LEDs are Moving on Up: C&I Upstream LED Lighting Program

Aaron Kwiatkowski, DNV KEMA Energy & Sustainability, Orlando, FL
Chad Telarico, DNV KEMA Energy & Sustainability, Geneva, NY
William Blake, National Grid, Waltham, MA

ABSTRACT

LED lighting has been gaining in popularity over the last few years. Massachusetts has begun to offer LED bulbs through an upstream lighting program to its commercial and industrial (C&I) customers. The program works by buying down certain LED, as well as T5 and T8, products for C&I customers through their lighting distributors. This differs from many other upstream programs, which focus on retail sales.

Since the inception of this program in the fall of 2011, there has been a significant amount of activity. Due to the rapid growth of this program administrators (PA) requested an early impact evaluation to determine the actual savings.

Tracking savings were derived based on bulb type, and assume an average delta watts and annual hours of operation per bulb type. Since this is an upstream program, there is no opportunity to collect site specific information such as operating hours or existing lamp type, which is typically done for downstream large C&I lighting applications in Massachusetts. Therefore, the impact evaluation was designed to provide results for the following key savings variables: building type, space type, installation rate, replaced lamp wattage, installed lamp wattage, and annual operating hours.

This type of impact evaluation differs from most other lighting impact evaluations because not much is known to the evaluator prior to going on-site to verify the installation other than quantity and type of bulb purchased, and in most cases, purchaser address. Evaluators must verify all of the purchased bulbs, whether they are installed or not, including all bulbs still in storage. Additionally, the evaluation must attempt to identify what type bulb was in place prior to the installation of the incented bulb.

There are many challenges that this impact evaluation is trying to overcome. The biggest challenge has been recruiting customers into the on-site effort. The initial dataset from which the sample was pulled lacked detailed customer information. This problem has been rectified as the program has evolved, but proved to be an issue for the initial impact evaluation. Another challenge that has been identified is that bulbs are being purchased in bulk for towns and campuses with multiple buildings. As with other upstream programs, some bulbs are found to be sitting in storage until older bulbs burn out.

Many of the customers that have so far participated in the evaluation effort have been able to answer the question of existing lamp type with reasonable confidence. The evaluation team is also finding that the customers are typically well aware of the bulbs that were purchased under this program, and are able to identify them in their facility.

The impact evaluation includes four to six weeks of monitoring at each facility in order to help inform annual operating hours similar to a traditional lighting impact evaluation. Initial data collection began in the fall of 2012, and will continue through July 2013 with a full report in September 2013.

This paper will cover the trends that have been found throughout the first phase of this study, and discuss the methodology, challenges and successes of this impact evaluation, as well as the success of the program.

Introduction

DNV KEMA is in the process of conducting an 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 MA Upstream Lighting Program is a new program, which attempts to increase the market penetration of energy-efficient LED lighting technologies through the use of upstream incentives that are used to buy down the cost of these lighting technologies at the lighting distributor level. All five electric Program Administrators (PA) in the state are participating in the program. The program began offering upstream incentives on LED lighting technologies in November 2011. In the case of the LED lighting technologies the upstream incentives take the place of the downstream incentives that the Massachusetts C&I programs 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 lamps they sold, as well as the name, location, and contact information of the customers to whom they sold the discounted lighting products. Every month the distributors submit their sales data to a third-party program manager who combines the data and then allocates the energy savings and incentives to each participating PA based on the location of each purchase.

Objectives

The objective of the MA Upstream Lighting Impact Evaluation was to provide early feedback on how well this program is performing, and to estimate the energy and demand savings resulting from a sample of 2011 and 2012 upstream bulb purchases in Massachusetts. Data collected as part of this evaluation will be used to provide retrospective savings adjustment factors, as well as help inform the deemed savings factors used by PAs going forward. In addition to providing an independent verification of energy and demand savings, a focus of this impact evaluation is to try to answer the following three questions:

- What are the building and space types where these LED purchases are being installed in?
- What are the baseline, or pre-existing, bulb type and wattage that the program LED bulbs are replacing?
- What are the operating hours of the LED bulbs?

Scope of Work

In order to achieve the research objectives and ensure the Sponsors' satisfaction with this C&I Upstream Lighting impact evaluation effort, DNV KEMA performed the following tasks:

- Examine the MA program data so that the evaluation team can better understand the characteristics of the C&I Upstream Lighting measures statewide;
- Apply PA savings assumptions to program data so that the evaluation team fully understands how the PAs are tracking energy and demand savings;

- Design an efficient sampling plan for the selection of end-users for on-site visits, optimized to the extent possible in order to achieve +/-10% precision at the 90% confidence interval for annual energy savings;
- Perform comprehensive data collection, including surveying building facility managers, at each impact sample site to support an independent analysis of adjusted gross energy and demand savings realization rates, and savings factors such as delta watts and hours of use; and
- Produce comprehensive reporting of gross savings results, including analysis methods, findings and trends.

