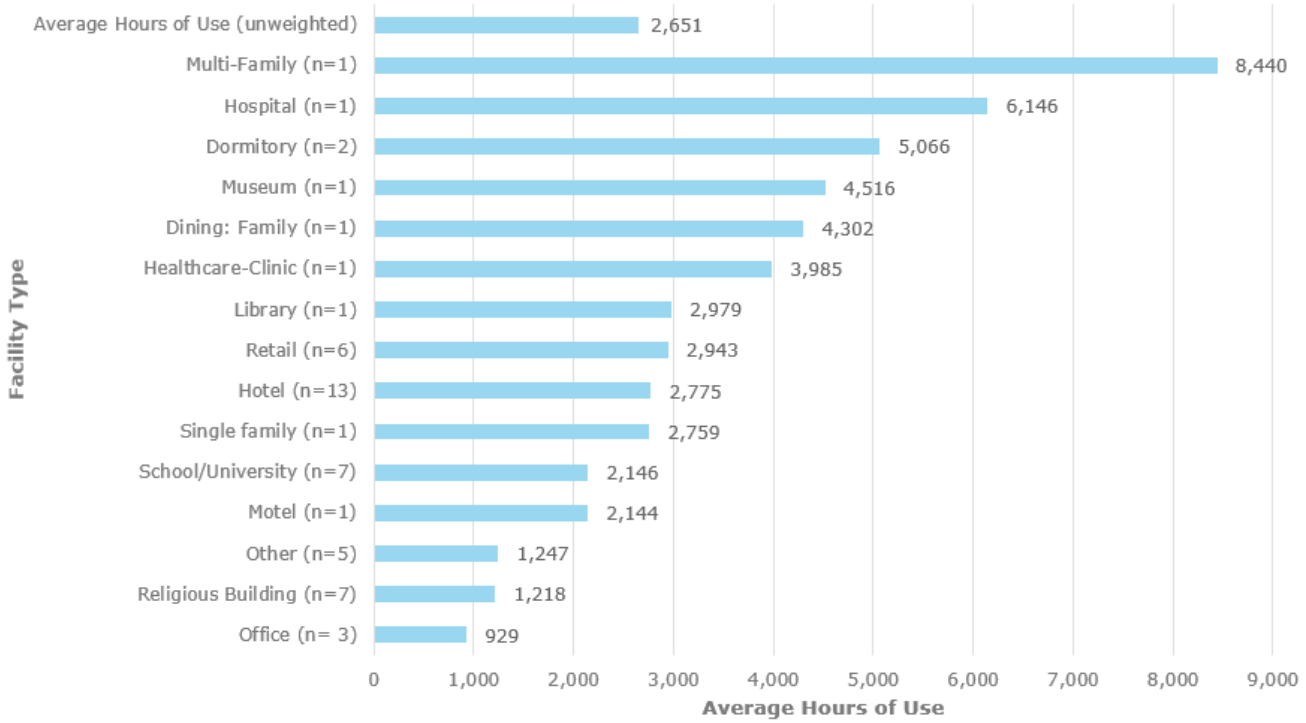
Table 4-10. Summary of category 4 savings factors

Savings Parameter	Category 4		
	Value	Precision at 90% Confidence	Precision at 80% Confidence
Installation Rate (Quantity Adjustment - kW) - with in-storage adj	66.6%	±12.1%	±9.4%
Installation Rate (Quantity Adjustment - kW) - without in-storage adj	62.4%	±13.0%	±10.1%
In-storage Adjustment	4.2%	-	-
Delta Watts (Technology Adjustment - kW)	64.8%	±18.6%	±14.5%
Connected kW Realization Rate	43.2%	±22.8%	±17.7%
Hours of Use estimate	2,400	-	-
Summer Coincidence Factor			
On Peak Hours	37.5%	±22.0%	±17.1%
Winter Coincidence Factor			
On Peak Hours	31.5%	±25.6%	±19.9%
Summer kW HVAC Interactive Effect			
On Peak Hours	118.7%	±2.4%	±1.9%
Winter kW HVAC Interactive Effect			
On Peak Hours	80.6%	±22.1%	±17.3%
kWh Factors			
kWh HVAC Interactive Effect	102.6%	±1.5%	±1.2%
Hours of Use Realization Rate	61.5%	±22.1%	±17.2%
% On Peak kWh	78.9%	±7.1%	±5.5%
Non-Electric			
Heating HVAC Interaction Effect (MMBtu/kWh)	-0.0000682070		

4.4.2 Key drivers

Category 4 had the lowest adjusted gross savings of any category, at 27%. This low number was driven by the technology adjustment number being much smaller than assumed, due to a lower wattage baseline than PA assumptions. We often found that A-lines, 40/60w and 75/100w were replacing CFLs, which were already relatively low-wattage. An additional driver is that the hours of use (2,400) observed onsite were lower than the assumed hours of use (3,901); Figure 4-4 shows the average hours of use by facility type before site weighting.

Figure 4-4. Category 4 average hours of use by facility type



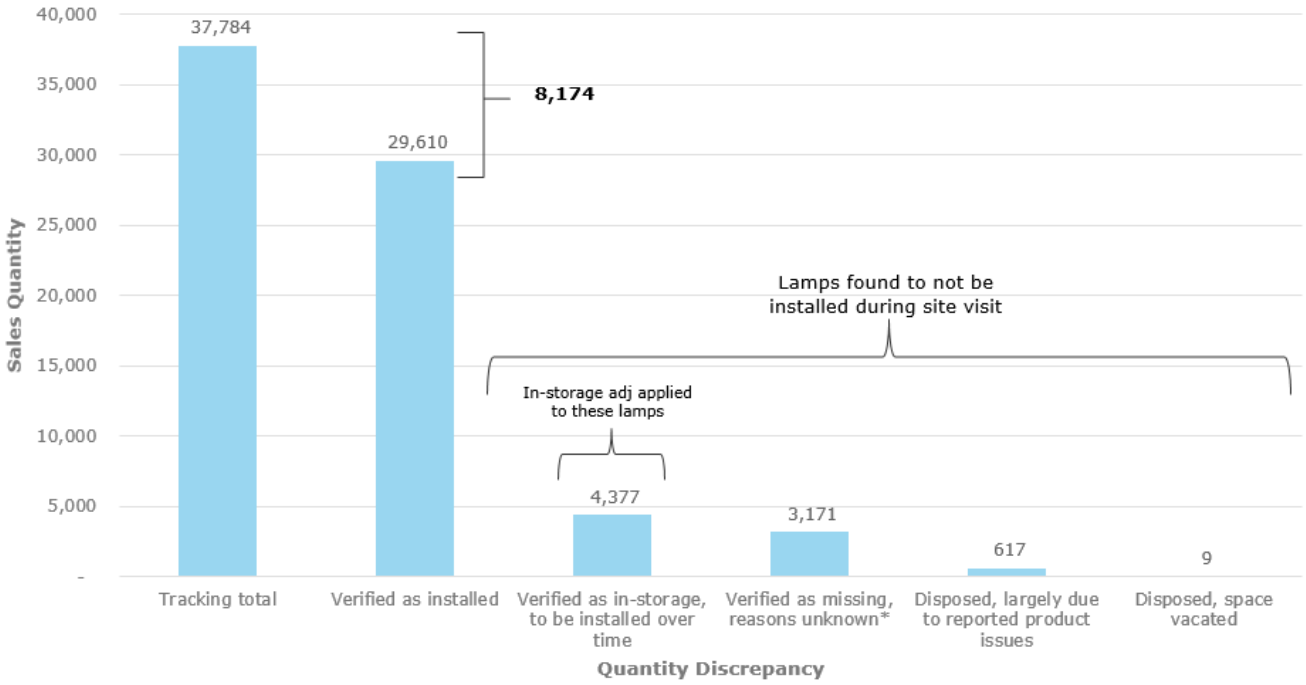
4.4.3 Quantity discrepancies

Site auditors found a slightly higher proportion of program A-lines and decoratives to be installed at the time of the site visit; this category had the highest installation rate of categories 3, 4 and 5 (62.4%, excluding the in-storage adjustment). Just over half of the bulbs site auditors did not find installed were verified as in storage, with the customer planning to install them over time. We applied an in-storage adjustment to these sites, which assumes that a subset of these products will eventually move from storage to socket. Nearly 40% of the bulbs not found installed were considered missing for reasons unknown or uncertain after speaking with the site contact. Half (1,637) of these were associated with two hotels and a motel. The DNV GL team checked the 2015 and 2016 program data for any returns or corrections, but did not find any to make adjustments to these sites. Of the other sites where program bulbs were not found installed or in storage, one site contact mentioned that it's possible the electrician installed the bulbs elsewhere (not in their church); another site contact mentioned that bulbs could have gone to their Rhode Island store location (retail); and contacts at two sites (one furniture store and one antique store) were unsure if a subset of the bulbs had burned out/were disposed of or if they were sold with lighting products purchased by store

customers. For 617 bulbs, the site contact reporting disposing of the lighting products either because they had burned out (poor application), or because the product had broken during installation.

The number of bulb sales included in the tracking data for visited sites is included in Figure 4-5 along with the bulbs not found to be installed for various reasons (i.e., in-storage, missing, or disposed of).

Figure 4-5. Category 4 quantity discrepancies



4.5 G24 findings

This section summarizes the study's findings for category 5: G24s.

4.5.1 Statewide results

Table 4-11 presents the category 5 statewide results with the in-storage installation adjustment applied to in-storage sites from this study based on previous study (P49) findings. The realization rate for category 5 was 111.9% with HVAC interaction effects and in-storage factor included. The relative precision for this estimate was ±19.4% at the 90% level of confidence. Note that the gross tracking savings did not include HVAC interactive effects. The error ratio was 0.71, which was higher than the estimated error ratio of 0.60.

Table 4-11. Summary of category 5 energy realization rate

Savings Parameter	Energy - Category 5	
	kWh	% Gross
Gross Savings (Tracking)	18,604,872	
Technology Adjustment	3,625,713	19%
Quantity Adjustment with in-storage adj	(8,244,415)	-44%
Quantity Adjustment without in-storage adj	*(9,429,465)*	

Savings Parameter	Energy - Category 5	
	kWh	% Gross
In-storage Adjustment	*1,185,050*	
Operational Adjustment	6,353,028	34%
HVAC Interactive Adjustment	474,987	3%
Adjusted Gross Savings	20,814,185	112%
Gross Realization Rate	111.87%	
Relative Precision	±19.4%	
Confidence Interval	90%	
Error Ratio	71%	

The category 5 installation rate is approximately 57%, and 63% with the in-storage installation adjustment.

Table 4-12 presents the statewide savings factors resulting from this analysis. All relative precisions were calculated at the 90% confidence level for energy and at 80% for demand. The summer on-peak coincidence factor was 81.5%, with a relative precision of ±5.0% at the 80% level of confidence. The on-peak winter coincidence factor was 80.9%, with a relative precision of ±4.6% at the 80% level of confidence. The table also provides savings factors for on-peak summer and winter kW HVAC interactive effects, kWh HVAC interactive effect, hours of use realization rate and percent on-peak kWh.

Table 4-12. Summary of category 5 savings factors

Savings Parameter	Category 5		
	Value	Precision at 90% Confidence	Precision at 80% Confidence
Installation Rate (Quantity Adjustment - kW) - with in-storage adj	62.9%	±13.9%	±10.8%
Installation Rate (Quantity Adjustment - kW) - without in-storage adj	56.7%	±14.5%	±11.3%
In-storage Adjustment	6.2%	-	-
Delta Watts (Technology Adjustment - kW)	119.5%	±6.0%	±4.7%
Connected kW Realization Rate	75.2%	±18.7%	±14.6%
Hours of Use estimate	5,673	-	-
Summer Coincidence Factor			
On Peak Hours	81.5%	±6.4%	±5.0%
Winter Coincidence Factor			
On Peak Hours	80.9%	±5.8%	±4.6%
Summer kW HVAC Interactive Effect			
On Peak Hours	112.9%	±1.8%	±1.4%
Winter kW HVAC Interactive Effect			
On Peak Hours	100.0%	±0.0%	±0.0%
kWh Factors			
kWh HVAC Interactive Effect	102.3%	±1.3%	±1.0%
Hours of Use Realization Rate	145.4%	±9.1%	±7.1%

Savings Parameter	Category 5		
	Value	Precision at 90% Confidence	Precision at 80% Confidence
% On Peak kWh	73.7%	±3.7%	±2.9%
Non-Electric			
Heating HVAC Interaction Effect (MMBtu/kWh)	-0.0006027575		

4.5.2 Key drivers

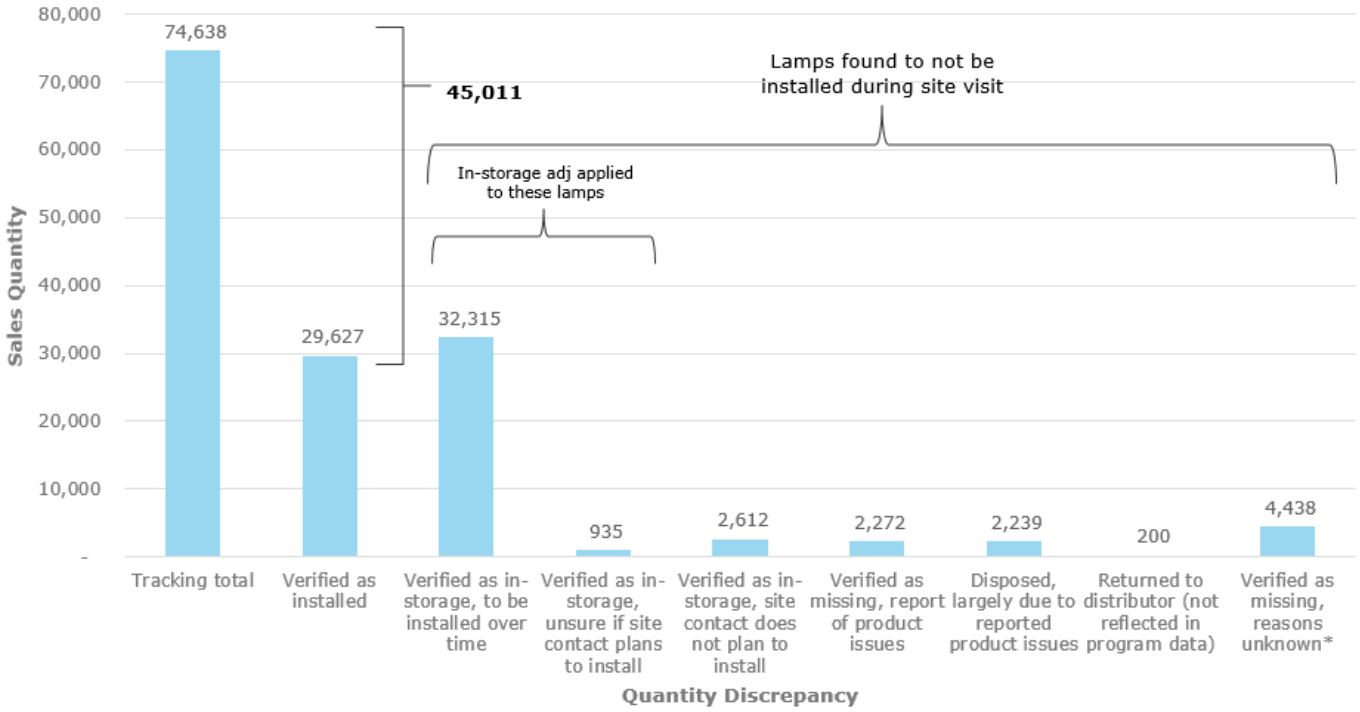
Category 5 had the second highest adjusted gross savings at 112%. The driver for this is that the hours of use and the technology adjustment number were both greater than assumed for this category. The low installation rate of 57% was driven by numerous reports of product issues, like flickering caused by a ballast incompatibility. Although sites said they had worked with PAs to exchange the products there was no related tracking information, we could not credit them for exchanged products without any evidence of their existence.

4.5.3 Quantity discrepancies

Category 5 had a significant number of lamps in-storage. Half of the sites visited had product issues, particularly reports of flickering due to ballast compatibility issues with early generation lamps. The PAs have worked with customers on these issues; however, it appears that exchanges are not being reflected in the program tracking data. For any sites where the contact reported having returned program lamps or having had product issues, the evaluation team manually performed a check of the program tracking data looking for a negative entry to indicate a correction or a return. There were no negative entries found in the 2016 data to indicate product returns or corrections but in several cases, it looks like customers did purchase other program products in 2016. There was one site that the site auditor was able to confirm a negative entry in the 2015 program data reflected a return of a subset of the G24 products purchased.

The number of lamp sales included in the tracking data for visited sites is included in Figure 4-6 along with the number of lamps not found to be installed for various reasons (i.e., in-storage, missing, or disposed).

Figure 4-6. Category 5 quantity discrepancies



4.6 Combined Category 3, 4, and 5 findings: retrofit kits, A-lines and decoratives, and G24s

This section summarizes combined findings in category 3, 4, and 5: retrofit kids, A-lines and decoratives, and G24s.

4.6.1 Statewide results

Table 4-13 presents the combined category 3, 4, and 5 statewide results with the in-storage installation adjustment applied to in-storage sites from this study based on previous study (P49) findings. The realization rate for these 3 categories was 48.6% with HVAC interaction effects and in-storage factor included. The relative precision for this estimate was ±18.7% at the 90% level of confidence. Note that the gross tracking savings did not include HVAC interactive effects. The error ratio was 1.30, which was higher than the estimated combined error ratio of 0.69.

