Getting Your Energy Savings Out of Storage

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ABSTRACT

Upstream lighting is proving to be a successful component for Massachusetts' commercial and industrial (C&I) energy efficiency offerings. Under the direction of the Massachusetts Program Administrators (PA) and Energy Efficiency Advisory Council (EEAC), DNV GL conducted a Year 1 impact evaluation, which found that the program was realizing almost all of the energy savings being claimed. Despite the positive evaluation results and the program's efforts to encourage the immediate installation of bulbs, the study found a significant portion of program bulbs, as identified by customer address, purchase date, lamp type and quantity, to be in storage.

During the Year 1 impact evaluation, evaluators visually inspected 81 sites approximately one year after the date of purchase to verify program bulbs. Site evaluators classified most program bulbs as installed, not found, removed, or in storage. In storage bulbs were visually verified by site evaluators, and were found at about 40% of all sites visited. Due to these findings, the PAs and EEAC were interested in revisiting sites with any number of in storage bulbs to calculate additional savings from bulbs moving from storage to sockets between Years 1 and 3.

This follow-up research found that LED installations increased from 82% in Year 1 to 85% in Year 3, while fluorescent installations increased from 80% to 85%. The study also concluded that there was little opportunity for increased savings beyond Year 3 as many of the remaining in-storage bulbs will be used in the future to replace current program bulbs on burnout.

Introduction

DNV GL recently completed a follow-up impact evaluation of the Massachusetts Commercial and Industrial (C&I) Upstream Lighting Program – alternatively known as the Bright Opportunities Program. The sponsors of this evaluation included all electric Program Administrators (PA) in Massachusetts (MA), including Cape Light Compact, National Grid, NSTAR, Unitil and Western Massachusetts Electric. The Massachusetts Energy Efficiency Advisory Council (EEAC) provided oversight and guidance of the impact evaluation.

Background

The Massachusetts Bright Opportunities Program uses upstream incentives to buy down the cost of energy efficient lighting technologies at the lighting distributor level for the Commercial and Industrial (C&I) sectors. The program buys down the cost of select LED lamps, including PAR20, PAR30, PAR38, MR16 and A-lamps, as well as high-efficient T5 and T8 fluorescent lamps. The program requires a minimum customer contribution depending on lamp type purchased, and also requires that the equipment is installed and operated at the customer's facility.

DNV GL completed an impact evaluation of this upstream lighting program in February of 2014 (the Year 1 impact evaluation). The Year 1 study included a sample of 81 sites from the very early stages of the Bright Opportunities Program (Q4 of 2011 through Q3 of 2012). As part of the Year 1 evaluation, DNV GL completed on-site visits, which included verification of installed equipment, a discussion with facility personnel regarding the baseline characteristics of the measure, and the collection and analysis of monitored

data. One important finding of this effort was that a significant number of program bulbs were found to be in storage, as opposed to being installed. In-storage bulbs were counted as "zero" in the installation rate calculation of the Year 1 impact evaluation. This produced installation rates for LED and linear fluorescent lighting of 82% and 80%, respectively.

Objectives

This follow-up study, referred to as the Year 3 impact evaluation, was designed to re-visit sites that were found to have in-storage bulbs to investigate when and whether these bulbs were eventually installed, and to calculate savings from bulbs moved from storage to sockets. Year 3 savings were estimated using the updated installation quantities combined with monitored hours of use from the Year 1 study. Logging was not part of the scope of the Year 3 study. In addition to calculating new savings estimates, the study also provided a summary of storage lamps to understand the circumstances around the phased approach to lighting installations, and what it might mean for program operations and savings claims, and provided recommendations at the statewide level on how the PAs may apply these findings to savings estimates going forward. This paper presents the findings of our Year 3 impact evaluation, and offers recommendations based on those findings.