Evaluation Methodologies

Program Data Analysis

In May 2012, DNV KEMA was provided with program tracking data, which covered the November 2011 to April 2012 period. The program data includes information about the types and quantities of products installed, company facility name and addresses, distributor names and addresses, and equipment manufacturers. The product types identified in the data are LEDs (MR16, PAR20, PAR30 and PAR38) and fluorescents (T5 and T8). Since no estimates of savings were provided with the program data, standard formulas were applied to calculate annual kWh savings by product type and wattage. The per lamp savings estimates for each product type are presented in

Table 1. These are the assumptions used by the MA PAs to generate program savings values.

Table 1. Per Lamp Deemed Savings Assumptions

Product Type	Baseline Fixture Wattage	Baseline Ballast Factor	Baseline Wattage	Installed Fixture Wattage	Installed Ballast Factor	Installed Wattage	Delta Watts	Annual Hours	kWh Savings
T8	32	0.88	28	28	0.88	25	3.5	3,380	12
T5	54	1.00	54	50	1.00	50	4.0	3,380	14
PAR20	38	1.00	38	8	1.00	8	29.8	4,500	134
PAR30	55	1.00	55	15	1.00	15	40.4	4,500	182
PAR38	61	1.00	61	14	1.00	14	46.8	4,500	211
MR16	31	1.00	31	8	1.00	8	23.4	4,500	105

The sample frame for the impact evaluation was defined as unique rows for each customer location and product type. For purposes of designing and selecting the sample, the level of detail for product types is the two major groups: LEDs and Fluorescents. The tracking data was aggregated by customer name, address and group. The initial 6,343 records produced 3,365 unique combinations. However, we noticed that there were many instances where names and addresses were spelled, abbreviated, or punctuated differently, creating multiple records. Software tools and manual review reduced the number of unique combinations of name, address and product group to 3,077. After eliminating a few records where the sales quantity was less than or equal to zero, the number of records was 3,070. The distribution of savings and quantities installed across the product groups follows in Table 2. Note that approximately half of all installations were linear fluorescent, which represented only 18% of the customer locations. This is because customers typically purchased larger quantities of linear florescent relative to LEDs, as they use these to replace existing linear

fluorescents throughout their buildings.

Table 2. Distribution of Upstream Lighting Projects by Product Group

Product Group	Savings (kWh)	% of Savings	Quantity Installed	% of Quantity Installed	Number of Customer Locations	% of Customer Locations
LED	37,478,740	93.21%	219,691	49.04%	2,513	81.86%
Fluorescent	2,728,501	6.79%	228,295	50.96%	557	18.14%
Total	**40,207,241**	**100.00%**	**447,986**	**100.00%**	**3,070**	**100.00%**

As a whole, the total claimed LED savings was roughly 93% of the entire program across the time period examined.

Sample Design

The goal of the impact evaluation is to estimate realization rates and other factors with ±10% relative precision at a 90% confidence interval. In light of the fact that LEDs make up such a large percentage of the program savings, it was most important that these results achieve the precision targets. Since fluorescents make up less than 7% of the total program savings, the 90/10 criteria was relaxed somewhat for that sample. The remainder of this paper will focus on LEDs, and will not include fluorescents.

The population for the impact evaluation includes only the sites that have been identified as end use customers. Summary statistics about the population frame for the impact evaluation are provided in Table 3.

Table 3. Population for Impact Evaluation

Customer Group	Product Group	Sites	Total KWh Savings	Average Savings	Minimum	Maximum
End User	LED	2,407	36,430,888	15,135	105	631,688

In order to estimate the sample sizes required to produce estimates that meet the precision targets described above, we made an assumption about the level of variability in the results (error ratio). Other studies of lighting impact evaluations have found an error ratio of 0.4 to be realistic. The sample design was stratified by size, based on the total savings at each location. After reviewing alternatives, the team settled on the sample design described in Table 3.

Table 4. Proposed Sample Design for Impact Evaluation

Product Group	Stratum	Maximum KWh Savings	Sites	Total KWh Savings	Sample	Inclusion Probability
LED	1	7,994	1,459	4,756,134	10	0.00685
	2	18,450	493	5,950,855	10	0.02028
	3	39,133	259	6,954,547	10	0.03861
	4	92,052	141	8,120,784	10	0.07092
	5	631,688	55	10,648,569	10	0.18182

Based on the information available at the current time regarding the distribution of customer

locations by size (total savings) and assumed error ratio, this design is anticipated to produce estimates of realization rates and other factors with the precisions indicated in Table 5.