Table 4-13. Summary of combined category 3, 4, and 5 energy realization rate

Savings Parameter	Energy - Categories 3,4,5	
	kWh	% Gross
Gross Savings (Tracking)	159,405,945	
Technology Adjustment	(24,310,274)	-15%
Quantity Adjustment with in-storage adj	(48,897,466)	-31%
Quantity Adjustment without in-storage adj	*(54,687,341)*	
In-storage Adjustment	*5,789,875*	
Operational Adjustment	(11,191,932)	-7%
HVAC Interactive Adjustment	2,370,425	1%
Adjusted Gross Savings	77,376,697	49%
Gross Realization Rate	48.55%	
Relative Precision	±18.7%	
Confidence Interval	90%	
Error Ratio	130%	

The combined category 3, 4, and 5 installation rate is approximately 60%, and 64% with the in-storage installation adjustment.

Table 4-14 presents the statewide savings factors resulting from this analysis. All relative precisions were calculated at the 90% confidence level for energy and at 80% for demand. The summer on-peak coincidence factor was 59%, with a relative precision of ±8.7% at the 80% level of confidence. The on-peak winter coincidence factor was 52.1%, with a relative precision of ±10.0% at the 80% level of confidence. The table also provides savings factors for on-peak summer and winter kW HVAC interactive effects, kWh HVAC interactive effect, hours of use realization rate and percent on-peak kWh.

Table 4-14. Summary of combined category 3, 4, and 5 savings factors

Savings Parameter	Categories 3,4,5		
	Value	Precision at 90% Confidence	Precision at 80% Confidence
Installation Rate (Quantity Adjustment - kW) - with in-storage adj	63.8%	±9.1%	±7.1%
Installation Rate (Quantity Adjustment - kW) - without in-storage adj	59.5%	±9.6%	±7.5%
In-storage Adjustment	4.3%	-	-
Delta Watts (Technology Adjustment - kW)	84.7%	±9.1%	±7.1%
Connected kW Realization Rate	54.1%	±13.9%	±10.8%
Hours of Use estimate	3,394	-	-
Summer Coincidence Factor			
On Peak Hours	59.0%	±11.1%	±8.7%
Winter Coincidence Factor			
On Peak Hours	52.1%	±12.8%	±10.0%

Savings Parameter	Categories 3,4,5		
	Value	Precision at 90% Confidence	Precision at 80% Confidence
Summer kW HVAC Interactive Effect			
On Peak Hours	125.6%	±9.4%	±7.3%
Winter kW HVAC Interactive Effect			
On Peak Hours	89.9%	±7.3%	±5.7%
kWh Factors			
kWh HVAC Interactive Effect	103.2%	±2.1%	±1.6%
Hours of Use Realization Rate	87.0%	±12.4%	±9.7%
% On Peak kWh	80.0%	±3.9%	±3.0%
Non-Electric			
Heating HVAC Interaction Effect (MMBtu/kWh)	-0.0003286551		

5 CONCLUSIONS AND RECOMMENDATIONS

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

5.1 Conclusions

For three LED categories, for three LED categories, the MA C&I Upstream Lighting Program is delivering substantially lower savings than claimed by the PAs. Site auditors were unable to locate products claimed in tracking, despite extensive efforts to track down products that were not installed at the locations indicated in the tracking information. The on-site teams observed a complex market that may not always lend itself to a one-to-one correspondence between a distributor sale and a specific installation site. Contractors buy product to install at multiple locations and to have on-hand for future work. Franchisees buy product that is first centrally stored and then deployed to multiple locations. Customers may install a majority of the product, but keep the balance in storerooms.

These results were similar to the PY2012 results, even though PAs had taken steps to better identify product destinations. Data collection done for this study showed large and sweeping discrepancies between the program tracking data and what was observed onsite, with the tracking data claiming LED lighting that turned out not to be installed, for a variety of reasons. As the PAs are aware, these discrepancies arose in large part due to initial tracking system inadequacies, including an inability to link specific purchases with ongoing customer activity (such as returns, exchanges, etc.). Since being alerted to these inadequacies, the PAs have begun proactively making systematic program changes to address them. While such proactiveness is undoubtedly positive, it is possible that further program changes will be needed to avoid discrepancies of this nature in the future.

5.2 Recommendations

Overall, category-level results with the in-storage installation adjustment applied to in-storage sites resulted in a small increase beyond the category-level evaluation savings. Table 5-1 shows the increase in kWh realization rate for each LED category as a result of an assumed installation rate increase for sites with lamps found to be in-storage. The DNV GL team recommends using in-storage adjusted values when applying results from this study.

Table 5-1. Final realization rates for the program by key product category

Savings Parameter	Energy - Category 1 TLEDs	Energy - Category 2 Stairwell kits	Energy - Category 3 Retrofit kits	Energy - Category 4 A-lines and Decoratives	Energy - Category 5 G24s	Energy - Categories 3, 4, 5 Combined
Gross Realization Rate (with in-storage adjustment)	195.20%	46.99%	51.38%	27.24%	111.87%	48.55%
Gross Realization Rate (without in-storage adj)	188.59%	45.72%	48.06%	25.92%	98.56%	44.84%

5.2.1 Savings assumptions

Annual (kWh) and connected kW realization rates. Category-level results with the in-storage installation adjustment produced the annual kWh and connected kW realization rates shown in Table 5-2. For application of these results, we recommend that the PAs adopt the below category-level results with the in-storage adjustment for the entire life of the measure.

Table 5-2. Category-level results for annual (kWh) and connected kW realization rates

Savings Parameter	Energy - Category 1 TLEDs	Energy - Category 2 Stairwell kits	Energy - Category 3 Retrofit kits	Energy - Category 4 A-lines and Decoratives	Energy - Category 5 G24s	Energy - Categories 3, 4, 5 Combined
Connected kW Realization Rate (with in-storage adjustment)	148.60%	53.93%	58.75%	43.15%	75.17%	54.07%
Connected kW Realization Rate (without in-storage adj)	143.65%	52.15%	55.21%	40.97%	66.48%	50.48%

- **Quantity.** The installation increased between category results and the category results with the in-storage installation adjustment. This change is the result of applying previous Year 1 revisit results, which found that some bulbs moved from storage to sockets between the initial site visits and the revisit. These results also assume that some bulbs that were previously installed will be removed and/or replaced by newly installed bulbs. We recommend that the PAs apply the category installation rate with the in-storage adjustment for savings estimates going forward. Note that the study-connected kW realization rate includes this adjustment factor, so the adjustment factor should not be applied if the realization rates are being used as recommended. Table 5-3 includes the installation rate with and without the in-storage installation adjustment for all LED categories.

Table 5-3. Installation rates for all measure categories

Savings Parameter	Energy - Category 1 TLEDs	Energy - Category 2 Stairwell kits	Energy - Category 3 Retrofit kits	Energy - Category 4 A-lines and Decoratives	Energy - Category 5 G24s	Energy - Categories 3, 4, 5 Combined
Installation Rate (with in-storage adjustment)	91.95%	69.77%	62.24%	66.63%	62.91%	63.81%
Installation Rate (without in-storage adj)	89.78%	65.94%	58.56%	62.42%	56.74%	59.54%

- **Delta watts.** The delta watts estimate resulting from the category-level results with the in-storage installation is shown in Table 5-4. Note that the study-connected kW realization rate includes this adjustment factor, so the adjustment factor should not be applied if the realization rates are being used as recommended.

Table 5-4. Delta watts for all measure categories

Savings Parameter	Energy - Category 1 TLEDs	Energy - Category 2 Stairwell kits	Energy - Category 3 Retrofit kits	Energy - Category 4 A-lines and Decoratives	Energy - Category 5 G24s	Energy - Categories 3, 4, 5 Combined
Delta watts (with in-storage adjustment)	161.60%	77.29%	94.39%	64.77%	119.49%	84.75%

- **Hours of Use.** The hours of use realization rate with the in-storage installation adjustment for each LED category is included in Table 5-5. Also included are the assumed hours of use based on lighting logger data at each of the sites for each category. Note that the study-connected kW realization rate does not include this adjustment for hours, which means that program savings estimates can be updated with the new hours estimates from this study. In this instance, the kWh realization rate would be based on the

product of the connected kW realization rate and the kWh HVAC interactive effect. The assumed hours of use used in the savings algorithms would need to be replaced with the evaluated hours of use included in the table below by category. The combination of these two adjustment would result in the category evaluated savings with the in-storage adjustment.

Table 5-5. Hours of use realization rates by measure category

Savings Parameter	Energy - Category 1 TLEDs	Energy - Category 2 Stairwell kits	Energy - Category 3 Retrofit kits	Energy - Category 4 A-lines and Decoratives	Energy - Category 5 G24s	Energy - Categories 3, 4, 5 Combined
Hours of Use Realization Rate (with in-storage adjustment)	129.79%	87.13%	84.10%	61.52%	145.42%	87.02%
Hours of Use estimate	4,426	7,633	3,281	2,400	5,673	3,394

5.2.2 Program process

- In their new address validation process, the PAs should include a flag for customers that have key account managers. This flag should direct those customers back to the PAs so that they don't go through the program. This would help close the gap between vendor-driven and key account-driven initiatives.[16]

- The PAs should record any customer follow-up activity relating to program products in the new inspection tracking system. This will help ensure that when the PAs are contacted by a customer directly and work with that customer to return or exchange any products received through the program, this activity gets tracked and saved, to be retrievable later.

5.3 Considerations

- Consider adding data validation to tracking data entries so that returns (negative entries) cannot be entered without linking sales to support the return. Program tracking data associated with a site can include a negative sales quantity which is typically from customer bulb returns. A negative sales quantity can also be a correction made to the tracking database if the third-party QC contractor could not find the bulbs at the site. In preparation of the sample frame for this study the DNV GL team worked with the third-party program manager to try and rectify sites that had more negative sales quantities than positive sales quantities; in several cases the purchases were made the previous year and returns were reflected in the 2015 data received by the evaluation team. However, for some customers, the third-party QC contractor was unable to locate the sales associated with the return. In order to more easily verify bulb returns made by customers and to avoid possible keying errors, negative sales entries should be linked to the sale in the tracking database.
- Consider engaging distributors in reporting practice trainings and tie reporting and verification to distributor. Several of the category 3 purchases were not found on site or in-storage but were associated with the customer installation address. There was at least one case where the customer information for a set of purchases (multiple line items in the tracking database) was the same but the customer only knew about a subset of the purchases. It is possible that if there are project changes, distributors are not going back and updating installation and purchase details in the tracking database. Distributors

[16] The evaluation team understands that the PAs have had a rule in place that if above a certain threshold of fixtures are purchased they should go through an account manager.

should be trained on how to accurately report sales, returns, and installations, and the program could consider a review of distributor reporting performance.

- In their new address validation process, the PAs may consider including a flag indicating that that customer has been served by another distributor in the past. This could help to inform distributor installation and performance thresholds. Additionally, consider making distributors who share the same customer share the installation rate if it cannot be clearly determined which products were installed by which distributor.
- In addition to linking distributor sales entries to account numbers, consider including distinct address fields to be auto-populated based on validation prompts. It's expected that large customers have separate addresses for billing, product delivery, and installation; the product delivery and installation addresses should be entered accurately by the distributor based on customer or contractor provided information.[17] Consider building in validation logic so that distributors don't have to enter the same address information multiple times for small customers/purchases.
- Consider adding a purchaser category field such as contractor, electrician, or end-use customer to help track performance progress by purchaser type. This can also help the QC vendor identify contractor projects to follow up with.
- In addition to training distributors on data entry, consider offering training and support communication materials that distributors can pass on to contractors and customers, to be able to communicate why they're getting discounts (PAs), what's needed from them in order to sell the products, and the rationale for the information requested.
- Consider including product literature about appropriate applications for each technology (i.e., "How to make your LEDs last their full measure life") and include this sort of information with a flier to purchasers that remind them about program rules, that the PAs are sponsoring the product, and that the PAs would like to hear from the customer if they experience any product issues.

5.4 Future research

- Consider further installation rate analysis. The program conducts quality control inspections for about 10 percent of the sites to make sure that they can verify on-site the lighting quantities and types claimed in the distributor sales reports. Part of the intention of the QC contractor visits is to establish that the installs are legitimate, and if not, provide a window for reconciliation after which, if not installed, the units would be backed out of the tracking data and appear as negative sales entries in the third-party provided data for the year of the install. The PAs could consider supporting further research into the discrepancy between installation rate shown by the QC contractor visits and those found in this evaluation. Interviews with the third-party program manager could help to explain potential tracking challenges.
- Conduct a process evaluation after program changes are complete to assess areas of improvement due to the changes. The last process evaluation of the MA C&I Upstream Lighting Program was conducted as part of the Year 1 evaluation (2012-2013). The timing for a process evaluation of the program within the next 6 to 8 months is good to inform and assess program delivery.
- Consider assessing the quality of the program data in early 2017 following the rollout of program changes.

[17] The DNV GL team assumes that distributors enter account information provided by the customer and the billing address and customer name auto populate. This type of data entry would keep customer name and addresses standardized within the data with data entry quality potentially varying in other fields to be entered by the distributor. Having at least the customer and account number accurate and consistent allows the PAs to efficiently track customer activity relating to the upstream lighting program.

- Consider identifying purchaser thresholds by account number, distributor, purchaser, and/or customer installation address. The program uses a threshold to prompt follow-up; having multiple thresholds can help identify the individual to follow-up with.
- Consider exploring the extent to which customer installation addresses and associated installation fields have more than one distributor selling products to that address. It's expected that this would be a more problematic issue prior to program changes since program changes will now include an address validation process as well as require more detailed information be entered around the location for where products are being installed.
- Consider conducting another set of on-sites revisiting in-storage and product issue sites to assess any changes in installation rates since the initial site visit. In 2015, a follow-up study (known as the revisit study, or Project 49) was performed to revisit Year 1 (Project 17) sites that were found to have in-storage bulbs, and investigate whether and when those bulbs were eventually installed, as well as calculate savings from bulbs moved from storage to sockets. The revisit study found that some of the bulbs in storage were later installed (within three years of the first site visit). The DNV GL team used the revisit study to inform an adjustment which was applied to this study's category 3 results. The PAs could consider a revisit study in 2018 to revisit in-storage sites as well as sites with product issues that are part of this study, and calculate savings from lamps that were eventually installed.

APPENDIX A. 2015 UPSTREAM LIGHTING PROGRAM LED PRODUCT DESCRIPTIONS

This section describes the LED products included in the MA C&I Upstream Lighting program in 2015; additional products were added in 2016 and are not included in Table 5-6.

Table 5-6. 2015 Upstream Lighting program product type descriptions, LEDs only

Product type name	Introduced into program/category updated	Description (type/base/typically replaces)	Image
A-line, 40/60w	January 2015	LED A Lamp, Edison base, Replaces < 60w INC and <15w CFLs A-lamps	
A-line, 75/100w	January 2015	LED A Lamp, Edison base, Replaces >75w INC and >18w CFLs A-lamps	

Product type name	Introduced into program/category updated	Description (type/base/typically replaces)	Image
Decorative	April 2012	LED Decorative , Candelabra base, Replaces 10w -60w INC and 3w to 14w CFLs	
G24 LED	July 2015	LED, Pin based, Pin based, Replaces G24 CFLs	
LED Retrofit kit, <25W	April 2013	LED down light, Plug/Hard wired fixture, Replaces INC, HAL, and CFL recessed can lamps	

Product type name	Introduced into program/category updated	Description (type/base/typically replaces)	Image
LED Retrofit kit, >25W	April 2013	LED down light, Dimmable, Plug/Hard wired fixture, Replaces INC, HAL, and CFL recessed can lamps	
MR16	October 2011	LED, Pin Based, Replaces HAL and CFL MR16s	
PAR20	October 2011	LED R20, Edison Base, Replaces INC/HAL/CFL PAR 20 lamps	

Product type name	Introduced into program/category updated	Description (type/base/typically replaces)	Image
PAR30	October 2011	LED PAR30, Edison socket, Replaces INC/HAL/CFL PAR 30 lamps	
PAR38	October 2011	LED PAR38, Edison socket, Replaces INC/HAL/CFL PAR 38 lamps	
Stairwell Kit w/sensor, 2ft and 4ft	June 2014	Linear bi-level Motion Sensor LED Light, Replaces fluorescent lamps	

Product type name	Introduced into program/category updated	Description (type/base/typically replaces)	Image
TLED, 2ft and 4ft	January 2015	LED T8 replacement, Pin based, Replaces 2ft and 4ft fluorescent lamps	

APPENDIX B. UPSTREAM LIGHTING PROGRAM BASELINE ADJUSTMENTS FOR NEW COMMERCIAL CONSTRUCTION LPD MEMOS

Memo to:

Massachusetts Program Administrators Research Team and Energy Efficiency Advisory Council EM&V Consultants

From: Ari Michelson, ERS
Sue Haselhorst, ERS

Date: July 15, 2016

Copied to:
Jessi Baldic, DNV GL
Chad Telarico, DNV GL

Upstream Lighting Program Baseline Adjustments for New Commercial Construction LPD

Overview

The Massachusetts Energy Efficiency Programs Commercial & Industrial Evaluation Contractor (CIEC) team prepared this memo as part of the Impact Evaluation of Massachusetts Commercial and Industrial Upstream Lighting Program (P58). This memo presents an adjustment factor for lighting power density (LPD) for new commercial construction buildings in the project sample. The CIEC team developed this adjustment factor to reflect LPD standard practice we observed in carrying out our 2015 Massachusetts Commercial New Construction Energy Code Compliance Follow-up Study (2015 Code Study). Based on our observations in the 2015 Code Study, and the methodology described below, the CIEC team recommends that an adjustment factor of 0.73 be used to "de-rate" code-required LPD for any new commercial construction buildings in the project sample. The savings calculation used for these sites would be:

- Savings kW = LPD Code * 0.73 – Installed LPD
- There have been some code changes since the 2015 Code Study, as Massachusetts has since adopted IECC-2012. The new code includes an optional enhanced lighting efficiency provision, but the LPD requirements for base compliance did not change for most building types. While the approach outlined in this memo is reasonable for the few new construction sites likely impacted by the Upstream Lighting evaluation, further discussions should occur between the CIEC team and the Energy Efficiency Advisory Council before applying this method or the adjustment factor more broadly.