Evaluation Methodology

File Review

The first task in this study was to review the data from the Year 1 impact evaluation to determine which sites had program-purchased bulbs in storage at the time of our initial visit. In order to do this, the evaluation team first looked at the entire sample of 81 sites, including 66 LED sites and 15 fluorescent sites. Of the 81 sites, 46 sites (37 LED and 9 fluorescent) were found to have had installation rates less than 100%. Figure 1 identifies that most of the sites (narrow bars) with installation rates less than 100% were schools/universities, offices and retail. The wider blue bars represent the percentage of Year 1 sampled sites that had installation rates of less than 100%.

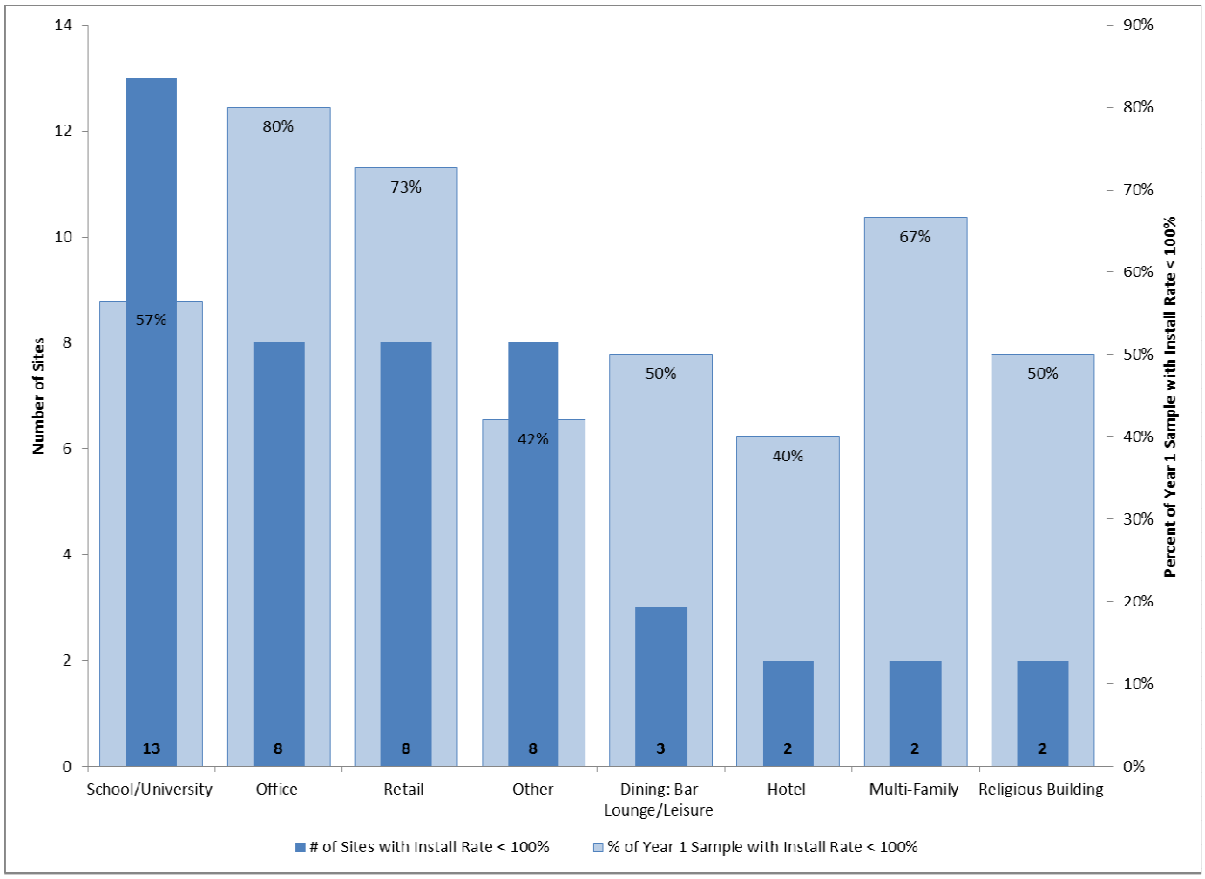

Figure 1. Original Sample with Installation Rates Less than 100% by Building Type

DNV GL examined the Year 1 data for each of these 46 sites to determine if the low installation rate was due to program bulbs being in storage, or some other reason (i.e., lamps were not installed, but also not confirmed to be in storage). This review identified 31 sites with in-storage program lamps from the Year 1 sample.