Table 5. Anticipated Precisions for Impact Evaluation

Product Group	Sites	Total Savings	Assumed Error Ratio	Confidence Level	Planned Sample Size	Anticipated Relative Precision
LED	2,407	36,430,888	0.4	90%	50	±9.57%

Data Collection and Metering

In general, each site visit consisted of a verification of installed equipment, a discussion with facility personnel regarding the baseline characteristics of the measure, and the collection and analysis of monitored data. Lighting operation was determined through the use of time-of-use (TOU) lighting loggers. These data were used for estimating the annual hours of use for calculating savings estimates for all purchased LEDs. If measure(s) were removed, evaluators gathered the reason(s) for removal. If measures were not yet installed, we tried to gather as much information as we could to understand when they are planning on being installed. Program measure operating characteristics and general building operation characteristics were also gathered; including information on heating and cooling systems to assess interactive effects. Information on the pre-existing or baseline conditions was collected to increase the accuracy of savings calculations. To gather this, the field auditor spoke to the person who is most knowledgeable about the lighting at each facility to ask questions such as:

- What type and wattage fixtures were replaced by the program fixtures?
- Do you have any of these old bulbs in storage for us to look at?
- Is there a part of your facility that still has similar old bulbs in place?

Analysis Methods

Data collected from the TOU lighting loggers was used to develop time-of-use load profiles and estimate total on-times during the monitoring period. Short-term metered data, like that obtained from the six- to eight-week minimum performed for this study, pose challenges in accurately expanding the data from the monitored period to a typical year or to specific periods of interest that do not coincide with the monitoring period, e.g., peak demand. In determining lighting schedules from time-of-use data, annual trends such as seasonal effects (e.g., daylight savings), production, and occupancy swings (such as vacations, business cycles, etc.) for were taken into account. 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 including reported operating schedules and holidays/shutdowns.

The data gathered from the on-sites were compiled into spreadsheets for analysis. The savings were calculated as line-by-line comparisons of pre- and post-retrofit electric use. Interactive cooling and heating effects of the installed measures were also calculated where applicable. The on-site savings calculations included all relevant information gathered during the on-site. In addition to estimating annual energy savings and peak demand savings, DNV KEMA also provided the sponsors with measure-specific estimates for the following savings input parameters, based on the data collected on-site:

- Installation Rate;
- Delta Watts; and

- Annual Hours of Use.

Evaluators combine the data gathered during the site visit with data provided by the Sponsors to estimate gross savings realization rates for annual kWh. Evaluators also used the combined data to estimate gross savings results for summer peak diversified kW, winter peak diversified kW, and percent energy on-peak. The study also produced new estimates of delta Watts and annual hours of use that may be applied by the PAs going forward. All reporting at this level was sample weighted and statistically representative of the population or appropriate population sub-groups. Final results included precisions associated with each level of disaggregation.

On-Site Findings

The findings presented in this paper are based on the first phase of the evaluation, which performed analysis on (31) of the proposed (50) sample sites. The second phase of this study is still underway, and will be completed in late summer of 2013. However, based on the results of the first phase of this impact evaluation, we can start to see useful trends in the performance of the program for various metrics including building type, baseline fixture wattage, installation rate and operating hours. These findings are discussed in the following sections.

Customer Recruitment

During the recruitment process, evaluators encountered several difficulties with this evaluation effort. First, participation in the evaluation was lower than typical impact evaluations. The primary reason for this is that this being an upstream program, many customers did not realize that they had participated in a utility program. Some customers that purchased these LED bulbs were unaware of some of the details that went along with the program, including third party verification of the new purchases. Part way through the evaluation, evaluators and program staff tried to stimulate participation by offering a monetary incentive to customers who agree to allow for metering. This did seem to help a bit, but it was certainly not a complete remedy. As such, the evaluation was split into two phases to be able to provide program staff and regulators earlier results. The first phase, which is included in this paper, was more than half of the original sample. The second phase is currently still ongoing.

There was some confusion at some facilities about which project and which bulbs were actually involved with what project. Many of the facilities that were visited had multiple projects done in different phases. In some cases, the facility contacts could not remember details of the upstream project to help the field auditor evaluate the correct project. This resulted in evaluators sweeping entire buildings trying to identify the program bulbs.

There were some facilities that had multiple buildings assigned to one application and DNV KEMA found that with multiple buildings or large campus sites, no one at the facility really was keeping track of where the bulbs were ending up. This was very common for applications that were completed for city buildings or city municipalities.

Building Types and Baseline Bulbs

One of the key areas of interest for this study was to identify the types of facilities where the LED purchases were being installed, since this was not being specifically tracked by the program. Evaluators

found an array of different facility types within the state of Massachusetts. This evaluation found LED installations in healthcare facilities, universities, primary and secondary educational facilities, corporate office buildings and city municipalities (city hall, police and fire stations, etc.).