Background

The 2015 Code Study assessed energy code compliance in the state of Massachusetts for buildings permitted under the 2009 International Energy Conservation Code.[18] There were 50 building sites included in the study. The CIEC team assessed code compliance for each of these buildings as a whole, by collecting building-envelope, mechanical, and lighting data from construction documents and through on-site inspections. In 45 of the 50 building sites, we examined the lighting fixtures that were either installed or

[18] The 2015 Code Study can be found on the EEAC website: http://ma-eeac.org/wordpress/wp-content/uploads/Commercial-New-Construction-Energy-Code-Compliance-Follow-up-Study.pdf.

planned (where construction was not complete) in representative spaces to determine whether or not each site met the applicable LPD requirements of the code. Notably, we found that in the standard practice observed in commercial new construction, LPD exceed the code requirement. However, because the focus of the study was on building compliance and not measure compliance, it did not the quantify differences between observed standard practice and code for LPD.

In developing the work plan for the Upstream Lighting Program evaluation, the CIEC team wanted to leverage the 2015 Code Study data to develop an adjustment factor for LPD that could be applied to any new commercial construction buildings in the project sample, to better reflect standard practice observed in Massachusetts.

Methodology

This section presents the methodology we used to develop the LPD adjustment factor, using the 2015 Code Study data.

1. **Aggregate 2015 Code Study data by site.** The objective of the 2015 Code Study was to assess LPD by performing fixture counts in representative spaces at the project sites. While the evaluators were able to complete a census LPD assessment at some of the small sites, at larger sites, spaces were sampled. They used a data collection tool that captured space type, space square footage, and a fixture inventory for multiple spaces at each site, and then calculated both the code-allowed wattage and the actual wattage for each space. These individual sampled wattages and areas were summed to determine an overall code-allowed wattage and LPD, and an actual wattage and LPD, for each project site. These data reflect only the sampled spaces at each site.
2. **Weight 2015 Code Study data by building square footage.** The next step applied each building's allowed and actual LPDs to the building's total square footage, to calculate building-level allowed and actual wattage.
3. **Weight 2015 Code Study data by project site weight.** The building-level wattage was then weighted by the 2015 Code Study project site weights to estimate LPD standard practice in Massachusetts. This approach was consistent with the 2015 Code Study's sample design and compliance results aggregation. The resulting LPD adjustment factor is the state-wide ratio of estimated actual wattage to estimated code-allowed wattage.
4. **Review data for outliers and potential for additional stratifications by building type and/or building size.** We reviewed the resulting data to identify outliers and determine whether sample sizes support additional stratification by building type or building size. This review showed that no individual site unduly influenced the outcome, and that values from potential subsectors were not significantly different from the state-wide value.

Results

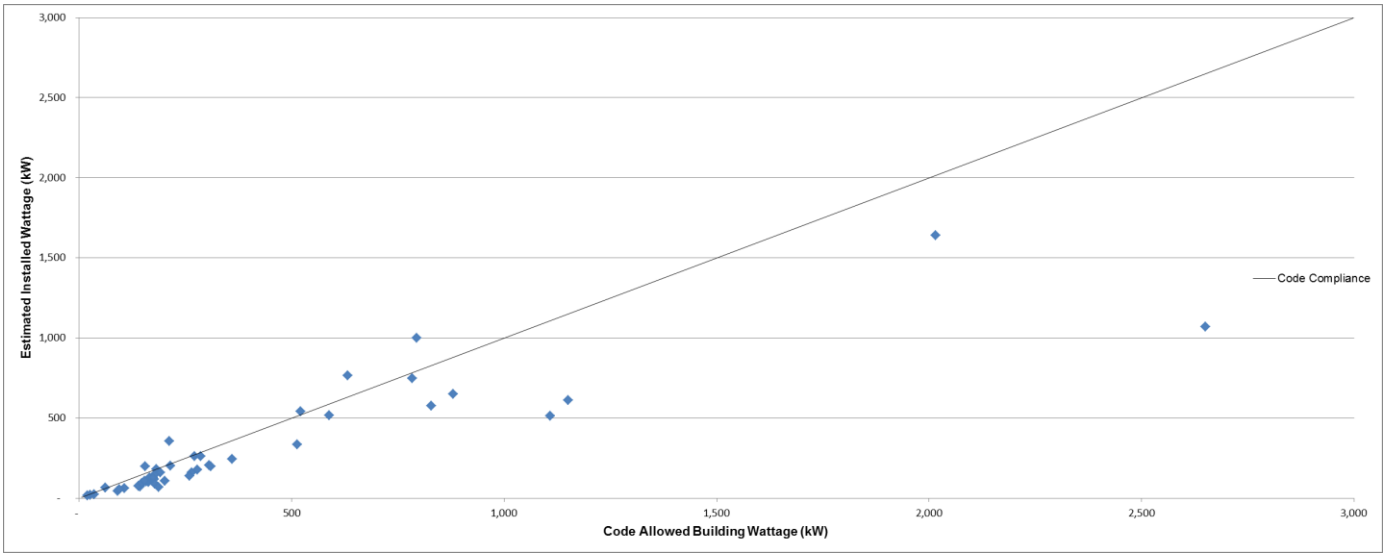
This section presents the results of our LPD adjustment factor analysis. The CIEC team recommends that an adjustment factor of 0.73 be used to "de-rate" code-required LPDs for any new commercial construction buildings in the project sample. We explored developing additional adjustment factors by building type and building size, but determined that sample sizes were not large enough to support this analysis. **Error! Reference source not found.** shows the Massachusetts state-wide estimate, weighted by building square footage and building site weight as outlined in the Methodology section above.

Table 5-7. Massachusetts state-wide estimate of new construction allowed and installed wattage

	Code Allowed Wattage (kW)	Installed Wattage (kW)	Ratio Installed to Allowed
Statewide Estimate	18,355	13,335	0.73

Figure 5-1 plots the estimated installed wattage against the code-allowed wattage for each of the 45 sites where LPD data was captured in the 2015 Code Study. The scatter plot also includes the line y=x, which signifies code compliance; any point above the line represents LPD worse than code, and any point below the line represents LPD better than code.

Figure 5-1. Estimate of Massachusetts installed LPD wattage vs. code-allowed LPD wattage



Memo to:

Massachusetts Program Administrators Research Team and Energy Efficiency Advisory Council EM&V Consultants

From: Ari Michelson, ERS
Sue Haselhorst, ERS

Date: January 13, 2017

Copied to:
Chad Telarico, DNV GL

Revised Baseline Adjustment for New Commercial Construction Lighting Power Density (LPD)

Overview

This updated memo presents a revised adjustment factor for lighting power density (LPD) that can be applied to analyses of new commercial construction buildings permitted under the 2009 International Energy Conservation Code (IECC 2009). The Massachusetts Energy Efficiency Programs Commercial & Industrial Evaluation Contractor team, DNV GL, prepared the original memo as part of the Impact Evaluation of the Massachusetts Commercial and Industrial Upstream Lighting Program (P58).[19] The adjustment factor reflects the LPD standard practice we observed during the 2015 Massachusetts Commercial New Construction Energy Code Compliance Follow-Up Study (2015 Code Study). The original memo did not address program administrator (PA) program participation; this revision builds upon the original memo, adding step 5 in the methodology below to incorporate PA program participation into the LPD adjustment. This revised memo was developed primarily for use in the DNV GL team's analysis of the CDA Impact Evaluation (P56).

Based on our observations presented in the 2015 Code Study, and the revised methodology described below, the DNV GL team recommends that an adjustment factor of 0.75 be used to "de-rate" code-required LPD for analyses of new commercial construction buildings. The following savings calculation used for these sites would be:

- $Savings\ kW = LPD\ Code * 0.75 - Installed\ LPD$

There have been some code changes since the 2015 Code Study, as Massachusetts adopted IECC 2012 in July 2014 and recently adopted IECC 2015, effective January 2017. The new codes include optional enhanced lighting efficiency provisions, and the IECC 2015 contains more stringent LPD requirements for most space types. While the approach outlined in this memo is reasonable for the few new construction sites likely impacted by the Upstream Lighting Evaluation (P58) and the sites under review for the CDA Evaluation (P56), further discussions should occur between the DNV GL team and the Energy Efficiency Advisory Council before applying this method or the adjustment factor more broadly.[20] To use this adjustment factor prospectively, the DNV GL team recommends additional analyses in order to better understand both changes in LED market adoption and in code stringency. Since LPD requirements did not change significantly in IECC 2012 (aside from the optional enhanced lighting efficiency package) and LED adoption has likely increased,

[19] The original memo was titled "P58 Baseline Adjustment Memo for NC from 2015 Code Study" and was distributed via email to the PAs and EEAC on 7/15/16 by Jessi Baldic of DNV GL.

[20] The DNV GL team held several discussions during its biweekly calls regarding this adjustment and its impact on net-to-gross (NTG) estimation, which is performed by the Massachusetts cross-cutting evaluation team. We have identified a need for greater communication and clarity in using consistent baselines across the evaluations and NTG studies, and while this is on the agenda of the baseline framework project that DNV GL is working on, this is a broader discussion and is out of scope for this specific LPD adjustment.

we expect that LPD standard practice may be even better than the base code for buildings constructed during this time period. Data from the IECC 2012 portion of P70 (Task 5) can be used to assess this. For prospective application with IECC 2015, the change in LPD stringency could be compared to an estimate of future changes in LED market adoption to estimate any changes in the LPD adjustment factor.

Background

The 2015 Code Study assessed energy code compliance in the state of Massachusetts for buildings permitted under IECC 2009.[21] There were 50 building sites included in the study. The DNV GL team assessed code compliance for each of these buildings as a whole by collecting the building-envelope, mechanical, and lighting data from construction documents and conducting on-site inspections. In 45 of the 50 building sites, we examined the lighting fixtures that were either installed or planned (where construction was not complete) in representative spaces to determine whether or not each site met the applicable LPD requirements of the code. Notably, we observed that the standard practice LPD for commercial new construction was better (i.e., lower LPDs) than the energy code requirements. However, because the focus of the study was on building compliance and not measure compliance, it did not quantify the differences between the observed standard practice and the code for LPD.

In conjunction with the PAs and EEAC, the DNV GL team leveraged the 2015 Code Study data to develop an adjustment factor for LPD that could be applied to new commercial construction buildings affected by other projects within the DNV GL team portfolio to better reflect standard practices observed in Massachusetts. The initial adjustment was developed for P58, the Upstream Lighting Project, and this revised estimate, incorporating program participation, was primarily developed for use in the P56 CDA project modeling of LPD.

Methodology and results

This section presents the methodology we used to develop the LPD adjustment factor, using the 2015 Code Study data. Steps 1 through 4 were completed as part of the original memo; Step 5 below is the new item for this revised memo.

1. **Aggregate 2015 Code Study data by site.** The objective of the 2015 Code Study was to assess LPD by performing fixture counts in representative spaces at the project sites. While the evaluators were able to complete a census LPD assessment at some of the small sites, spaces were sampled at larger sites. The team used a data collection tool that captured space type, space square footage, and a fixture inventory for multiple spaces at each site, and then they calculated both the code-allowed wattage and the actual wattage for each space. These individual sampled wattages and areas were summed to determine an overall code-allowed wattage and LPD and an actual wattage and LPD for each project site. This data reflects only the sampled spaces at each site.
2. **Weight 2015 Code Study data by building square footage.** For the next step, the team applied each building's allowed and actual LPDs to the building's total square footage to calculate building-level allowed and actual wattage. One exception to note here is for multifamily buildings; since only common areas are subject to the commercial LPD requirements, the team used the sampled areas as a better approximation of the common-area wattage than the overall building square footage.
3. **Weight 2015 Code Study data by project site weight.** The building-level wattage was then weighted by the 2015 Code Study project site weights to estimate LPD standard practice in

[21] The 2015 Code Study can be found on the EEAC website: http://ma-eeac.org/wordpress/wp-content/uploads/Commercial-New-Construction-Energy-Code-Compliance-Follow-up-Study.pdf.

Massachusetts. This approach was consistent with the 2015 Code Study's sample design and compliance results aggregation. The resulting LPD adjustment factor is the statewide ratio of estimated actual wattage to estimated code-allowed wattage (herein referred to as the "compliance ratio").

4. **Review data for outliers and potential for additional stratifications by building type and/or building size.** We reviewed the resulting data to identify outliers and determine whether sample sizes support additional stratification by building type or building size. This review showed that no individual site unduly influenced the outcome, and that values from potential subsectors were not significantly different from the statewide value.
5. **Adjust for program participation.** The DNV GL team accounted for program participation among the 2015 Study sites. This was a three-step process:
6. ***Identify program participation within the sample.*** The DNV GL team cross-referenced the 2015 Study sites with the aggregated program database to identify the participants in lighting programs. Of the 45 sites with lighting data, 27 (60%) participated in a PA lighting program (upstream, performance, prescriptive, customer, and/or CDA). Table 1 shows the participation rate and corresponding compliance ratios (actual / code-allowed wattage) for participants (P) and non-participants (Np). As shown by having a comparatively lower (better) compliance ratio (0.63) than non-participants (0.76), program participation appears to have had a positive influence on the LPD installed in new buildings permitted under IECC 2009. However, rather than just relying solely on the Np compliance ratio to represent standard practice LPD, we also need to take into account what the standard practice LPD would have been from the perspective of the participants. In the next step, we adjust the participant compliance ratio (0.63) to estimate this value as a way to characterize a more comprehensive, unbiased view of the baseline or standard practice LPD under this code.

Table 5-8. 2015 Study Participation and Compliance Ratios

2015 Study Site Type	Number of Sites	2015 Study Participation Rate	Compliance Ratio
PA program participants (P)	27	60%	0.63
Non-participants (Np)	18	40%	0.76

7. ***Adjust the participant compliance ratio to account for program influence.*** We adjusted the participant compliance ratio (0.63) to account for (i.e., remove) the influence of the programs using the free ridership (FR) rate.

8. **Calculate rate of free ridership of program participants -** The team utilized free ridership (FR) values from the Massachusetts 2014 Technical Resource Manual for the various lighting programs, evaluated each participating site's program and corresponding FR estimate, and averaged the FR for all sampled participants. The resulting FR estimate was 0.17, which we use to approximate the proportion of the difference between the nonparticipant and participant compliance ratios that is not attributable to program influence.

9. **Adjust participant compliance ratio to account for free ridership -** To reflect the market compliance ratio from the perspective of participants, we calculate the participant-adjusted value (Padj), by accounting for program influence (1-FR) from the difference between Np and the P values, as shown in the following equation:

$$Padj = P + [(Np - P) * (1 - FR)] = 0.63 + [(0.76 - 0.63) * (1 - 0.17)] = 0.74$$

As shown above, 83% (1-0.17) of the difference between the nonparticipant and participant compliance ratios is used to approximate program influence, and we estimate an adjusted compliance ratio (Padj) of 0.74 for program participants without program influence.

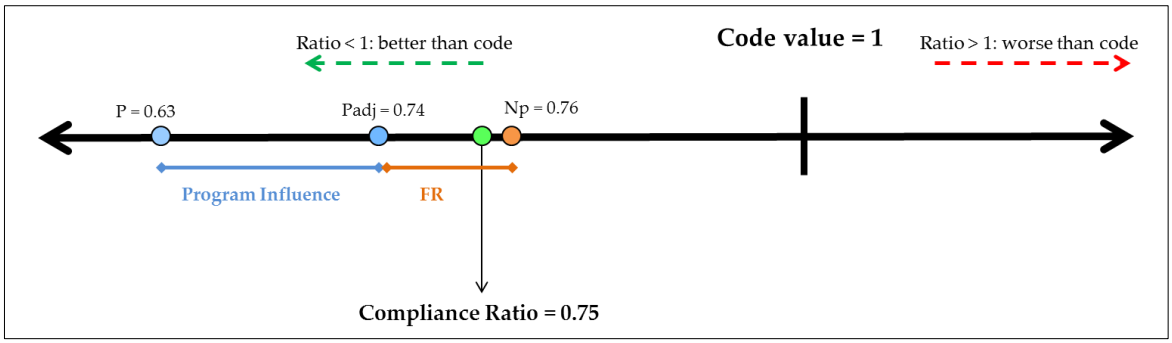
10. ***Apply to population***. The DNV GL team analyzed Dodge records and program tracking data to estimate a population participation rate of 40%. This participation rate was used to compute a weighted average compliance ratio for the adjusted participants and the non-participants. These results are presented in Table 5-9.

Table 5-9. Compliance Ratio for LPD Adjustment

2015 Study Site Type	Number of Sites	Sample Participation Rate	Unweighted Compliance Ratio	Adjusted Compliance Ratio	Population Participation Rate
PA program participants (P)	27	60%	0.63	0.74	40%
Non-participants (Np)	18	40%	0.76	0.76	60%
Weighted average adjustment factor				0.75	

The DNV GL team recommends that an adjustment factor of 0.75 be used to "de-rate" code-required LPDs for any new commercial construction buildings in the project sample. We explored developing additional adjustment factors by building type and building size but determined that sample sizes were not large enough to support this analysis. Figure 5-2 presents a graphical representation of the LPD adjustment.

Figure 5-2. Graphical Representation of LPD Adjustment Calculations



APPENDIX C. UPSTREAM LIGHTING PROGRAM HEAT LOSS ASSUMPTION FOR HVAC INTERACTION

This appendix summarizes the findings from the HVAC interaction assumption investigation completed as part of this study. These findings were initially shared with the PAs and EEAC Consultants in January 2017.