Recruitment

DNV GL along with the PAs and EEAC agreed to proceed with targeting all 31 sites for re-visit rather than sampling on these 31 sites. This approach allowed the evaluation team to collect as much data as possible for the Year 3 study, while also recognizing that 100% participation would be an unreasonable expectation.

DNV GL attempted to recruit all 31 sites by reaching out to the end-user who met with the DNV GL engineer during the Year 1 impact evaluation. DNV GL offered an incentive of $100 to thank participating customers for the initial site visit(s) and for making the time for another site visit to verify the amount of bulbs still in storage.

During this initial contact, the site recruiter reminded customers that bulbs were originally found to be in storage during the Year 1 site visit, and that the purpose of the additional site visit was to determine if any of the bulbs in storage were installed since the Year 1 visit.

DNV GL successfully recruited 23 sites, including 18 LED and 5 fluorescent. The remaining eight sites, which were all LED sites, were either unresponsive (4), firm refusals (2), or out of business (2).

DNV GL examined the bulb-quantity data from the Year 1 impact evaluation to determine if there were any key differences between the 18 LED sites that agreed to participate in a second site visit and the 6 LED sites that refused or were unresponsive.

Table 1 shows that LED sites that agreed to a re-visit had fewer bulbs in storage during the Year 1 evaluation. In general, the sites that refused or were unresponsive made larger purchases. These differences could suggest that the sites that refused or were unresponsive may not have installed bulbs at the same rate as those we re-visited; however, without site visits we cannot verify that theory.

Table 1. Average Bulbs per Site Purchased and Year 1 Storage

Customer Disposition	Number of Sites	Average Number of Purchased Bulbs per Site	Average Number of Year 1 In-Storage Quantity per Site	Percent of Bulbs In-Storage in Year 1
Completed Site Re-visit	18	184	70	38%
Refused or Unresponsive	6	297	162	55%
Out of Business	2	88	46	52%

We also compared the facility types of sites (both LED and fluorescent) that agreed to a re-visit versus those that did not. We found that schools and retail were very receptive to follow-up site visits (13 of 14 successfully recruited), while office and religious buildings (3 of 7 successfully recruited) were more difficult to recruit. These are small sample sizes, so we are not convinced that the type of building was a factor in whether or not we were able to re-visit the site.

Site Re-Visits

Between December 2014 and February 2015, the DNV GL team performed re-visits to 23 sites, including 18 LED and 5 fluorescent. For each site re-visit, our project team members conducted the following tasks:

- Reviewed individual end-user program purchases and quantity of Year 1 in-storage bulbs;
- Performed a field walk-through to provide a current observation of in-storage and installed equipment;
- Conducted interviews with site personnel regarding operating hours and patterns;
- Confirmed previously-collected information regarding holiday, shutdown, and other site schedules;
- Conducted interviews to verify pre-existing or baseline conditions with site personnel;
- Confirmed HVAC equipment for use in interactive savings calculations; and
- Computed Year 3 and accumulated program installation rates and savings based on site-specific information, and hours of use from the Year 1 evaluation.

DNV GL staff developed and used an on-site data collection form for this study to ensure that the data collection needs were met. The form included questions relating to reasons for having bulbs in storage, timing of installation (if any) of in-storage bulbs, quantities of bulbs moved from storage to installation, locations and pre-existing equipment replaced, reasons for installing/discarding, and customer satisfaction with the program bulbs.

Site-Level Analysis

DNV GL incorporated data gathered from the on-site visits into a lighting savings spreadsheet that was developed for use in the Year 1 impact evaluation.

In the Year 1 evaluation, each site had its own spreadsheet analysis, which calculated lighting savings using line-by-line comparisons of pre- and post-retrofit electrical use. Line items were usually defined as either different lighting types or different uses and schedules.