Overview

In the 2012 evaluation and in previous impact evaluations of custom lighting measures, an assumption of 80 percent was used to calculate HVAC interaction according the following equations:

Cooling kW Effects = 80% * Lighting kW Savings / Cooling System COP

Heating kW Effects = -80% * Lighting kW Savings / Heating System COP

The 80 percent values represent the assumed percentage of the lighting energy that translates to heat, which either must be removed from the space by the air conditioning system or added to the space by the heating system during hours that lighting and HVAC are assumed to operate in unison. The DNV GL team performed a brief review of the literature to investigate whether the 80 percent value used in calculating HVAC interactive effects should be updated since this study includes only LED lighting. Based on the below findings and discussion with the PAs and EEAC Consultants, the DNV GL team recommends continuing to use the 80 percent value to calculate HVAC interaction.

Findings

There was no research found to support changing the assumed percentage of the lighting energy that translates to heat from 80 percent.

- In at least one study[22], it was recommended to try and reroute LED lighting heat outside of the building during the cooling season; this would be accomplished by integrating a thermal management system for LED lighting with a heat exchange module and HVAC ductwork to move lighting heat outdoors. This provides some evidence that waste heat produced by LEDs is significant enough to warrant investigation and investment into the development of such a system.
- In at least one source it was stated that high-efficiency LEDs convert 15-20 percent of electric power into visible light, the rest is transformed into heat. This supports the continued use of the 80 percent assumption directly.
- Several sources included information about how thermal management and control of the junction temperature is critical for effective and efficient LED performance. Heat sink design helps with cooling performance in LED lighting and in at least one source it was stated that waste heat from the heat sink can be transferred to the ceiling and from the ceiling into an indoor space by convective heat transfer, increasing indoor air temperature.

Conclusion

Evidence supports that it's the lower absolute wattage value of LEDs that makes them "cooler" than their less efficient counterparts rather a difference in light conversion efficiency.

[22] Savings in Cooling Energy with a Thermal Management System for LED Lighting in Office Buildings. Byung-Lip Ahn, et. al., June 30, 2015. *Energies 2015, 8, 6658-6671*

APPENDIX D. METHOD FOR INCORPORATING FIRST REVISIT STUDY FINDINGS

The first "In-storage" revisit study (P49) [23] revisited the first evaluation[24] (Year 1) sites that were identified to have lamps in-storage and calculated installation rates and savings based on observed changes in Year 3. Thirty-one sites were targeted for the revisits, 23 of which a revisit was completed (others were either unresponsive, out of business or refused participation); of the 23 completed revisits in P49, 18 were LED and 5 fluorescent. For LEDs (overall), Year 1 installation rate was 82 percent and Year 3 installation rate was 85 percent.

Table 5-10 presents the installation rates for LEDs in Year 1 and Year 3.

Table 5-10. Summary of Year 1 and Year 3 installation rates

	Year 1 (42)*	Sites Revisited (18)	Year 1 (6)	Overall LED (66)
Year 1 weighted kWh tech adj	54,045,412	24,121,332	9,543,554	87,710,298
Year 1 weighted kWh quantity adj	51,008,882	16,015,979	5,051,093	72,075,954
Year 1 Installation rate (quantity adj/tech adj)	**94%**	**66%**	**53%**	**82%**
Year 3 weighted kWh tech adj	54,045,412	24,078,738	9,543,554	87,667,704
Year 3 weighted kWh quantity adj	51,008,882	18,765,525	5,051,093	74,825,500
Year 3 Installation rate (quantity adj/tech adj)	**94%**	**78%**	**53%**	**85%**

*Numbers in parenthesis are number of site visits

This study (P58) found that 20 category 3 sites had lamps in-storage at the time of the first site visit. The DNV GL team compared these sites to those revisited as part of P49 and found that they were relatively comparable as shown in the figures below.

[23] Massachusetts Commercial and Industrial Upstream Lighting Program: "In Storage" Lamps Follow-up Study, Final Report; prepared by DNV GL for Massachusetts Energy Efficiency Program Administrators and Massachusetts Energy Efficiency Advisory Council; March 27, 2015. http://ma-eeac.org/wordpress/wp-content/uploads/CI-Upstream-Lighting-Program-In-Storage-Lamps-Follow-up-Study.pdf

[24] Impact Evaluation of the Massachusetts Upstream Lighting Program, Final Report; prepared by KEMA, Inc. for Massachusetts Energy Efficiency Program Administrators and Massachusetts Energy Efficiency Advisory Council; February 19, 2014. http://ma-eeac.org/wordpress/wp-content/uploads/Upstream-Lighting-Impact-Evaluation-Final-Report.pdf

Figure 5-3. Number of in-storage sites, P49 and P58 (category 3)

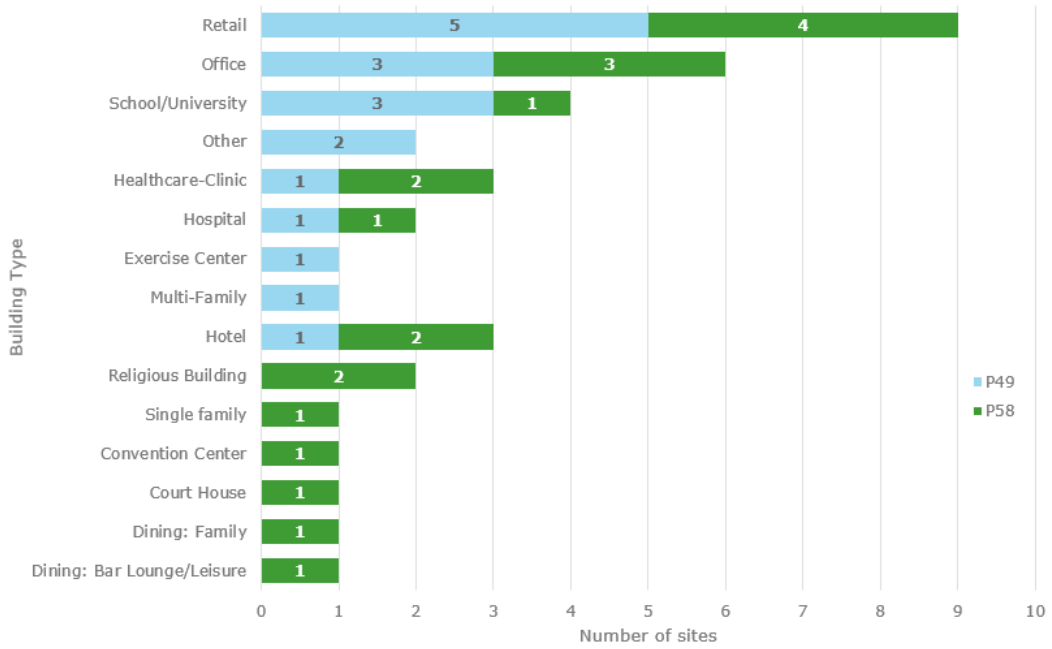
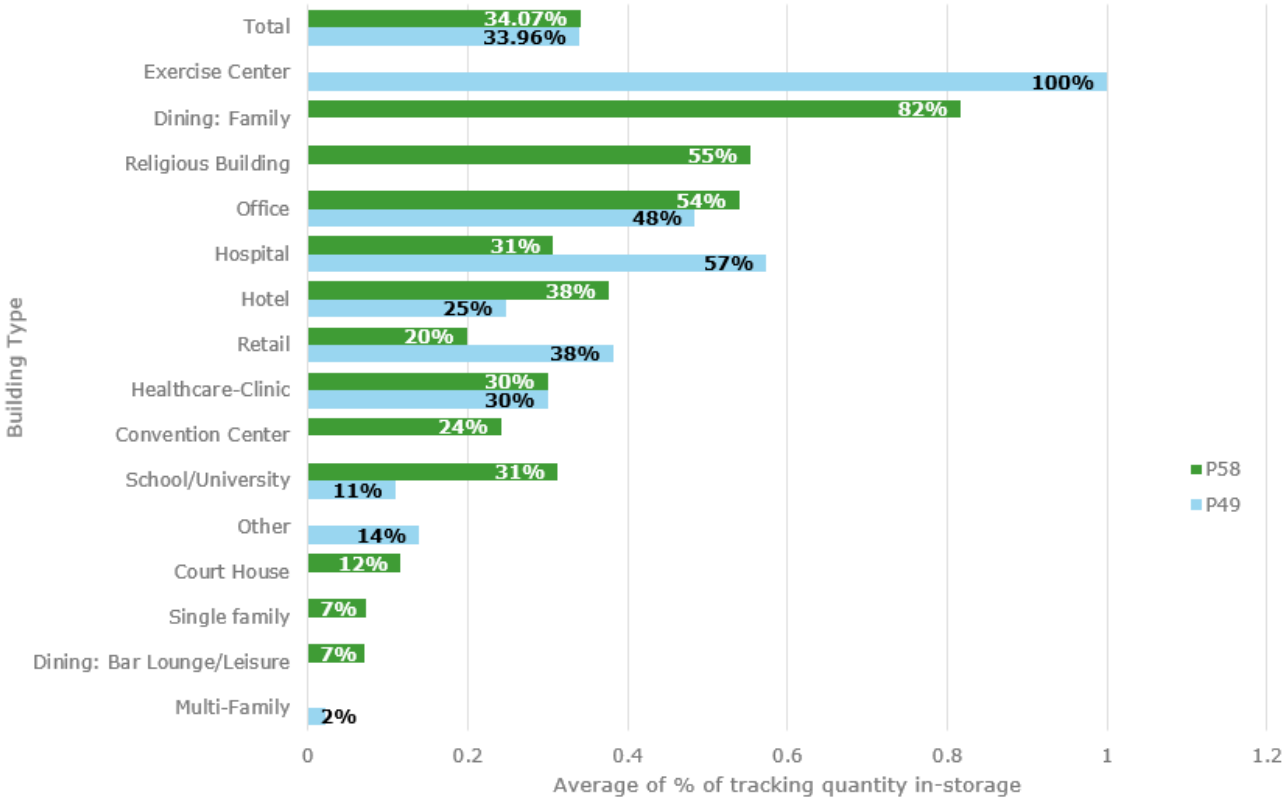


Figure 5-4. In-storage sites – percent of tracking quantity in storage, P49 and P58 (category 3)



The DNV GL team assumed similar savings would result if another revisit study were performed to revisit in-storage sites from this study and applied an adjustment of 117 percent of savings to in-storage sites (Sites Revisited Year 3 installation rate/Sites Revisited Year 1 installation rate), capping at the number of in-storage lamps. For two in-storage sites, the DNV GL team kept savings at zero rather than assuming an increase.

This adjustment to in-storage sites is recommended to be used until another revisit study is conducted.

APPENDIX E. SITE-LEVEL RESULTS

Category 1, TLEDs

This section presents the site-level results for category 1 site-level results.

Table 5-11. Category 1 tracking and evaluation savings estimates

		Tracking			Evaluation								
Site ID	Facility Type	Annual kWh Savings	Connected kW Savings	Average Hours of Use	Annual kWh Savings	kWh HVAC Factor	On-Peak % Annual kWh	Connected kW Savings	Summer kW Coincidence Factor	Summer kW HVAC Factor	Winter kW Coincidence Factor	Winter kW HVAC Factor	Average Hours of Use
004051	Parking Garage	9,663	2.8	3,410	41,385	1.00	73%	5.3	1.00	1.00	1.00	1.00	7,767
007631	Hotel	3,221	0.9	3,410	961	1.01	76%	1.8	0.07	1.27	0.08	1.00	539
030201	Workshop	580	0.2	3,410	-	1.00	0%	0.0	0.00	1.00	0.00	1.00	0
048981	Hospital	58,038	17.0	3,410	144,658	1.03	80%	30.0	0.84	1.17	0.61	1.00	4,702
058601	Dining: Bar Lounge/Leisure	174	0.1	3,410	0	1.04	100%	0.1	0.00	1.27	0.00	1.00	0
063241	Manufacturing Facility	24,492	7.2	3,410	35,231	1.12	100%	13.8	0.88	1.27	0.73	1.00	2,294
065921	Library	26,987	7.9	3,410	17,565	1.04	77%	9.1	0.31	1.14	0.26	1.00	1,862
076011	Retail	871	0.3	3,410	375	0.40	100%	0.5	0.67	1.20	0.34	-0.20	1,994
082271	Sports Arena	57,342	16.8	3,410	78,887	1.01	76%	19.4	0.56	1.03	0.54	1.00	4,026
082831	Office	3,076	0.9	3,410	2,460	1.03	96%	1.1	0.63	1.27	0.32	1.00	2,210
085511	Parking Garage	4,237	1.2	3,410	21,622	1.01	67%	2.4	1.00	1.05	1.00	1.00	8,760
088541	Manufacturing Facility	9,983	2.9	3,410	14,896	1.05	84%	3.9	0.75	1.15	0.55	1.00	3,673
098011	School/University	217,496	63.8	3,410	343,590	1.00	70%	64.7	0.72	1.00	0.68	1.00	5,309
111721	Dining: Cafeteria/Fast Food	116	0.0	3,410	100	1.04	96%	0.1	0.27	1.27	0.39	1.00	1,201
120081	Motion Picture		2.6	3,410		0.00	0%	0.0	0.00	1.00	0.00	1.00	0

		Tracking			Evaluation								
Site ID	Facility Type	Annual kWh Savings	Connected kW Savings	Average Hours of Use	Annual kWh Savings	kWh HVAC Factor	On-Peak % Annual kWh	Connected kW Savings	Summer kW Coincidence Factor	Summer kW HVAC Factor	Winter kW Coincidence Factor	Winter kW HVAC Factor	Average Hours of Use
	Theatre	8,706			-								
126431	Retail	38,305	11.2	3,410	183,662	1.04	83%	26.4	1.00	1.27	1.00	1.00	6,706
045761	Office	11,594	3.4	3,410	17,961	1.04	92%	5.6	0.88	1.27	0.88	1.00	3,070
046241	School/University	20,313	6.0	3,410	20,070	1.02	87%	3.9	0.89	1.17	0.81	1.00	5,034
053451	Police/Fire Station	435	0.1	3,410	425	1.04	75%	0.2	0.31	1.27	0.33	1.00	1,746
058351	School/University	80,818	23.7	3,410	161,199	1.04	77%	44.0	0.49	1.17	0.49	1.00	3,535

Table 5-12. Category 1 realization rates and reasons for discrepancies

		Realization Rates			Evaluation
Site ID	Facility Type	Annual kWh (Including HVAC)	Connected kW	Average Hours of Use	Primary Reasons for Discrepancies
004051	Parking Garage	428%	188%	228%	The assumption for tracking hours of use are (3,410) and the logged hours of use are (7,767).
007631	Hotel	30%	187%	16%	The assumption for tracking hours of use are (3,410) and the logged hours of use are (539).
030201	Workshop	0%	0%	0%	All (20) of the program TLEDs for this site were reported by the site contact to be defective (burned out) and were scheduled to be returned to the distributor. This customer does not appear in the 2016 program data.
048981	Hospital	249%	176%	138%	The assumed wattage difference (8.5) was lower than the wattage difference found on-site (15) for TLEDs, 4ft. Also, the assumption for tracking hours of use are (3,410) and the logged hours of use are (4,702).
058601	Dining: Bar Lounge/Leisure	0%	165%	0%	The assumption for tracking hours of use are (3,410) and the logged hours of use are (0). All TLEDs were installed in a restaurant area of a bowling ally that were not used often (or

		Realization Rates			Evaluation
Site ID	Facility Type	Annual kWh (Including HVAC)	Connected kW	Average Hours of Use	Primary Reasons for Discrepancies
					at all during the logged period) in lieu of other fixtures; the site contact confirmed that the program TLED lamps (12) were not used very often.
063241	Manufacturing Facility	144%	192%	67%	The assumed wattage difference (8.5) was lower than the wattage difference found on-site (16) for TLEDs, 4ft.
065921	Library	65%	115%	55%	The assumption for tracking hours of use are (3,410) and the logged hours of use are (1,862).
076011	Retail	43%	182%	58%	The assumption for tracking hours of use are (3,410) and the logged hours of use are (1,994).
082271	Sports Arena	138%	116%	118%	The assumed wattage difference (8.5) was lower than the wattage difference found on-site (17) for TLEDs, 4ft.
082831	Office	80%	119%	65%	The assumption for tracking hours of use are (3,410) and the logged hours of use are (2,210).
085511	Parking Garage	510%	197%	257%	The assumption for tracking hours of use are (3,410) and the logged hours of use are (8,760).
088541	Manufacturing Facility	149%	132%	108%	The assumed wattage difference (8.5) was lower than the wattage difference found on-site (13) for TLEDs, 4ft.
098011	School/University	158%	101%	156%	The assumption for tracking hours of use are (3,410) and the logged hours of use are (5,309).
111721	Dining: Cafeteria/Fast Food	86%	235%	35%	The assumption for tracking hours of use are (3,410) and the logged hours of use are (1,201). Also, the assumed wattage difference (8.5) was lower than the wattage difference found on-site (20) for TLEDs, 4ft.
120081	Motion Picture Theatre	0%	0%	0%	None (300) of the program tracking TLEDs were received nor installed; the site contact did report having received other (non-TLED) products through the program, however.
126431	Retail	479%	235%	197%	The assumption for tracking hours of use are (3,410) and the logged hours of use are (6,706). Also, the assumed wattage difference (8.5) was lower than the wattage difference found on-site (20) for TLEDs, 4ft.
045761	Office	155%	165%	90%	The assumed wattage difference (4) was lower than the wattage difference found on-site (7) for TLEDs, 2ft.
046241	School/University	99%	66%	148%	Sixty percent (420) of program tracking TLED lamps were not found installed nor in-storage. Also, the assumption for tracking hours of use are (3,410) and the logged hours of use

		Realization Rates			Evaluation
Site ID	Facility Type	Annual kWh (Including HVAC)	Connected kW	Average Hours of Use	Primary Reasons for Discrepancies
					are (5,034).
053451	Police/Fire Station	98%	183%	51%	The assumption for tracking hours of use are (3,410) and the logged hours of use are (1,746). Also, the assumed wattage difference (8.5) was lower than the wattage difference found on-site (15) for TLEDs, 4ft.
058351	School/University	199%	186%	104%	The assumed wattage difference (8.5) was lower than the wattage difference found on-site (16) for TLEDs, 4ft.

Category 2, stairwell kits

This section presents the category 2 site-level results.

Table 5-13. Category 2 tracking and evaluation savings estimates

		Tracking			Evaluation								
Site ID	Facility Type	Annual kWh Savings	Connected kW Savings	Average Hours of Use	Annual kWh Savings	kWh HVAC Factor	On-Peak % Annual kWh	Connected kW Savings	Summer kW Coincidence Factor	Summer kW HVAC Factor	Winter kW Coincidence Factor	Winter kW HVAC Factor	Average Hours of Use
001062	Multi-Family	37,423	4.3	8,760	4,133	1.00	62%	0.5	0.67	1.00	1.00	1.00	7,601
002022	Multi-Family	19,342	2.2	8,760	15,285	1.00	65%	1.7	0.93	1.00	1.00	1.00	8,760
002232	School/ University	604,440	69.0	8,760	645,690	1.00	66%	73.7	0.97	1.00	0.98	1.00	8,760
017322	School/ University	140,335	16.0	8,760	55,512	1.00	73%	8.7	0.88	1.00	0.84	1.00	6,381
022232	Multi-Family	49,585	5.7	8,760	11,050	1.00	67%	1.3	1.00	1.00	1.00	1.00	8,760
023672	Office	8,865	1.0	8,760	4,660	1.00	65%	0.5	0.91	1.00	0.96	1.00	8,760
033092	School/ University	151,916	17.3	8,760	26,818	1.00	67%	3.4	0.94	1.00	0.93	1.00	7,969
033282	Office	308,667	35.2	8,760	22,121	1.00	79%	7.2	0.56	1.00	0.39	1.00	3,062
039402	School/ University	302,623	34.5	8,760	80,345	1.00	65%	8.7	0.94	1.00	0.97	1.00	9,248
046532	Office	30,222	3.5	8,760	10,656	1.00	56%	1.2	0.52	1.14	0.60	1.00	8,760
064842	School/ University	33,849	3.9	8,760	3,638	1.00	70%	2.0	0.23	1.00	0.21	1.00	1,803
073622	Multi-Family	19,342	2.2	8,760	11,484	1.00	67%	1.3	1.00	1.00	1.00	1.00	8,760
078672	Dining: Family	806	0.1	8,760	97	1.00	96%	0.0	0.98	1.00	1.00	1.00	4,834
083312	Office	7,656	0.9	8,760	5,127	1.00	64%	0.6	0.84	1.00	1.00	1.00	8,760
084162	Multi-Family	44,907	5.1	8,760	10,007	1.00	67%	1.1	1.00	1.00	1.00	1.00	8,760
098522	Office	92,278	10.5	8,760	74,040	1.00	65%	8.5	0.93	1.00	0.93	1.00	8,760
098582	Other	2,418	0.3	8,760	(67)	1.00	78%	0.0	0.36	1.27	0.14	1.00	2,247
105972	Office	201,480	23.0	8,760	63,108	1.00	65%	9.6	0.70	1.17	0.68	1.00	6,572
126002	Hospital	328,850	37.5	8,760	348,426	1.00	40%	39.8	0.68	1.00	0.60	1.00	8,760
118662	School/ University	1,205,253	137.6	8,760	722,021	1.00	66%	82.4	0.97	1.01	0.97	1.00	8,760
124942	Multi-Family	302,220	34.5	8,760	18,748	1.00	75%	22.0	0.11	1.14	0.11	1.00	852

Table 5-14. Category 2 realization rates and reasons for discrepancies

		Realization Rates			Evaluation
Site ID	Facility Type	Annual kWh (Including HVAC)	Connected kW	Average Hours of Use	Primary Reasons for Discrepancies
001062	Multi-Family	11%	13%	87%	The baseline watts were lower than the assumed watts. About a third of tracking sales quantity ((29) Stairwell kits with sensors) were found in-storage and were reported by the site contact to be installed over time.
002022	Multi-Family	79%	79%	100%	Seventeen percent (8) of the program tracking Stairwell kits with sensor were not found installed nor in-storage.
002232	School/University	107%	107%	100%	The baseline watts were lower than the assumed watts for stairwell kits with sensors.
017322	School/University	40%	54%	73%	The baseline watts were lower than the assumed watts for stairwell kits with sensors. Also, fixtures were not on for 100% of the time.
022232	Multi-Family	22%	22%	100%	The baseline watts were lower than the assumed watts for stairwell kits with sensors.
023672	Office	53%	53%	100%	Just over a quarter (6) of the program tracking Stairwell kits with sensor were reported by the site contact to have burnt out due to driver issues. Also, the baseline watts were lower than the assumed watts for stairwell kits with sensors.
033092	School/University	18%	19%	91%	Nearly eighty percent (301) of tracking Stairwell kits with sensors were found in-storage and are planned to be installed over time.
033282	Office	7%	21%	35%	The baseline watts were lower than the assumed watts for stairwell kits with sensors. Just over 40 percent (336) of the program Stairwell kits with sensor were found to not be installed; (180) of which are in-storage and are planned to be installed over time.
039402	School/University	27%	25%	106%	Seventy-five percent (570) of the program Stairwell kits with sensor were found to not be installed; (300) of which are in-storage and are planned to be installed over time.
046532	Office	35%	35%	100%	The baseline watts were lower than the assumed watts for

		Realization Rates			Evaluation
Site ID	Facility Type	Annual kWh (Including HVAC)	Connected kW	Average Hours of Use	Primary Reasons for Discrepancies
					stairwell kits with sensors.
064842	School/University	11%	52%	21%	The fixtures were not on 100% of the time. Also, one third (28) of the program Stairwell kits with sensor were found in-storage and are planned to be installed over time.
073622	Multi-Family	59%	59%	100%	The baseline watts were lower than the assumed watts for stairwell kits with sensors.
078672	Dining: Family	12%	22%	55%	Half (1) of the tracking Stairwell kits with sensors were not received according to the site contact. There are no negative entries for this customer in 2015 (indicating a correction/return) nor does this customer appear in the 2016 program data. Also, the baseline watts were lower than the assumed watts for the installed stairwell kit with sensor.
083312	Office	67%	67%	100%	Thirty-seven percent (7) of the program Stairwell kits with sensor were found to not be installed nor were they in-storage.
084162	Multi-Family	22%	22%	100%	The baseline watts were lower than the assumed watts for stairwell kits with sensors.
098522	Office	80%	80%	100%	About a quarter (61) of the program Stairwell kits with sensors were not found installed nor in-storage.
098582	Other	-3%	-11%	26%	The baseline watts were lower than the assumed watts for stairwell kits with sensors. Half (3) of the program Stairwell kits with sensor were found in-storage and are planned to be installed over time.
105972	Office	31%	42%	75%	Nearly forty percent (195) of the program Stairwell kits with sensor were found in-storage and are planned to be installed over time.
126002	Hospital	106%	106%	100%	The baseline watts were higher than the assumed watts for stairwell kits with sensors.
118662	School/University	60%	60%	100%	Forty-eight percent (1,423) of the program Stairwell kits with sensors were not found installed, (132) were found in-

		Realization Rates			Evaluation
Site ID	Facility Type	Annual kWh (Including HVAC)	Connected kW	Average Hours of Use	Primary Reasons for Discrepancies
					storage and are planned to be installed over time.
124942	Multi-Family	6%	64%	10%	The stairwell kits with sensors were not on 100% of the time.

Category 3, retrofit kits

This section presents the category 3 site-level results.

Table 5-15. Category 3 tracking and evaluation savings estimates

		Tracking			Evaluation								
Site ID	Facility Type	Annual kWh Savings	Connected kW Savings	Average Hours of Use	Annual kWh Savings	kWh HVAC Factor	On-Peak % Annual kWh	Connected kW Savings	Summer kW Coincidence Factor	Summer kW HVAC Factor	Winter kW Coincidence Factor	Winter kW HVAC Factor	Average Hours of Use
000013	Warehouse	5,464	1.4	3,901	0	1.00	0%	0.0	0.00	1.00	0.00	1.00	0
004773	Hotel	235,245	60.3	3,901	7,008	1.05	72%	1.0	0.87	1.14	0.87	1.00	6,498
004873	Dining: Cafeteria/Fast Food	2,837	0.7	3,901	1,329	1.10	93%	0.2	1.00	1.27	1.00	1.00	6,037
009983	Retail	3,925	1.0	3,901	449	1.11	100%	0.2	0.94	1.27	0.89	1.00	2,552
010353	Single-family	3,528	0.9	3,901	165	0.83	60%	0.7	0.01	1.27	0.03	0.63	283
015903	Religious Building	59,403	15.2	3,901	1,706	1.08	95%	0.5	0.63	1.27	0.63	1.00	3,204
016653	Multi-Family	15,861	4.1	3,901	0	1.00	0%	1.1	0.00	1.00	0.00	1.00	0
018923	Hotel	52,999	13.6	3,901	30,324	0.53	89%	17.9	0.35	1.27	0.80	-0.13	3,170
021233	Retail	4,166	1.1	3,901	2,793	1.12	82%	0.6	0.96	1.22	0.95	1.00	4,049
023003	Warehouse	2,696	0.7	3,901	0	1.00	0%	0.0	0.00	1.00	0.00	1.00	0
026833	Dining: Family	9,756	2.5	3,901	1,461	1.00	99%	0.5	1.00	1.00	0.00	1.00	3,075
027053	Retail	9,141	2.3	3,901	6,788	1.11	85%	1.3	0.98	1.27	1.00	1.00	4,738
028133	Hospital	82,583	21.2	3,901	203,395	1.03	67%	22.7	1.00	1.13	1.00	1.00	8,713
030013	Retail	2,049	0.5	3,901	2,203	1.14	100%	0.8	1.00	1.25	0.51	1.00	2,350
037063	Retail	7,226	1.9	3,901	8,999	1.12	100%	2.6	1.00	1.27	0.75	1.00	3,040
037663	School/University		0.3	3,901	0	1.00	0%	0.0	0.00	1.00	0.00	1.00	0

		Tracking			Evaluation								
Site ID	Facility Type	Annual kWh Savings	Connected kW Savings	Average Hours of Use	Annual kWh Savings	kWh HVAC Factor	On-Peak % Annual kWh	Connected kW Savings	Summer kW Coincidence Factor	Summer kW HVAC Factor	Winter kW Coincidence Factor	Winter kW HVAC Factor	Average Hours of Use
		1,269											
045533	Convention Center	31,174	8.0	3,901	9,942	1.10	98%	5.5	0.48	1.27	0.23	1.00	1,645
050623	Library	1,395	0.4	3,901	3,106	1.00	68%	0.4	0.86	1.00	0.79	1.00	7,044
053803	Multi-Family	35,975	9.2	3,901	16,235	1.06	93%	6.7	0.38	1.27	0.50	1.00	2,275
057433	School/University	115,753	29.7	3,901	48,327	1.00	89%	18.3	0.54	1.00	0.26	1.00	2,634
061233	Multifamily	59,573	15.3	3,901	1,102	0.34	85%	2.9	0.33	1.27	0.17	-0.57	1,116
064113	Religious Building	9,559	2.5	3,901	9,462	1.00	100%	3.1	0.79	1.00	0.68	1.00	3,039
064583	Healthcare-Clinic	13,641	3.5	3,901	0	1.00	0%	0.0	0.00	1.00	0.00	1.00	0
066783	Retail	19,425	5.0	3,901	16,423	1.03	99%	6.2	0.77	1.17	0.56	1.00	2,574
069723	Dining: Bar Lounge/Leisure	9,993	2.6	3,901	2,959	1.10	75%	0.6	0.74	1.27	1.00	1.00	4,818
071803	Dining: Cafeteria/Fast Food	7,109	1.8	3,901	11,546	1.03	59%	2.0	0.27	1.27	0.92	1.00	5,665
076193	Dining: Cafeteria/Fast Food	13,950	3.6	3,901	0	1.00	0%	0.0	0.00	1.00	0.00	1.00	0
080053	Automotive Facility	183	0.0	3,901	240	1.00	36%	0.1	0.02	1.00	0.41	1.00	3,994
081983	School/University	4,747	1.2	3,901	455	1.12	100%	0.6	0.20	1.27	0.03	1.00	642
084483	Office	47,584	12.2	3,901	14,937	1.11	100%	3.7	1.00	1.27	1.00	1.00	3,610
089093	Healthcare-Clinic	41,897	10.7	3,901	11,438	1.11	93%	2.9	0.97	1.27	0.90	1.00	3,530
090573	Office	12,062	3.1	3,901	10,479	1.12	95%	2.7	0.93	1.27	0.28	1.00	3,475
096473	Hotel	26,895	6.9	3,901	7,519	0.72	86%	2.9	0.38	1.27	0.83	0.20	3,634

		Tracking			Evaluation								
Site ID	Facility Type	Annual kWh Savings	Connected kW Savings	Average Hours of Use	Annual kWh Savings	kWh HVAC Factor	On-Peak % Annual kWh	Connected kW Savings	Summer kW Coincidence Factor	Summer kW HVAC Factor	Winter kW Coincidence Factor	Winter kW HVAC Factor	Average Hours of Use
097543	Multi-Family	12,246	3.1	3,901	1,799	1.10	87%	1.2	0.88	1.27	0.00	1.00	1,367
098053	Single family	8,799	2.3	3,901	4,768	1.02	87%	1.5	0.32	1.30	0.99	1.00	3,038
098413	Healthcare-Clinic	1,903	0.5	3,901	327	0.68	98%	0.2	0.75	1.27	0.74	0.20	2,157
100453	Hotel	24,113	6.2	3,901	0	1.00	0%	0.0	0.00	1.00	0.00	1.00	0
103163	Court House	21,908	5.6	3,901	40,402	1.31	82%	7.6	0.81	3.42	0.94	1.00	4,053
104663	Office	4,547	1.2	3,901	1,459	0.77	98%	0.7	0.99	1.27	0.68	0.20	2,714
104763	Single family	4,917	1.3	3,901	100	1.01	58%	0.0	0.07	1.30	0.76	1.00	2,797
106243	Retail	4,382	1.1	3,901	2,456	1.09	100%	0.8	1.00	1.27	0.55	1.00	2,784
110703	Healthcare-Clinic	2,522	0.6	3,901	161	1.09	80%	0.1	0.33	1.27	0.27	1.00	1,848
115743	Retail	34,017	8.7	3,901	43,655	1.12	95%	8.9	0.98	1.27	0.94	1.00	4,388
117083	Dining: Bar Lounge/Leisure	23,843	6.1	3,901	6,745	1.04	74%	6.3	0.08	1.25	0.09	1.00	1,018
120923	Retail	30,298	7.8	3,901	1,481	1.13	99%	0.4	0.99	1.27	0.96	1.00	3,492
123303	Office	5,477	1.4	3,901	0	1.00	0%	0.0	0.00	1.00	0.00	1.00	0
124833	School/University	19,224	4.9	3,901	21,001	1.05	97%	9.6	0.63	1.16	0.22	1.00	2,090
130213	School/University	120,307	30.8	3,901	62,947	1.06	74%	20.7	0.51	1.16	0.44	1.00	2,883
132483	Museum	946	0.2	3,901	986	0.92	100%	0.4	1.00	1.27	0.17	0.20	2,842
112443	School/University	319,310	81.9	3,901	167,525	1.00	73%	76.0	0.27	1.00	0.38	1.00	2,204
126003	Hospital	65,856	16.9	3,901	25,658	1.07	95%	5.1	1.00	1.14	0.54	1.00	4,707

Table 5-16. Category 3 realization rates and reasons for discrepancies

		Realization Rates			Evaluation
Site ID	Facility Type	Annual kWh (Including HVAC)	Connected kW	Average Hours of Use	Primary Reasons for Discrepancies
000013	Warehouse	0%	0%	0%	None of the program fixtures were installed at the time of the site visit. Site contact (electrical contractor) mentioned that 3 of the fixtures were installed for demo purposes but those have since been removed. The other fixtures were purchased and sold to a construction company.
004773	Hotel	3%	2%	167%	Several fixtures were not found on-site and were not familiar to the site contact. For the fixtures that were found on-site, (18) PAR38s and (292) PAR30s were in storage and (206) PAR30s were installed. Of the installed PAR30s, the assumed wattage difference (40) was more than the wattage difference (5) found on-site. Also, the assumption for tracking hours of use are (3,901) and the logged average hours of use are (6,498).
004873	Dining: Cafeteria/Fast Food	47%	28%	155%	Site contact stated that (13) of the fixtures were not purchased and are not in storage. (5) fixtures were purchased and installed. The assumption for tracking hours of use are (3,901) and the logged hours of use are (6,037).
009983	Retail	11%	16%	65%	A small quantity of fixtures were installed, several were in-storage or not on-site.
010353	Single-family	5%	78%	7%	The purchased bulbs were installed in a single-family home; the assumption for tracking hours of use are (3,901) and the logged hours of use are (283). About half (7) of the PAR38s were not installed.
015903	Religious Building	3%	3%	82%	Nearly all (96% of tracking amount) fixtures were found to be in storage; the site contact indicated that they planned to install the fixtures in storage over time.
016653	Multi-Family	0%	26%	0%	The only program fixtures found for this site were exterior emergency egress fixtures which are an entirely new system, i.e., no prior system. These fixtures run on an emergency generator circuit only and only turn on when the utility supplied power goes down; operating hours = zero.
018923	Hotel	57%	132%	81%	The baseline wattage was higher than the assumed baseline wattage for all product categories (PAR38s and PAR30s).
021233	Retail	67%	58%	104%	The baseline wattage (15) was lower than the assumed baseline wattage (53) for retrofit kits <25W.