For the Year 3 impact evaluation, we took the new data from the site re-visits, and updated each of the existing lighting analysis spreadsheets from the Year 1 impact evaluation. In most cases, the only adjustments included updating the number of bulbs installed versus those in storage. We did not look at those fixtures verified in Year 1, meaning that they are all assumed to have persisted into Year 3 in our savings calculation work. The only exception to this would be when we found that the in-storage bulbs replaced previously installed program bulbs.

The Year 1 spreadsheets were also updated, where applicable, to include baseline lamp type and wattage for newly installed lamps, based on information evaluators obtained through on-site interviews with facility personnel. "Hours of use" were not logged as part of this Year 3 impact evaluation study, so we used existing logger data from the Year 1 evaluation and/or reported hours from facility personnel if the newly installed lamps were installed in areas that were not previously monitored.

These adjusted key savings parameters culminated in new energy savings estimates for each of the re-visited sites.

Expansion Analysis

Following the completion of the new site analysis workbooks, the site savings were then expanded up to the original population using a two-step process. First, the eight sites, which were found to have light bulbs in storage but were not available for a re-visit, were excluded from the Year 3 impact sample for the estimation of the quantity adjustment factor. Additionally, their former Year 1 evaluation weights were redistributed to the 23 sites that had been re-visited. This new weighting applied only to the quantity component of the savings analysis. The eight sites were then reinserted for the calculation of the other savings estimates, including delta watts and hours of use. This step resulted in new savings estimates for all 31 in storage sites based on the 23 that participated in a re-visit.

In addition to this modification, the larger 81-site sample from the Year 1 evaluation was also re-stratified to reflect the change in evaluated savings. This slightly altered the site weights, thereby affecting the overall realization rates and standard errors.

Results: Savings from Bulbs Moved from Storage to Sockets

The results presented in this section include the Year 3 statewide-level realization rates (and associated precision levels) for annual kWh savings. The adjusted gross energy realization rate is presented with its associated relative precision for each lighting measure at the 90% confidence interval. These tables present results as adjustments to tracking savings. Each of these adjustments, or discrepancies, is described below:

- **The Documentation Adjustment** reflects any change in savings due to discrepancies in project documentation. Evaluators recalculated the tracking estimates of savings using all quantities, fixture types/wattages, and hours documented in the project file. All tracking system discrepancies and documentation errors are reflected in this adjustment.
- **The Technology Adjustment** reflects the change in savings due to the identification of a different lighting technology (fixture type and wattage), including installed and baseline lamps, at the site than represented in the tracking system estimate of savings.
- **The Quantity Adjustment** reflects the change in savings due to the identification of a different quantity of lighting fixtures at the site than presented in the tracking system estimate of savings.
- **The Operational Adjustment** reflects the change in savings due to the observation or monitoring of different lighting operating hours at the site than represented in the tracking system estimate of savings.

- **The Electric HVAC Interactive Adjustment** reflects changes in electric 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.

LED Results

Figure 2 presents a scatter plot of annual energy savings results for LEDs using all 66 LED sample points included in the Year 1 impact evaluation, after adjusting for the newly installed lamps. In other words, this is the scatter plot of savings after the accumulated three years of program lighting installations at these sites. The dashed line in this graph represents a realization rate of 100%. The slope of the solid line in this graph is an indication of the overall realization rate, and can be seen to be slightly greater than 100%. This means that the evaluated energy savings for LED lamps are slightly greater than program savings estimates.