		Realization Rates			Evaluation
Site ID	Facility Type	Annual kWh (Including HVAC)	Connected kW	Average Hours of Use	Primary Reasons for Discrepancies
023003	Warehouse	0%	0%	0%	The site contact stated that they had not purchased the fixtures and instead the program fixtures were purchased by an electrical contractor who has done different work at the facility.
026833	Dining: Family	15%	19%	79%	Site contact indicated having installed some PAR38s but removed and replaced with the original fixtures because they were disappointed in lighting quality/levels; all (10) PAR38s are now in storage at the site contact's house. Similarly, site contact was disappointed in the quality of the PAR30s they received; (10) are installed, some have failed and the rest (<38) serve as replacements and are stored at the site contact's house.
027053	Retail	74%	55%	121%	Fewer (64% of tracking amount) PAR30s were found to be installed; the other PAR30s could not be located and were not in storage. The assumption for tracking hours of use are (3,901) and the logged hours of use are (4,738).
028133	Hospital	246%	107%	223%	The assumption for tracking hours of use are (3,901) and the logged hours of use are (8,713).
030013	Retail	108%	156%	60%	The assumption for tracking hours of use are (3,901) and the logged hours of use are (2,350). The assumed wattage difference (40) was less than the wattage difference (63) found on-site.
037063	Retail	125%	142%	78%	The baseline wattages was higher than the assumed baseline wattage for all product categories (PAR30s, PAR38s, and PAR20s).
037663	School/University	0%	0%	0%	None (8) of the downlights were located and installed; site contact did receive A-lamps, however.
045533	Convention Center	32%	69%	42%	Site contact indicated that PAR38s (32) and PAR20s (11) were purchased and not received from the distributor; also several fixtures are in storage and are planned to be installed over time ((20) PAR38s, (26) PAR30s and (4) PAR20s). Also, the assumption for tracking hours of use are (3,901) and the logged hours of use are (1,645).
050623	Library	223%	123%	181%	The assumption for tracking hours of use are (3,901) and the logged hours of use are (7,044); hallway lights are on 24-7.
053803	Multi-Family	45%	73%	58%	The site contact claims that fewer (132) purchases were made than what was reflected in the tracking data (227). The assumption for tracking hours of use are (3,901) and the logged hours of use are (2,275).
057433	School/University	42%	62%	68%	The baseline wattage was lower than the assumed baseline wattage for PAR30s and retrofit kits <25W. The assumption for tracking hours of use

		Realization Rates			Evaluation
Site ID	Facility Type	Annual kWh (Including HVAC)	Connected kW	Average Hours of Use	Primary Reasons for Discrepancies
					are (3,901) and the logged hours of use are (2,634).
061233	Multifamily	2%	19%	29%	The baseline wattage was lower (20) than the assumed baseline wattage (55) for PAR30s. The assumption for tracking hours of use are (3,901) and the logged hours of use are (1,116).
064113	Religious Building	99%	127%	78%	The baseline wattage was higher than the assumed baseline wattage for both PAR30s and PAR38s. The assumption for tracking hours of use are (3,901) and the logged hours of use are (3,039).
064583	Healthcare-Clinic	0%	0%	0%	(10) retrofit kits <25Ws are in storage and will be installed over time; the owner returned (73) retrofit kits <25Ws and changed to a new lighting product.
066783	Retail	85%	124%	66%	The assumption for tracking hours of use are (3,901) and the logged hours of use are (2,574).
069723	Dining: Bar Lounge/Leisure	30%	22%	124%	The baseline wattage was lower than the assumed baseline wattage for retrofit kits <25W.
071803	Dining: Cafeteria/Fast Food	162%	109%	145%	The assumption for tracking hours of use are (3,901) and the logged hours of use are (5,665).
076193	Dining: Cafeteria/Fast Food	0%	0%	0%	Confirmed that the program bulbs were not present in the building or in storage.
080053	Automotive Facility	131%	128%	102%	The baseline wattage was higher (75) than the assumed baseline wattage (61) for PAR38s.
081983	School/University	10%	52%	16%	Over half (15) of the program bulbs were claimed by the site contact to have not been purchased. Also, the assumption hours of use are (3,901) and the logged hours of use are (642) for PAR38s.
084483	Office	31%	31%	93%	The assumed wattage difference (41) was more than the wattage difference (13) found on-site. Nearly 80% of the program fixtures were found to be in storage and are planned to be installed over time.
089093	Healthcare-Clinic	27%	27%	90%	Nearly half (108 PAR30s, 36 PAR20s and 1 MR16) of the program bulbs were found to be in storage.
090573	Office	87%	87%	89%	Several (21) PAR38s were found to be in storage. Also, the assumption hours of use are (3,901) and the logged average hours of use are (3,475).
096473	Hotel	28%	41%	93%	The assumed wattage difference (41) was more than the wattage

		Realization Rates			Evaluation
Site ID	Facility Type	Annual kWh (Including HVAC)	Connected kW	Average Hours of Use	Primary Reasons for Discrepancies
					difference (14) found on-site for PAR38s.
097543	Multi-Family	15%	38%	35%	Several program fixtures (48) were unaccounted for (i.e., not installed, not in storage and site contact could not account for them). The assumption for tracking hours of use are (3,901) and the logged hours of use are (1,367). The assumed wattage difference (40) was less than the wattage difference (50) found on-site for PAR30s.
098053	Single family	54%	68%	78%	The assumed wattage difference (41) was more than the wattage difference (14) found on-site for LED Retrofit kits <25W. The assumption for tracking hours of use are (3,901) and the logged hours of use are (3,038).
098413	Healthcare-Clinic	17%	46%	55%	The assumed wattage difference (41) was more than the wattage difference (21 and 8) found on-site.
100453	Hotel	0%	0%	0%	All program bulbs were found in storage or were not accounted for; none were found to be installed.
103163	Court House	184%	136%	104%	The assumed wattage difference (47) was more than the wattage difference (72) found on-site for PAR38s.
104663	Office	32%	60%	70%	Over half (9 MR16s, 8 PAR30s and 4 PAR38s) were in storage and planned to be installed over time.
104763	Single family	2%	3%	72%	Site contact indicated that most (26) fixtures were returned after renovation plans fell through.
106243	Retail	56%	72%	71%	Several (10) fixtures were in storage and planned to be installed over time.
110703	Healthcare-Clinic	6%	12%	47%	The assumed wattage difference (40) was more than the wattage difference (5) found on-site for PAR30s.
115743	Retail	128%	102%	112%	The assumption for tracking hours of use are (3,901) and the logged hours of use are (4,388). The assumed wattage difference (47) was less than the wattage difference (55) found on-site for PAR38s.
117083	Dining: Bar Lounge/Leisure	28%	104%	26%	The assumption for tracking hours of use are (3,901) and the logged hours of use are (1,018).
120923	Retail	5%	5%	90%	The assumed wattage difference (40 and 41) was higher than the wattage difference (1 and 7) found on site for LED Retrofit kit, <25W and PAR30s, respectively.
123303	Office	0%	0%	0%	None of the program fixtures are installed. The program fixtures were purchased and installed in a space leased by the participant. The space has recently been vacated and is not used anymore; the program fixtures

		Realization Rates			Evaluation
Site ID	Facility Type	Annual kWh (Including HVAC)	Connected kW	Average Hours of Use	Primary Reasons for Discrepancies
					have been removed.
124833	School/University	109%	194%	54%	The assumption for tracking hours of use are (3,901) and the logged hours of use are (2,090). The assumed wattage difference (23, 47 and 40) was lower than the wattage difference (43, 62 and 65) found on-site for MR16s, PAR38s, and PAR30s.
130213	School/University	52%	67%	74%	Just over one third (199 PAR38s and 20 PAR30s) were found to be in storage and are planned to be installed over time. The assumption for tracking hours of use are (3,901) and the logged hours of use are (2,833).
132483	Museum	104%	156%	73%	The assumed wattage difference (40) was less than the wattage difference (63) found on-site for PAR30s.
112443	School/University	52%	93%	56%	The assumption for tracking hours of use are (3,901) and the logged hours of use are (2,204).
126003	Hospital	39%	30%	121%	The assumed wattage difference was higher than the wattage difference found on-site for PAR38s, PAR30s and PAR20s; each of the program LED products were replacing relatively low wattage CFLs.

Category 4, A-lines and decoratives

This section presents the category 4 site-level results.

Table 5-17. Category 4 tracking and evaluation savings estimates

		Tracking			Evaluation								
Site ID	Facility Type	Annual kWh Savings	Connected kW Savings	Average Hours of Use	Annual kWh Savings	kWh HVAC Factor	On-Peak % Annual kWh	Connected kW Savings	Summer kW Coincidence Factor	Summer kW HVAC Factor	Winter kW Coincidence Factor	Winter kW HVAC Factor	Average Hours of Use
018924	Hotel	193,236	49.5	3,901	130,268	0.48	84%	71.2	0.43	1.27	0.81	-0.20	3,791
057434	School/		23.6	3,901		1.00	91%	22.5	0.55	1.00	0.25	1.00	2,590

		Tracking			Evaluation								
Site ID	Facility Type	Annual kWh Savings	Connected kW Savings	Average Hours of Use	Annual kWh Savings	kWh HVAC Factor	On-Peak % Annual kWh	Connected kW Savings	Summer kW Coincidence Factor	Summer kW HVAC Factor	Winter kW Coincidence Factor	Winter kW HVAC Factor	Average Hours of Use
	University	92,096			58,243								
081984	School/ University	6,279	1.6	3,901	455	1.12	100%	0.6	0.20	1.27	0.03	1.00	642
098054	Single family	1,308	0.3	3,901	1,378	1.02	87%	0.5	0.29	1.30	0.90	1.00	2,759
123304	Office	1,177	0.3	3,901	-	1.00	0%	0.0	0.00	1.00	0.00	1.00	0
130214	School/ University	235,473	60.4	3,901	227,513	1.06	81%	65.8	0.52	1.16	0.51	1.00	3,270
025494	Library	1,047	0.3	3,901	1,061	1.04	81%	0.3	0.74	1.27	0.74	1.00	2,979
037304	School/ University	6,279	1.6	3,901	1,378	1.00	83%	1.5	0.14	1.00	0.08	1.00	906
046804	Hospital	4,709	1.2	3,901	5,066	1.01	58%	1.0	0.61	1.09	0.43	1.00	5,198
094634	Religious Building	657	0.2	3,901	224	1.04	100%	0.3	0.03	1.27	0.10	1.00	772
129474	Other	4,709	1.2	3,901	210	1.02	81%	0.1	0.37	1.16	0.24	1.00	1,781
131964	Religious Building	3,532	0.9	3,901	389	1.03	100%	1.1	0.12	1.17	0.08	1.00	340
000204	Hotel	198,140	50.8	3,901	43,450	1.00	74%	22.0	0.26	1.27	0.23	1.00	1,973
001354	Retail	73,258	18.8	3,901	55,615	1.00	95%	12.8	0.99	1.27	0.99	1.00	4,336
017414	Dining: Family	8,503	2.2	3,901	3,175	1.00	67%	0.7	0.34	1.27	0.67	1.00	4,302
023764	Healthcare-Clinic	166,963	42.8	3,901	68,944	1.00	81%	17.3	0.60	1.28	0.59	1.00	3,985
026294	School/ University	17,007	4.4	3,901	1,554	1.00	73%	0.4	0.59	1.00	0.45	1.00	4,048
026324	Hotel	89,094	22.8	3,901	30,650	1.00	71%	11.2	0.30	1.27	0.33	0.20	2,732
027234	Religious Building	39,246	10.1	3,901	3,144	1.00	84%	2.3	0.13	1.27	0.11	1.00	1,356
034964	Religious Building	13,082	3.4	3,901	5,435	1.00	84%	3.5	0.20	1.00	0.13	1.00	1,562
053864	School/ University	27,472	7.0	3,901	4,860	1.00	74%	2.9	0.18	1.14	0.17	1.00	1,672

		Tracking			Evaluation								
Site ID	Facility Type	Annual kWh Savings	Connected kW Savings	Average Hours of Use	Annual kWh Savings	kWh HVAC Factor	On-Peak % Annual kWh	Connected kW Savings	Summer kW Coincidence Factor	Summer kW HVAC Factor	Winter kW Coincidence Factor	Winter kW HVAC Factor	Average Hours of Use
112444	School/ University	317,165	81.3	3,901	41,201	1.00	66%	21.8	0.12	1.00	0.44	1.00	1,894
118994	Hotel	270,827	69.4	3,901	25,671	1.00	70%	11.2	0.24	1.17	0.28	1.00	2,292
055174	Hotel	186,225	47.7	3,901	45,426	1.00	77%	24.7	0.26	1.27	0.25	1.00	1,835
126424	Hotel	261,637	67.1	3,901	6,020	1.00	68%	4.2	0.15	1.27	0.20	0.20	1,433
012764	Hotel	915,992	234.8	3,901	46,739	1.07	77%	42.0	0.14	1.14	0.08	1.00	1,038
006534	Office	82,541	21.2	3,901	48,889	1.09	83%	16.6	0.55	1.17	0.55	1.00	2,719
078274	Retail	1,570	0.4	3,901	1,558	1.04	100%	0.6	0.88	1.17	0.54	1.00	2,555
132984	Office	26,164	6.7	3,901	662	1.00	6%	9.6	0.00	1.00	0.00	0.00	69
113484	Other	12,973	3.3	3,901	18	1.00	63%	0.2	0.01	1.00	0.02	1.00	111
031674	Hospital	45,902	11.8	3,901	4,846	1.01	68%	0.7	0.85	1.06	0.85	1.00	7,095
096934	Other	785	0.2	3,901	-	1.00	0%	0.0	1.00	1.00	1.00	1.00	-512
115844	Other	30,219	7.7	3,901	3,954	1.00	40%	0.8	0.03	1.00	0.86	1.00	4,857
121804	Retail	23,732	6.1	3,901	4,990	1.00	100%	2.5	0.82	1.27	0.47	1.00	1,984
128314	Dormitory	97,067	24.9	3,901	8,867	1.00	84%	5.9	0.21	1.30	0.16	1.00	1,494
007254	Other	9,419	2.4	3,901	-	0.00	0%	0.0	0.00	1.00	0.00	1.00	0
062134	Retail	48,453	12.4	3,901	5,259	1.09	98%	1.8	0.96	1.27	0.45	1.00	2,670
094924	Museum	302,714	77.6	3,901	47,676	1.00	90%	10.6	0.90	1.00	0.81	1.00	4,516
065794	Retail	6,283	1.6	3,901	424	1.00	100%	0.1	0.96	1.27	0.92	1.00	3,283
061964	Hotel	110,262	28.3	3,901	4,668	1.09	84%	4.2	0.13	1.27	0.11	0.20	1,024
017984	Dormitory		6.6	3,901		1.00	66%	1.1	0.97	1.00	0.97	1.00	8,639

		Tracking			Evaluation								
Site ID	Facility Type	Annual kWh Savings	Connected kW Savings	Average Hours of Use	Annual kWh Savings	kWh HVAC Factor	On-Peak % Annual kWh	Connected kW Savings	Summer kW Coincidence Factor	Summer kW HVAC Factor	Winter kW Coincidence Factor	Winter kW HVAC Factor	Average Hours of Use
		25,926			9,200								
080224	Hotel	252,741	64.8	3,901	232,546	1.09	67%	29.1	0.85	1.17	0.83	1.00	7,346
122444	Multi-Family	7,326	1.9	3,901	3,781	1.00	67%	0.4	0.96	1.00	0.96	1.00	8,440
122784	Hotel	71,165	18.2	3,901	1,346	1.11	78%	1.7	0.07	1.27	0.09	0.20	704
095724	Hotel	308,059	79.0	3,901	181,830	1.00	67%	23.6	0.90	1.17	0.90	1.00	7,697
011324	Retail	45,786	11.7	3,901	4,165	1.09	100%	1.3	0.96	1.27	0.02	1.00	2,831
092254	Motel	181,445	46.5	3,901	26,005	1.09	82%	11.1	0.27	1.27	0.27	0.20	2,144
096794	Religious Building	12,277	3.1	3,901	13,844	1.11	99%	5.2	0.40	1.27	0.12	1.00	2,375
004124	Hotel	87,910	22.5	3,901	20,519	1.11	79%	11.4	0.14	1.27	0.17	0.20	1,612
007764	Hotel	55,878	14.3	3,901	26,577	1.07	91%	9.5	0.49	1.18	0.37	-1.24	2,602
018784	Religious Building	3,675	0.9	3,901	274	1.09	99%	1.0	0.01	1.27	0.00	1.00	253
094094	Religious Building	20,669	5.3	3,901	1,334	1.09	86%	0.7	0.13	1.27	0.14	1.00	1,866

Table 5-18. Category 4 realization rates and reasons for discrepancies

		Realization Rates			Evaluation
Site ID	Facility Type	Annual kWh (Including HVAC)	Connected kW	Average Hours of Use	Primary Reasons for Discrepancies
018924	Hotel	67%	144%	97%	HVAC interaction included (electric heating penalty). The baseline wattage was higher than the assumed baseline wattage for A-lines (40/60w) and decoratives.