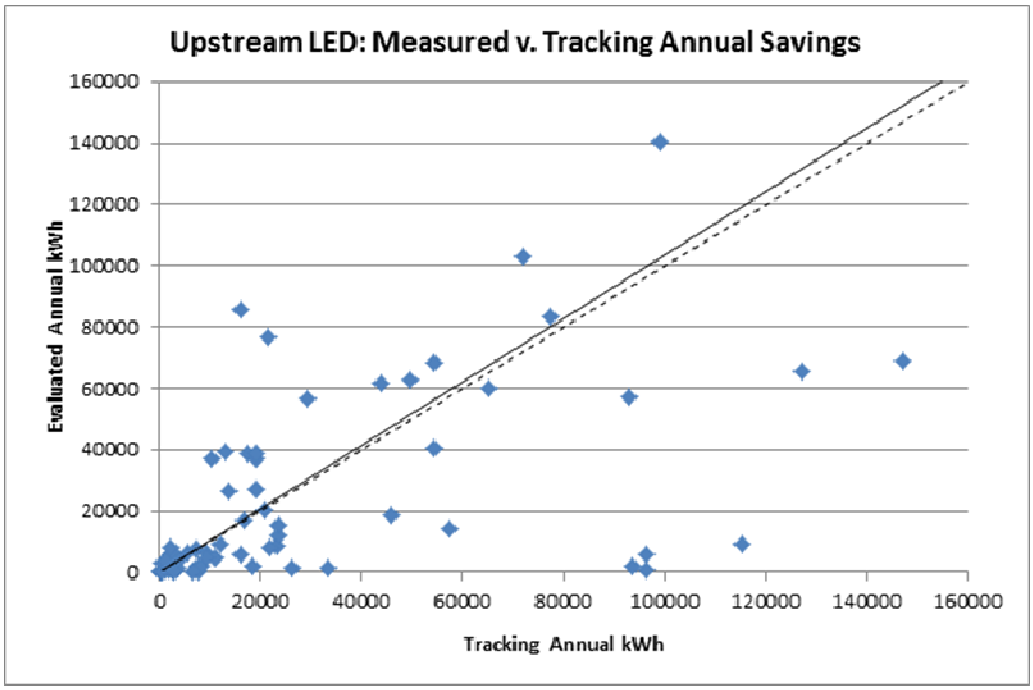

Figure 2. Scatter Plot of Evaluation Results for LEDs for Annual kWh Savings

Table 2 summarizes the statewide LED results for this Year 3 analysis. In the case of annual kWh savings, the realization rate for LEDs was found to be 103.4% with HVAC interactive effects included. The relative precision for this estimate was found to be ±25.7% at the 90% level of confidence. This was an increase of about 1.5% over the Year 1 results. As can be seen in the table, this change was due to the improvement in the quantity adjustment, which was the only parameter updated in this study.

Table 2. Summary of LED Energy Realization Rate

Savings Parameter	LED Energy (kWh) % Adjustment	
	Year 1	Year 3
Documentation Adjustment	0%	0%
Technology Adjustment	33%	33%
Quantity Adjustment	-24%	-16%
Operational Adjustment	-13%	-13%
HVAC Interactive Adjustment	6%	7%
Gross Realization Rate	101.9%	103.4%
Relative Precision	±17.5%	±25.7%
Confidence Interval	90%	90%

Fluorescent Results

Figure 3 presents a scatter plot of annual energy savings results for fluorescent lamps using all 15 fluorescent sample points included in the Year 1 impact evaluation, after adjusting for newly installed lamps. Once again, the dashed line in this graph represents a realization rate of 100%. The slope of the solid line in this graph is an indication of the overall realization rate, and can be seen to be slightly lower than 100%. This plot highlights some sample points that fall well below the dashed line. These were cases that included a large percentage of lamps that were not yet installed.

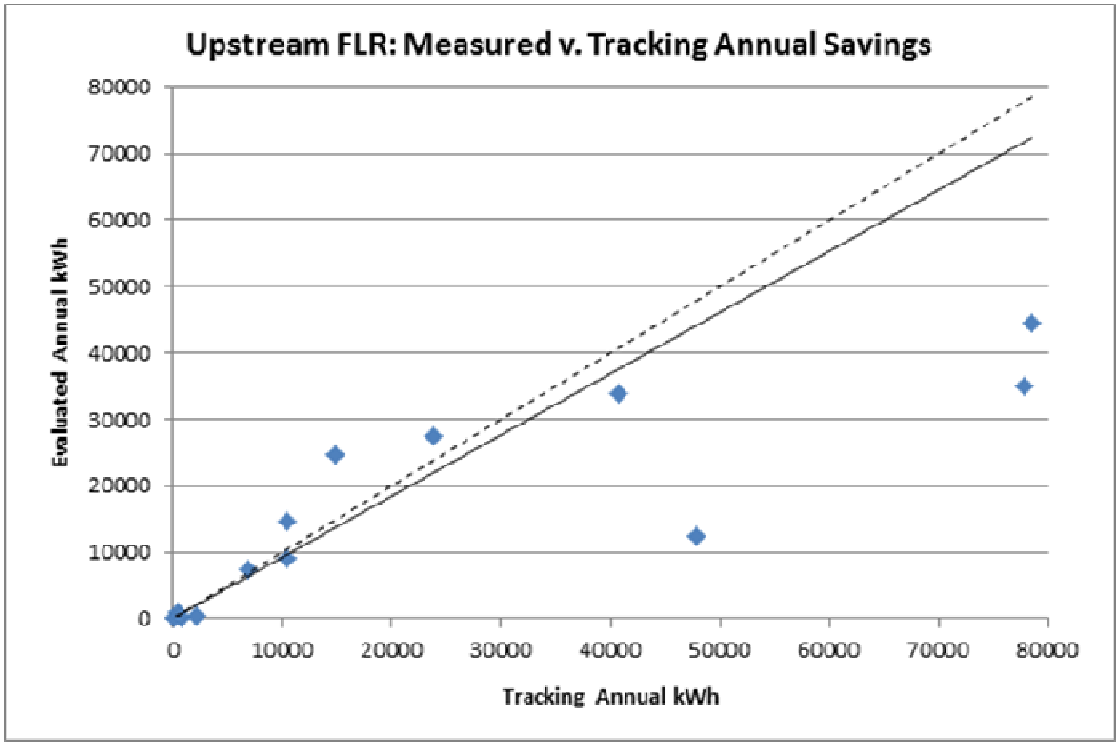

Figure 3. Scatter Plot of Evaluation Results for Fluorescents for Annual kWh Savings

Table 3 summarizes the fluorescent statewide results for this Year 3 analysis. In the case of annual kWh savings, the realization rate for fluorescent lamps was found to be 92.4% with HVAC interactive

effects included. The relative precision for this estimate was found to be ±24.0% at the 90% level of confidence. This was an increase of about 3.7% over the Year 1 results. Similar to LEDs above, this change was due to the improvement in the quantity adjustment.

Table 3. Summary of Fluorescent Energy Realization Rate

Savings Parameter	FLR Energy (kWh) % Adjustment	
	Year 1	Year 3
Documentation Adjustment	0%	0%
Technology Adjustment	0%	0%
Quantity Adjustment	-20%	-15%
Operational Adjustment	2%	1%
HVAC Interactive Adjustment	6%	7%
Gross Realization Rate	89.1%	92.4%
Relative Precision	±26.9%	±24.0%
Confidence Interval	90%	90%
Error Ratio	62%	53%

Comparison of Installation Rates

Figure 4 presents the installation rate by technology type and study year. For LEDs, the Year 1 installation rate was found to be 82%, while the Year 3 installation rate was found to be 85%. This represents an increase of about 3%. For fluorescents, the Year 1 installation rate was found to be 80%, and the Year 3 installation rate was found to be 85%. This represents an increase of about 5%.