		Realization Rates			Evaluation
Site ID	Facility Type	Annual kWh (Including HVAC)	Connected kW	Average Hours of Use	Primary Reasons for Discrepancies
057434	School/University	63%	95%	66%	The assumption for tracking hours of use are (3,901) and the logged hours of use are (2,590).
081984	School/University	7%	40%	16%	Fewer (21% of tracking amount) A-lines, 40/60w were found to be installed; the other A-lines, 40/60w could not be located and were not in-storage.
098054	Single family	105%	146%	71%	The baseline wattage was higher (60) than the assumed baseline wattage (45) for A-lines, 40/60w. The assumption for tracking hours of use are (3,901) and the logged hours of use are (2,759).
123304	Office	0%	0%	0%	None of the program lamps are installed; the program lamps were purchased and installed in a space leased by the participant. The space has recently been vacated and is not used anymore; the program lamps have been removed.
130214	School/University	97%	109%	84%	The assumption for tracking hours of use are (3,901) and the logged hours of use are (3,270). The assumed wattage difference (34) was lower than the wattage difference (49) found on-site for A-lines, 40/60w.
025494	Library	101%	128%	76%	The assumption for tracking hours of use are (3,901) and the logged hours of use are (2,979). The assumed wattage difference (34) was lower than the wattage difference (49) found on site for A-lines, 40/60w.
037304	School/University	22%	94%	23%	The assumption for tracking hours of use are (3,901) and the logged hours of use are (906). Under half (20 A-lines, 40/60w) were found to be installed, (14 A-lines, 40/60w) were in-storage and (14 A-lines, 40/60w) were reported by the site contact to have likely been disposed of during building demolition (school building project in 2016).
046804	Hospital	108%	80%	133%	Nearly half (16 A-lines, 40/60w) were not installed; (11) were in-storage and are planned to be installed over time, (4) were reported by the contact to be disposed of because they were defective and (1) could not be located and was not thought to be disposed of by the site contact. This customer appears in the 2016 program data but there are no associated A-line, 40/60w purchases or negative entries to reflect a return of

		Realization Rates			Evaluation
Site ID	Facility Type	Annual kWh (Including HVAC)	Connected kW	Average Hours of Use	Primary Reasons for Discrepancies
					defective products.
094634	Religious Building	34%	166%	20%	The assumption for tracking hours of use are (3,901) and the logged hours of use are (772).
129474	Other	4%	10%	46%	The assumed wattage difference (34) was higher than the wattage difference (4) found on-site for A-lines, 40/60w. (29 A-line, 40/60w) were installed, (6 A-line, 40/60w) were in-storage and are planned to be installed over time; (1 A-line, 40/60w) was reported by the site contact to be discarded due to defect; the 2016 program data does not include this customer (i.e., does not reflect a return of a defective product).
131964	Religious Building	11%	123%	9%	The assumption for tracking hours of use are (3,901) and the logged hours of use are (340).
000204	Hotel	22%	43%	51%	The assumed wattage difference (34) was higher than the wattage difference (18) found on site for A-lines, 40/60w. The assumption tracking hours of use are (3,901) and the logged hours of use are (1,973). Twenty percent (306 A-lines, 40/60w and 4 Decoratives) were not installed, most of which (301 A-lines, 40/60w) were reported to be thrown out due to malfunction or burnout; (5 A-lines, 40/60w) and (2 Deocoratives) were found in-storage and (2 Decoratives) were thrown out after dropping. This customer appears in the 2016 program data but there are no negative entries to reflect a return of defective products; there are purchases listed for: G24s, TLEDs (4ft), A-lines (75/100w), A-lines (40/60w), and MR16s.
001354	Retail	76%	68%	111%	Over half (318 A-line, 40/60w) were not found to be installed at the store location; according to site contact it's possible that missing purchases went to possible went to other store location(s) (over 15 different locations in Southern New England (MA and RI).

		Realization Rates			Evaluation
Site ID	Facility Type	Annual kWh (Including HVAC)	Connected kW	Average Hours of Use	Primary Reasons for Discrepancies
017414	Dining: Family	37%	34%	110%	Site contact reported throwing out (24 A-lines, 40/60w) due to dimming issues; the 2016 program data does not include this customer (i.e., does not reflect a return of product). The assumed wattage difference (34) was higher than the wattage difference (18) found on site for A-lines, 40/60w.
023764	Healthcare-Clinic	41%	40%	102%	The assumed wattage difference was higher than the wattage difference found on-site for A-lines, 40/60w and decoratives. Nearly 20 percent of the purchased products were found to not be installed: (118 A-lines, 40/60w) were in-storage and are planned to be installed, (5 A-lines, 40/60w) were reported by the site contact to be disposed of, and (136 A-lines, 40/60w) could not be located and were not in-storage. This customer appears in the 2016 program data but there are no negative entries to reflect a return, in 2016 this customer purchased (60 A-lines 40/60w) and (6 Decoratives) in November 2016.
026294	School/University	9%	9%	104%	The assumed wattage difference (47) was higher than the wattage difference found on-site (4) for A-lines, 75/100w.
026324	Hotel	34%	49%	70%	The assumed wattage difference (34) was higher than the wattage difference found on-site (15) for A-lines, 40/60w. The assumption for tracking hours of use are (3,901) and the logged hours of use are (2,732).
027234	Religious Building	8%	23%	35%	Over half (178 A-line, 40/60w) were found not to be installed at the church location; (60 A-line, 40/60w) were in-storage to be installed over time and (118 A-line, 40/60w) could not be located, the site contact (pastor) referred the auditor to the electrician who probably would know more. This customer appears in the 2016 program data but there are no negative entries indicating product returns, instead a positive entry of (36 A-lines, 40/60w) is shown for a May 2016 purchase.
034964	Religious Building	42%	104%	40%	The assumption for tracking hours of use are (3,901) and the logged hours of use are (1,562).
053864	School/University	18%	41%	43%	The assumed wattage difference (34) was higher than the wattage difference found on-site (19) for A-lines, 40/60w. Just over a quarter (57 A-lines, 40/60w) were not found to be installed nor in-storage across the three schools. The

		Realization Rates			Evaluation
Site ID	Facility Type	Annual kWh (Including HVAC)	Connected kW	Average Hours of Use	Primary Reasons for Discrepancies
					assumption for tracking hours of use are (3,901) and the logged hours of use are (1,672).
112444	School/University	13%	27%	49%	(216 Decoratives) were found to be in-storage and are planned to be installed over time. The assumed wattage difference (34) was higher than the wattage difference found on-site (9) for A-lines, 40/60w. The assumed wattage difference (47) was higher than the wattage difference found on-site (16) for A-lines, 75/100w. The assumption for tracking hours of use are (3,901) and the logged hours of use are (1,894).
118994	Hotel	9%	16%	59%	The assumed wattage difference (47) was higher than the wattage difference found on-site (15) for A-lines, 75/100w. The assumed wattage difference (34) was higher than the wattage difference found on-site (5) for A-lines, 40/60w. About 40 percent were not installed, (480 A-lines) were found to be in-storage and are planned to be installed and (211 A-lines, 40/60w) were reported to be thrown out, site contact thinks they overheated in 24/7 hallway canisters. (12 A-lines, 40/60w) were not found to be installed nor in-storage; the site contact was unsure of their location. This customer appears in the 2016 program data but there are no negative entries indicating product returns, instead a positive entry of (332 G24s) is shown for a February 2016 purchase.
055174	Hotel	24%	52%	47%	The assumed wattage difference (34) was higher than the wattage difference found on-site (18) for A-lines, 40/60w. The assumption for tracking hours of use are (3,901) and the logged hours of use are (1,835).
126424	Hotel	2%	6%	37%	Over half (1,160 A-lines, 40/60w) were found to be in-storage and are planned to be installed over time. (540 A-lines, 40/60w) were not found to be installed nor in-storage; the site contact was unsure of their location. This customer location does not appear in the 2016 program tracking data; but other locations do appear, none have a negative sales entry.
012764	Hotel	5%	18%	27%	The assumed wattage difference (34) was higher than the wattage difference found on-site (6) for A-lines, 40/60w. The

		Realization Rates			Evaluation
Site ID	Facility Type	Annual kWh (Including HVAC)	Connected kW	Average Hours of Use	Primary Reasons for Discrepancies
					assumption for tracking hours of use are (3,901) and the logged hours of use are (1,038).
006534	Office	59%	78%	70%	One third (186 A-lines) were found in-storage and are planned to be installed once old bulbs burnout. The assumption for tracking hours of use are (3,901) and the logged hours of use are (2,719).
078274	Retail	99%	146%	66%	The assumption for tracking hours of use are (3,901) and the logged hours of use are (2,555). The assumed wattage difference (34) was lower than the wattage difference found on-site (49) for A-lines, 40/60w.
132984	Office	3%	143%	2%	The assumption for tracking hours of use are (3,901) and the logged hours of use are (69).
113484	Other	0%	5%	3%	Almost all (50 A-lines, 40/60w and 33 A-line, 75/100w) were reported by the site contact to not be installed in the project location, the contact indicated it's likely that the missing bulbs were installed in their RI location. The assumption for tracking hours of use are (3,901) and the logged hours of use are (111).
031674	Hospital	11%	6%	182%	Over half (115 A-line, 75/100w and 42 A-line, 40/60w) were found in-storage and are planned to be installed over time.
096934	Other	0%	0%	-13%	All (6 A-lines, 40/60w) were installed in a bread/pizza oven and were thrown out after dying; site contact was not aware that the lamps are not designed to be installed such a hot environment.
115844	Other	13%	11%	125%	The assumed wattage difference (34) was higher than the wattage difference found on-site (5) for A-lines, 40/60w. (63 A-lines, 40/60w) were found in-storage and are planned to be installed over time.
121804	Retail	21%	41%	51%	The assumed wattage difference (34 and 21) was higher than the wattage difference found on-site (15 and 4) for A-lines, 40/60w and Decoratives, respectively. The assumption for tracking hours of use are (3,901) and the logged hours of use are (1,984).
128314	Dormitory	9%	24%	38%	The assumed wattage difference (34) was higher than the wattage difference found on-site (8) for A-lines, 40/60w. The

		Realization Rates			Evaluation
Site ID	Facility Type	Annual kWh (Including HVAC)	Connected kW	Average Hours of Use	Primary Reasons for Discrepancies
					assumption for tracking hours of use are (3,901) and the logged hours of use are (1,494).
007254	Other	0%	0%	0%	None (72 A-line, 40/60w) were found on-site nor were they located in-storage. Site contact does not think that they would have been ordered by condo residents and did not know about the purchases (3 batches of 24 A-lines). This customer with a different address appears in the 2016 program data but there are no negative entries indicating product returns or corrections, instead a couple of positive entries of (2 A-lines, 40/60w and 10 PAR38s) is shown for a February 2016 purchase.
062134	Retail	11%	15%	68%	Just over half (132 A-lines, 40/60w and 88 Decoratives) were reported by the site contact to have burned out or were sold with table lamps they sell in the store (this retailer is a furniture store). Site contact stated that burnout was happening in enclosed fixtures and he started to remove the lens to help prevent overheating. The assumed wattage difference (34) was higher than the wattage difference found on-site (4) for A-lines, 40/60w.
094924	Museum	16%	14%	116%	The assumed wattage difference (34) was higher than the wattage difference found on-site (8) for A-lines, 40/60w. Over a third (797 A-lines, 40/60w) were found in-storage and are planned to be installed; 40 A-line, 40/60w were reported by the site contact to have burned out.
065794	Retail	7%	8%	84%	The assumed wattage difference (34) was higher than the wattage difference found on-site (3) for A-lines, 40/60w.
061964	Hotel	4%	15%	26%	The assumed wattage difference (47) was higher than the wattage difference found on-site (7) for A-lines, 75/100w. The assumption for tracking hours of use are (3,901) and the logged hours of use are (1,024).
017984	Dormitory	35%	16%	221%	The assumed wattage difference (47, 34, and 21) was higher than the wattage difference found on-site (8, 9 and 4) for A-lines 75/100w, A-lines 40/60w and Decoratives, respectively. The assumption for tracking hours of use are (3,901) and the logged hours of use are (8,639).

		Realization Rates			Evaluation
Site ID	Facility Type	Annual kWh (Including HVAC)	Connected kW	Average Hours of Use	Primary Reasons for Discrepancies
080224	Hotel	92%	45%	188%	The assumed wattage difference (34) was higher than the wattage difference found on-site (19) for A-lines, 40/60w. The assumption for tracking hours of use are (3,901) and the logged hours of use are (7,346).
122444	Multi-Family	52%	24%	216%	The assumed wattage difference (34) was higher than the wattage difference found on-site (8) for A-lines, 40/60w. The assumption for tracking hours of use are (3,901) and the logged hours of use are (8,440).
122784	Hotel	2%	9%	18%	Over 90 percent (500 A-lines, 40/60w) were found in-storage and are reported by the site contact to be installed over time. The assumption for tracking hours of use are (3,901) and the logged hours of use are (704).
095724	Hotel	59%	30%	197%	(931 A-lines, 40/60w) were not found to be installed nor in-storage; the site contact was unsure of their location. This customer appears in the 2016 program data but there are no negative entries indicating product returns, instead positive entries are shown for purchases made in each quarter of 2016. (54 Decoratives) were found to be in storage and are planned to installed over time.
011324	Retail	9%	11%	73%	The assumed wattage difference (34) was higher than the wattage difference found on-site (4) for A-lines, 40/60w.
092254	Motel	14%	24%	55%	The assumed wattage difference (34) was higher than the wattage difference found on-site (10) for A-lines, 40/60w. About 20 percent (297 A-lines, 40/60w) were not found to be installed nor in-storage; the site contact was unsure of their location. This customer does not appear in the 2016 program data.
096794	Religious Building	113%	166%	61%	The assumed wattage difference (34 and 21) was lower than the wattage difference found on-site (82 and 55) for A-lines, 40/60w and Decoratives, respectively.
004124	Hotel	23%	51%	41%	The assumed wattage difference (34) was higher than the wattage difference found on-site (17) for A-lines, 40/60w. The assumption for tracking hours of use are (3,901) and the logged hours of use are (1,612).

		Realization Rates			Evaluation
Site ID	Facility Type	Annual kWh (Including HVAC)	Connected kW	Average Hours of Use	Primary Reasons for Discrepancies
007764	Hotel	48%	67%	67%	The assumed wattage difference (34) was higher than the wattage difference found on-site (4) for A-lines, 40/60w. The assumption for tracking hours of use are (3,901) and the logged hours of use are (2,602).
018784	Religious Building	7%	105%	6%	The assumption for tracking hours of use are (3,901) and the logged hours of use are (253).
094094	Religious Building	6%	12%	48%	The assumed wattage difference (34) was higher than the wattage difference found on-site (4) for A-lines, 40/60w. The assumption for tracking hours of use are (3,901) and the logged hours of use are (1,866).

Category 5, G24s

This section presents the category 5 site-level results.

Table 5-19. Category 5 tracking and evaluation savings estimates

		Tracking			Evaluation								
Site ID	Facility Type	Annual kWh Savings	Connected kW Savings	Average Hours of Use	Annual kWh Savings	kWh HVAC Factor	On-Peak % Annual kWh	Connected kW Savings	Summer kW Coincidence Factor	Summer kW HVAC Factor	Winter kW Coincidence Factor	Winter kW HVAC Factor	Average Hours of Use
017325	School/ University	775,904	198.9	3,901	1,962,146	1.00	67%	241.2	0.97	1.00	0.96	1.00	8,133
046535	Office	175,204	44.9	3,901	189,131	1.00	72%	36.2	0.71	1.14	0.71	1.00	5,220
068115	School/ University	300,350	77.0	3,901	70,080	1.00	68%	9.1	0.88	1.03	0.93	1.00	7,703
002005	Library	8,510	2.2	3,901	4,635	1.03	87%	1.2	0.89	1.19	0.76	1.00	3,846

		Tracking			Evaluation								
Site ID	Facility Type	Annual kWh Savings	Connected kW Savings	Average Hours of Use	Annual kWh Savings	kWh HVAC Factor	On-Peak % Annual kWh	Connected kW Savings	Summer kW Coincidence Factor	Summer kW HVAC Factor	Winter kW Coincidence Factor	Winter kW HVAC Factor	Average Hours of Use
002625	Office	10,512	2.7	3,901	22,232	1.09	68%	3.4	0.76	1.17	0.75	1.00	6,005
004745	Dormitory	84,849	21.8	3,901	33,908	1.00	68%	21.1	0.23	1.00	0.25	1.00	1,606
015945	Hospital	133,305	34.2	3,901	6,116	1.01	71%	0.9	0.99	1.14	0.91	1.00	6,623
018465	School/ University	61,271	15.7	3,901	47,329	1.00	70%	8.1	0.80	1.13	0.74	1.00	5,877
020365	School/ University	19,122	4.9	3,901	4,480	1.00	78%	1.5	0.49	1.17	0.47	1.00	2,899
023015	Office	114,834	29.4	3,901	140,791	1.02	76%	22.8	0.95	1.14	0.93	1.00	6,062
034995	School/ University	40,047	10.3	3,901	17,490	1.04	96%	7.0	0.72	1.14	0.55	1.00	2,402
035955	Office	245,286	62.9	3,901	474,853	1.01	70%	68.6	0.90	1.17	0.90	1.00	6,850
039405	School/ University	47,155	12.1	3,901	23,193	1.02	68%	2.8	0.95	1.17	0.95	1.00	8,026
045195	Office	52,461	13.4	3,901	47,674	1.00	74%	9.6	0.73	1.02	0.70	1.00	4,942
046285	Office	22,376	5.7	3,901	36,025	1.01	78%	6.0	0.98	1.14	0.98	1.00	5,932
056875	Office	10,012	2.6	3,901	16,896	1.00	72%	2.5	0.94	1.17	0.93	1.00	6,860
066005	Hotel	53,963	13.8	3,901	16,513	1.00	67%	1.9	0.99	1.00	0.99	1.00	8,700
074665	Hospital	1,702	0.4	3,901	1,061	1.00	84%	0.3	0.95	1.17	0.75	1.00	4,079
075245	School/ University	2,503	0.6	3,901	474	1.00	95%	0.2	0.80	1.27	0.66	1.00	3,161
082515	Hotel	184,815	47.4	3,901	342,345	1.07	68%	50.0	0.74	1.17	0.74	1.00	6,388
085345	Multi-Family		1.0	3,901		1.00	69%	0.8	0.58	1.00	0.67	1.00	5,107