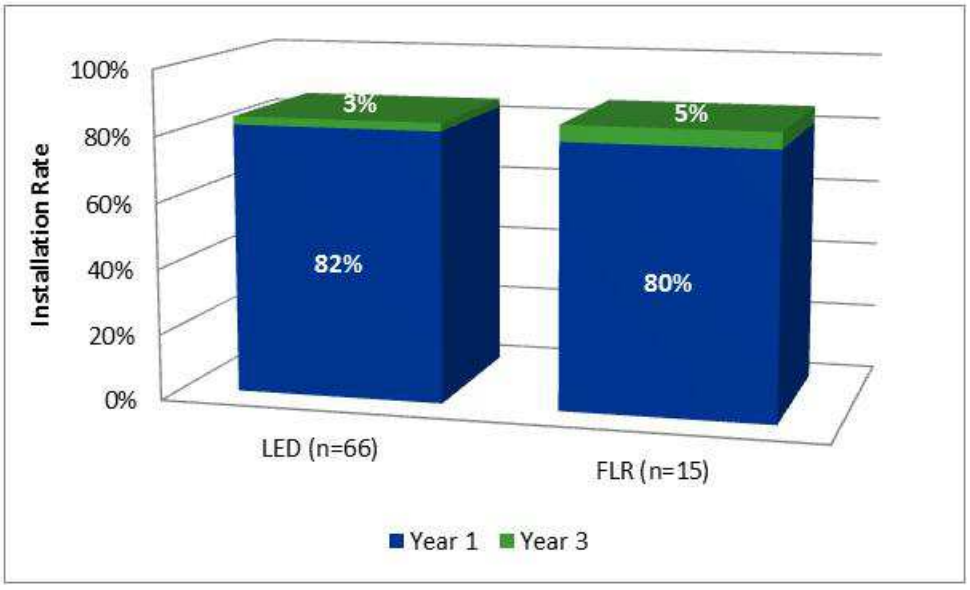

Figure 4. Installation Rate by Study Year

Summary of Storage and Installation Observations

Table 4 presents an overall summary of in storage bulbs from the Year 1 evaluation to the Year 3 evaluation. The sites are classified into five distinct categories. We've excluded one site, which was

considered to be an outlier, as the total number of bulbs (>115,000) would dilute the "No Additional Bulbs Installed" row. As shown in the table, 12 of the 22 sites have had all their remaining in storage bulbs installed since the Year 1 evaluation. The table shows that there were 919 bulbs in storage across these 12 sites at the time of the Year 1 evaluation, and that there are now zero bulbs in storage.

This study found that two of the sites, three if you include the large outlier, had no bulbs installed since the Year 1 evaluation. These two sites included only 14 bulbs total. In one case, the business had moved out, but the space was occupied by a new business, and all of the previously installed bulbs remained. However, the in-storage bulbs were no longer on-site. We assume the previous owner took the bulbs with them when they moved out. The second site is a retail store, which has no room to install the remaining bulbs, and has no plans to install them unless any of the currently installed program bulbs burn out.

There were six sites which had some (73%) of their bulbs installed since the Year 1 evaluation. For five of the six sites in this group, the customers stated that the remaining bulbs were not needed until other bulbs burn out, including either program or non-program bulbs. In one site, a portion of the in-storage bulbs were installed, and the remaining bulbs were not found on-site. The customer was not able to provide details on where they ended up.

One site, which was a hospital, not only didn't install any in-storage bulbs, but also removed all of the PAR lamps they received due to a strobing issue. They did not replace these bulbs with program bulbs or new LEDs, but went back to their pre-existing lamp.

In one case, the site used all three of its remaining in storage LED bulbs to replace program bulbs that had burned out.

Table 4. Summary of Bulbs for Re-Visited Sites between Year 1 and Year 3

Year 3 Classification	Number of Sites	Average Number of Days between Purchase and Year 1 Visit	Number of In Storage Bulbs - Year 1	Average Number of Days between Purchase and Year 3 Visit	Number of In Storage Bulbs - Year 3
All Bulbs Installed	12	254	919	917	0
No Additional Bulbs Installed	2	252	14	1,029	14
Program Bulbs Removed	1	358	846	1,057	0
Replaced Program Bulbs	1	212	3	822	0
Some Bulbs Installed	6	353	2,732	935	747
Total	**22**	**284**	**4,514**	**934**	**761**

In the table above, the column labeled "Number of In-Storage Bulbs-Year 3" represents the remaining number of bulbs that still have the potential of being installed at some point in the future. Note that many of these bulbs will remain in storage until current program bulbs burn out, which limits the ability for the program to achieve more savings through an increased installation rate.