		Tracking			Evaluation								
Site ID	Facility Type	Annual kWh Savings	Connected kW Savings	Average Hours of Use	Annual kWh Savings	kWh HVAC Factor	On-Peak % Annual kWh	Connected kW Savings	Summer kW Coincidence Factor	Summer kW HVAC Factor	Winter kW Coincidence Factor	Winter kW HVAC Factor	Average Hours of Use
		3,905			3,983								
094755	Manufacturing Facility	47,555	12.2	3,901	15,954	1.03	71%	2.2	0.94	1.17	0.87	1.00	6,985
096545	Office	160,187	41.1	3,901	38,282	1.01	86%	8.1	0.98	1.17	0.97	1.00	4,649
098535	Office	15,017	3.8	3,901	27,843	1.02	71%	4.5	0.86	1.14	0.84	1.00	6,025
119745	School/ University	23,027	5.9	3,901	40,826	1.03	67%	5.3	0.95	1.17	0.91	1.00	7,521
120295	School/ University	215,251	55.2	3,901	34,783	1.02	69%	5.4	0.74	1.14	0.80	1.00	6,292
021595	School/ University	23,227	6.0	3,901	37,118	1.01	92%	10.0	0.56	1.14	0.73	1.00	3,680
022915	School/ University	20,424	5.2	3,901	40,999	1.00	98%	10.7	0.90	1.17	0.90	1.00	3,826
085475	Convention Center	175,204	44.9	3,901	327,550	1.00	81%	56.8	0.82	1.00	0.82	1.00	5,766
126005	Hospital	611,913	156.9	3,901	21,071	1.07	74%	2.7	0.99	1.14	0.86	1.00	7,265
125955	Hotel	96,362	24.7	3,901	217,230	1.08	69%	25.4	0.96	1.14	0.95	1.00	7,871

Table 5-20. Category 5 realization rates and reasons for discrepancies

		Realization Rates			Evaluation
Site ID	Facility Type	Annual kWh (Including HVAC)	Connected kW	Average Hours of Use	Primary Reasons for Discrepancies
017325	School/University	253%	121%	208%	The assumption for tracking hours of use are (3,901) and the logged hours of use are (8,133). The assumed wattage difference (13) was lower than the wattage difference found

		Realization Rates			Evaluation
Site ID	Facility Type	Annual kWh (Including HVAC)	Connected kW	Average Hours of Use	Primary Reasons for Discrepancies
					on-site (41) for G24s.
046535	Office	108%	81%	134%	The assumption for tracking hours of use are (3,901) and the logged hours of use are (5,220). (912 G24s) were found in-storage and between (200 and 300 G24s) were reported to be burned out due to ballast compatibility issues. This customer reported working with Eversource on the issue to replace the G24s with later generation models. This customer appears in the 2016 data however there are no negative entries indicating product returns or corrections, instead positive entries indicating purchases of TLEDs, Stairwell kits with sensors, T8s and Retrofit kits appear for purchases made in Q1, Q2, Q3 and Q4 of 2016.
068115	School/University	23%	12%	197%	Most (just under 90 percent) of the program tracking G24s were found to not be installed, they were in-storage (3,708 G24s), reported to have burned out (351 G24s) or were missing (1,272) and likely being swapped out for a different type of G24s. This customer appears in the 2016 program data but there are no negative entries indicating product returns, instead positive entries are shown for other product types (PAR30s. TLEDs, and LED troffers) for purchases made in Q1, Q2 and Q4 of 2016.
002005	Library	54%	54%	99%	Just over half of the program tracking G24s (90) were found to be in-storage are planned to be installed over time. The site contact reported disposing of (7 G24s). This customer appears in the 2016 data however there are no negative entries indicating product returns or corrections, instead positive entries indicating purchases of TLEDs appear for purchases made in Q4 of 2016.
002625	Office	211%	127%	154%	The assumption for tracking hours of use are (3,901) and the logged hours of use are (6,005).
004745	Dormitory	40%	97%	41%	The assumption for tracking hours of use are (3,901) and the logged hours of use are (1,606).

		Realization Rates			Evaluation
Site ID	Facility Type	Annual kWh (Including HVAC)	Connected kW	Average Hours of Use	Primary Reasons for Discrepancies
015945	Hospital	5%	3%	170%	Almost all (2,606 G24s) were found in-storage and according to the site contact were not planned to be installed. This customer appears in the 2016 program data but there are no negative entries indicating product returns, instead positive entries are shown for purchases made in Q1, Q2 and Q3 for G24s, A-lines, stairwell kits, TLEDs, PAR20s, and Troffers.
018465	School/University	77%	51%	151%	About 65 percent of program tracking G24s were found to not be installed (214 G24s) were found to be in-storage and (585 G24s) were reported by the site contact to be thrown out due to flickering issues. This customer appears in the 2016 data however there are no negative entries indicating product returns or corrections, instead positive entries indicating purchases of PAR20s, A-lines, Retrofit kits, MR16s, T8s and Troffers appear for purchases made in Q1, Q3 and Q4 of 2016.
020365	School/University	23%	32%	74%	Just over three quarters of program tracking G24s were found to not be installed (295 G4s); of those (6) were found in-storage and are not planned to be installed and the rest were reported to be discarded due to product flickering issues. This customer appears in the 2016 program tracking data however the only negative sales entries (indicating a return) were for PAR38s.
023015	Office	123%	77%	155%	About half of program tracking G24s were found to not be installed (1,096 G24s); of those (600 G24s) were found in-storage and the rest were missing or reported to be disposed of due to product flickering issues. This customer appears in the 2016 program data but there are no negative entries indicating product returns, instead positive entries are shown for TLEDs for purchases made in Q1, Q2 and Q4 of 2016. The assumption for tracking hours of use are (3,901) and the logged hours of use are (6,062). The assumed wattage difference (13) was lower than the wattage difference found on-site (19) for G24s.

		Realization Rates			Evaluation
Site ID	Facility Type	Annual kWh (Including HVAC)	Connected kW	Average Hours of Use	Primary Reasons for Discrepancies
034995	School/University	44%	68%	62%	About one third of program tracking G24s were found to not be installed (262 G24s); of those (47 G24s) were found in-storage, (15 G24s) were reported to be disposed of and (200 G24s) were reported to be returned to the distributor due to product flickering issues. This customer does not appear in the 2016 program data despite the site contact indicating that they had returned (200 G24s) to the distributor; only positive entries appear for this customer in 2015. The assumption for tracking hours of use are (3,901) and the logged hours of use are (2,402).
035955	Office	194%	109%	176%	The assumption for tracking hours of use are (3,901) and the logged hours of use are (6,850). The assumed wattage difference (13) was lower than the wattage difference found on-site (19) for G24s.
039405	School/University	49%	23%	206%	Seventy percent of the program tracking G24s were found to not be installed (942 G24s); of those (105 G24s) were found in-storage and the rest were not found on-site or in-storage. This customer appears in the 2016 data however there are no negative entries indicating product returns or corrections, instead positive entries indicating purchases of PAR30s, T8s, and A-lines appear for purchases made in all quarters (1, 2, 3 and 4) of 2016.
045195	Office	91%	72%	127%	About half (528 G24s) were found to be in-storage and were reported by the site contact to be installed over time.
046285	Office	161%	104%	152%	The assumption for tracking hours of use are (3,901) and the logged hours of use are (5,932).
056875	Office	169%	96%	176%	The assumption for tracking hours of use are (3,901) and the logged hours of use are (6,860).
066005	Hotel	31%	14%	223%	Over eighty-five percent of program tracking G24s were found not to be installed (182 G24s) were found in-storage to be installed over time and (750 G24s) were not found installed or in-storage. This customer appears in the 2016 program data but there are no negative entries indicating product returns, instead positive entries are shown for Decoratives, Retrofit kits, PAR38s and PAR 30s for purchases made in Q1, Q2, Q3

		Realization Rates			Evaluation
Site ID	Facility Type	Annual kWh (Including HVAC)	Connected kW	Average Hours of Use	Primary Reasons for Discrepancies
					and Q4 of 2016.
074665	Hospital	62%	60%	105%	Eighty percent of the program tracking G24s were found to not be installed (27 G24s); of those (25 G24s) were found in-storage and (2 G24s) were reported to be disposed of. This customer appears in the 2016 program data but there are no negative entries indicating product returns, instead positive entries are shown for PAR38s, A-lines, Retrofit kits and Troffers for purchases made in Q1, Q2, Q3 and Q4 of 2016.
075245	School/University	19%	23%	81%	Eighty percent (40) of the program tracking G24s were found in-storage.
082515	Hotel	185%	106%	164%	The assumption for tracking hours of use are (3,901) and the logged hours of use are (6,388).
085345	Multi-Family	102%	78%	131%	The assumption for tracking hours of use are (3,901) and the logged hours of use are (5,107). (18 G24s) were found in-storage and are planned to be installed over time.
094755	Manufacturing Facility	34%	18%	179%	Eighty percent (766) of the program tracking G24s were found in-storage.
096545	Office	24%	20%	119%	Just over eight-five percent (2,772 G24s) were found to be in-storage; site contact reported waiting for ballast upgrade.
098535	Office	185%	117%	154%	The assumption for tracking hours of use are (3,901) and the logged hours of use are (6,025).
119745	School/University	177%	89%	193%	The assumption for tracking hours of use are (3,901) and the logged hours of use are (7,521).
120295	School/University	16%	10%	161%	Eighty-seven percent (3,754) of the program tracking G24s were found in-storage. This customer appears in the 2016 program data but there are no negative entries indicating product returns, instead positive entries are shown for several product type purchases made in Q1, Q2, Q3 and Q4 of 2016.
021595	School/University	160%	167%	94%	The assumed wattage difference (13) was lower than the wattage difference found on-site (22) for G24s.
022915	School/University	201%	205%	98%	The assumed wattage difference (13) was lower than the wattage difference found on-site (31) for G24s.

		Realization Rates			Evaluation
Site ID	Facility Type	Annual kWh (Including HVAC)	Connected kW	Average Hours of Use	Primary Reasons for Discrepancies
085475	Convention Center	187%	126%	148%	The assumption for tracking hours of use are (3,901) and the logged hours of use are (5,766) for G24s.
126005	Hospital	3%	2%	186%	Nearly all (12,016) of the tracking G24s were found in-storage (several pallets) and are reported to be installed over time.
125955	Hotel	225%	103%	202%	The assumption for tracking hours of use are (3,901) and the logged hours of use are (7,871) for G24s.

APPENDIX F. DATA COLLECTION INSTRUMENT

Auditor: _____ Logger Install: _____

Total Logger: _____ Logger _____

Area ID	Space Descr.	Detailed Space Descr.	Controls (Occupancy Sensors, Dimmers, etc)	Baseline Lighting Fixtures				Program Lighting Fixtures					Logger Installed		
				Qty	Product type	Watts	Descr. (Length, lamps, ballast, etc)	Qty	Prod-uct type	Model No.	Watts	Descr. (Length, lamps, ballast, etc)	Code	Logger ID	Notes
A1	*Office*	*Bldg 1, Flr 2, Office #732*	*OS*	*4*	*T8*		*2L 4' T8/EB HIGH LMN*		*T8-28*	*2F32SH*			*Log1*	*38655*	

**Note: For stairwells with sensors, auditor to record pre/post for lighting and pre/post for sensors.

Functional areas

Major functional spaces with distinct schedules or HVAC systems.

Area ID	Space Description	% of Facility[25]	Lighting Schedule ID(s)	Cooling System ID	Heating System ID
A1		%	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 V H	0 1 2 3 4	0 1 2 3 4
A2		%	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 V H	0 1 2 3 4	0 1 2 3 4
A3		%	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 V H	0 1 2 3 4	0 1 2 3 4
A4		%	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 V H	0 1 2 3 4	0 1 2 3 4
A5		%	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 V H	0 1 2 3 4	0 1 2 3 4
A6		%	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 V H	0 1 2 3 4	0 1 2 3 4
A7		%	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 V H	0 1 2 3 4	0 1 2 3 4
A8		%	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 V H	0 1 2 3 4	0 1 2 3 4
A9		%	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 V H	0 1 2 3 4	0 1 2 3 4
A10		%	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 V H	0 1 2 3 4	0 1 2 3 4
A11		%	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 V H	0 1 2 3 4	0 1 2 3 4
A12		%	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 V H	0 1 2 3 4	0 1 2 3 4

Notes: _____

_____

_____

_____

[25] Estimated fraction of the total square footage of the facility.

Operating schedules

SCH ID	Days[26]	Operating Hours		Operating Season[27]		%Lit[28]
		Start Time	End Time	Start Date	End Date	
L1	ALWAYS ON	0:00	24:00	Jan 1	Dec 31	100%
L2		:	:			%
L3		:	:			%
L4		:	:			%
L5		:	:			%
L6		:	:			%
L7		:	:			%
L8		:	:			%
L9		:	:			%
L10		:	:			%
L11		:	:			%
L12		:	:			%
L13		:	:			%
L14		:	:			%
L15		:	:			%
L16		:	:			%
LV	Vacation/Shutdown	N/A	N/A			%
LH	Holidays	N/A	N/A	Days/year:		%

☐ *New Years Day* ☐ *Independence Day* ☐ *Thanksgiving Friday*
☐ *MLK Day* ☐ *Labor Day* ☐ *Christmas*
☐ *Washington's Birthday* ☐ *Columbus Day* ☐ *Other*_____
☐ *Good Friday* ☐ *Veterans Day* ☐ *Other*_____
☐ *Memorial Day* ☐ *Thanksgiving Day* ☐ *Other*_____

Notes: _____

_____

_____

[26] Categorize operation as appropriate for this business, e.g. Mon-Fri, Mon-Wed, Sat-Sun, Holidays, etc.
[27] For use when schedules are different by season, month, or other time period.
[28] Estimated diversity fraction of occupied space that is lit under this schedule.

Important questions

Schedule changes since installation?_____

_____

Seasonal variation in schedules?_____

_____

Occupancy/production/business variations? _____

_____

Monitored month(s) typical? _____

_____

Has the quantity of light fixtures/lamps increased or decreased since participating in the program? [If yes, record how many] _____
[If the contact can show the field engineers an area where the pre-existing lighting is installed then collect baseline info (wattage, and if similar room/application qty)].

Part of a major renovation [obtain square footage information]? [Auditor seeking to answer whether renovation or addition is major enough to trigger code]. _____

[If part of a major renovation, auditor to check off all that apply] What other equipment was replaced at the time of the renovation project?

- ☐ Ceiling grid removed
- ☐ Terminal AC units replaced
- ☐ Studs were exposed
- ☐ Anything else? [Auditor to list what, if anything else] _____

  _____

Reason for LED installation (replacing failed or failing equipment)? [Auditor seeking to understand whether there was some type of systemic failure, or incipient failure, of overall lighting systems]. _____

What was the age of the replaced equipment? [This information will help inform measure life moving forward]. ___

_____

Interactive cooling systems

ID	Description	Type	Fuel	Efficiency	Qty	Size (tons)	Age (yrs)
C1		☐ Direct Expansion ☐ Chilled Water ☐ Heat Pump - Air / Wtr / Gnd ☐ _____	☐ Electricity ☐ Natural gas ☐ LP gas ☐ _____	_____kW/ton _____EER _____SEER			
Notes:							
C2		☐ Direct Expansion ☐ Chilled Water ☐ Heat Pump - Air / Wtr / Gnd ☐ _____	☐ Electricity ☐ Natural gas ☐ LP gas ☐ _____	_____kW/ton _____EER _____SEER			
Notes:							
C3		☐ Direct Expansion ☐ Chilled Water ☐ Heat Pump - Air / Wtr / Gnd ☐ _____	☐ Electricity ☐ Natural gas ☐ LP gas ☐ _____	_____kW/ton _____EER _____SEER			
Notes:							
C4		☐ Direct Expansion ☐ Chilled Water ☐ Heat Pump - Air / Wtr / Gnd ☐ _____	☐ Electricity ☐ Natural gas ☐ LP gas ☐ _____	_____kW/ton _____EER _____SEER			
Notes:							

Notes: _____

_____

_____

Interactive heating systems

ID	Description	Type	Fuel	Efficiency	Qty	Size (Btuh)	Age (yrs)
H1		☐ Hydronic ☐ Steam ☐ Direct Fired ☐ Heat Pump - Air / Wtr / Gnd ☐ _____	☐ Electricity ☐ Natural gas ☐ LP gas ☐ #2 / #4 / #6 ☐ _____	_____% _____COP			
Notes:							
H2		☐ Hydronic ☐ Steam ☐ Direct Fired ☐ Heat Pump - Air / Wtr / Gnd ☐ _____	☐ Electricity ☐ Natural gas ☐ LP gas ☐ #2 / #4 / #6 ☐ _____	_____% _____COP			
Notes:							
H3		☐ Hydronic ☐ Steam ☐ Direct Fired ☐ Heat Pump - Air / Wtr / Gnd ☐ _____	☐ Electricity ☐ Natural gas ☐ LP gas ☐ #2 / #4 / #6 ☐ _____	_____% _____COP			
Notes:							
H4		☐ Hydronic ☐ Steam ☐ Direct Fired ☐ Heat Pump - Air / Wtr / Gnd ☐ _____	☐ Electricity ☐ Natural gas ☐ LP gas ☐ #2 / #4 / #6 ☐ _____	_____% _____COP			
Notes:							

Notes: _____

_____

_____

About DNV GL

Driven by our purpose of safeguarding life, property and the environment, DNV GL enables organizations to advance the safety and sustainability of their business. We provide classification and technical assurance along with software and independent expert advisory services to the maritime, oil and gas, and energy industries. We also provide certification services to customers across a wide range of industries. Operating in more than 100 countries, our 16,000 professionals are dedicated to helping our customers make the world safer, smarter, and greener.