Conclusions and Recommendations

Overall, this Year 3 study resulted in a small increase in program savings beyond the Year 1 evaluation savings. The LED kWh realization rate increased from 101.9% to 103.4%, while the fluorescent realization rate increased from 89.0% to 92.4%. These increases were the result of installation rate increases

in both groups. The following sections present the conclusions and recommendations from this study, which may benefit other utilities or states that are implementing C&I upstream lighting programs.

Savings Assumptions

- **Annual Energy (kWh) and Connected kW Realization Rates.** For prospective application of these results—both for LEDs and fluorescents—we recommended that the MA PAs utilize the Year 3 results (since the potential for additional savings due to increased installations after Year 3 is limited).
- **Quantity.** The LED installation rate increased from 82.1% to 84.6% between Year 1 and Year 3, and the fluorescent installation rate increased from 80.3% to 85.3%. Although many lamps remain in storage at three of the five fluorescent sites, these lamps are not likely to be used until currently installed program lamps burn out. This limits any future increase in savings due to installation of in-storage bulbs. For both LEDs and fluorescents, we recommended that the PAs apply the Year 3 installation rate to savings estimates.

On-Going Quality Control

This study, as well as the Year 1 study, included a sample of sites from the very early stages of the Bright Opportunities Program (Q4 of 2011 through Q3 of 2012). Controls have since been put into place to try to avoid the issue of stockpiling going forward. One measure put in place was the implementation of an ongoing QA/QC process. An independent QA/QC vendor is currently in place to verify quantities and lamp types, and categorize their inspections as Pass, Fail or Pass with Notes. The process includes inspection of 5% of the locations that purchased lamps through the program with 70% of the inspections targeted at the large sites, and 30% at the small sites. Determination of large versus small sites is based on a quartile analysis of monthly incentive data, and may differ by month. The QA/QC effort also performs visits to locations submitted by each distributor, and at least one site from each PA's service territory.

The QA/QC vendor supplies the PAs with a monthly report that includes the number of sites they visited, what they found and didn't find, and any applicable notes for each site. The PAs review the reports, and look for any large issues or unusual activity. If there are any large issues, such as a high percentage of lamps not installed, the PAs and the program implementation contractor investigate them to ensure that the reports are correct. The PAs look to see if this is a one-time event, or if there is a pattern of unusual activity from a distributor. Ultimately, this information is used to develop programmatic changes to correct the issues. This includes adjusting the required minimum buy-in from customers to prevent any possibility of "free" giveaways.

Continued Evaluation

Based on feedback from the Year 1 study, as well as the monthly QA/QC reports, it is possible that the program has matured in the three years since the impact evaluation sample was drawn. There could be reason to believe that the growth of the program, and the controls that have been put in place to help limit the stockpiling issue, may have contributed to improved installation rates. It is recommended that a program that has undergone these changes since its inception should be monitored again to determine if these changes have impacted the program in any way.

A suggested approach may be to start with a review of the monthly QA/QC reports to investigate if there have been any trends in verified installations over the past three years. These reports may give an indication of the direction of the installation rate over time, and may provide compelling evidence to conduct a new impact evaluation.

The authors have identified other research and guidelines on installation rates over time for residential upstream lighting, but not for commercial/industrial. Residential installation rates discussed in a recent residential lighting evaluation protocol (Apex, NREL 2014) are better than those found in this

evaluation, reaching 92% after 3 years. Though the project team reviewed and discussed the residential upstream lighting work, the findings from these studies were determined to be non-applicable to the C&I program being evaluated. Continued evaluation of C&I upstream lighting programs can help to build a research base around this topic.

References

Apex Analytics, LLC (Apex) and NREL 2014. "Chapter 21: Residential Lighting Evaluation Protocol." *The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures.*