Many of these facilities had more than one building involved with the installation upgrades. In the case of healthcare facilities, these facilities mainly had the LEDs installed in common areas such as waiting rooms and lobbies. These selected common areas tend to operate on a different schedule from the bulk of the facility's other lighting schedules. Through interviews it was found that most of the LEDs replaced halogen track lighting and in some cases compact florescent bulbs. This was also found to be true for the primary education facilities as well. These facilities had the LEDs installed in main hallways, corridors and a few maintenance areas throughout the school's campus. Through interviews with facility staff, it was found that the LEDs were installed in place of recessed halogen bulbs and some recessed compact florescent bulbs. This was also true for the apartment complexes that were evaluated, again the LEDs were installed in common areas, lobbies and hallways in place of halogen bulbs. In regards to city municipalities the installation of LEDs were found primarily in elevator lobbies, in some private offices and conference rooms mainly spread throughout multiple buildings.

A large portion of the facilities that were evaluated were considered small business or retail shops. These sites included facilities such as restaurants, hair salons, art galleries and retail showrooms. These facilities had the new LEDs installed throughout their entire space, not just in common areas. Most of the LED bulbs replaced halogen track lighting. Halogen track lighting is a very common fixture type in retail because it allows the owners to direct light on specific areas or merchandise. Replacing the halogen track with LEDs allows for a longer burn time and to burn at lower temperature and creates a more comfortable experience for the customers. In the restaurants that were evaluated, it was found through discussion with the managers, that the LED bulbs also replaced mostly halogen bulbs.

There were some facilities that combine showroom or retail space with warehouse or shipping departments. These facilities had the LED bulbs installed in loading dock fixtures in place of halogen flood lights. These fixtures tend to operate on a lower hourly schedule, mainly for loading and unloading trucks, which is different from the main operating schedule.

Installation Rate

During the evaluation process DNV KEMA's field staff found that a high percent of the newly purchased bulbs and equipment were installed. In many of the facilities the new equipment was instantly installed. Evaluators found that the program documentation that DNV KEMA acquired was very accurate in terms of the technology, quantity and location (installation address).

There were some instances in which the new bulb installation was delayed because the existing lamps were still operating adequately for the spaces in which they were located. After speaking with these customers, it was explained that they did not want to discard functioning equipment. It was discussed that as the existing lamps began to deteriorate and fail, the new equipment would be installed accordingly. This issue occurred most often in smaller facilities. Many of the larger tended to replace the equipment immediately upon receiving the new bulbs.

Data Analysis

As DNV KEMA completed the first phase of the analysis, a few key trends became very obvious. The most prevalent was the technology savings adjustment, which represents the delta watts. It was

discovered through the on-site process and facility contact interviews that most of the sites that had installed their new LED bulbs actually had a higher wattage existing bulb than what was assumed by the PAs. This led to a higher delta watts than was previously anticipated, which will result in an increase in program savings.

It was also discovered that the installation rate was less than 100%. There were a small number of sites that had not installed any of the purchased bulbs at the time of the on-site visit, and other sites where they had not yet installed all of their purchased bulbs. Based on discussions with facility staff, these sites were generally waiting for the existing bulbs to expire before replacing them with the new program LEDs.

The hours of use difference was another factor that negatively affected the phase one results to this point as well. The ex-ante assumption of 4,500 hours per year appears to be overestimating tracked energy savings for LED lamps. Actual time-of-use metering found that the actual hours of use are trending lower than the ex-ante estimate.

Conclusions and Recommendations

Overall, this C&I LED upstream lighting program appears to be successfully delivering energy savings. The program has seen significant participation since its inception in early 2012, and the first phase of the impact evaluation is showing positive trends so far. The second phase of the impact evaluation will look to strengthen on these results, and will provide useful feedback on adjustments to program savings estimates going forward.

The following section presents some high level recommendations for impact evaluations of this type of C&I upstream program. These are based on observations from our work throughout the first phase of this study, and may be applicable to other programs as well.

Future Evaluations

The following recommendations are directed towards future impact evaluations of similar C&I Upstream LED programs.

- It is recommended that the program data includes the final installation address of the bulb purchases. One common issue during the evaluation was that the customer address was not always the location where the new bulbs were installed. Facility personnel sometimes rely on the evaluators to tell them where the bulbs are located. It would please customers more if the evaluators had more information up front. This can be done by providing more education to participating distributors on the important information to collect at the time the purchase is made.
- It is recommended that program staff attempt to create more awareness of the rebates that the customers are receiving. In some cases, facility managers didn't know which lamps were included in the program. They also sometimes did not know when, or if they were installed. One suggestion is that program staff follow-up with the customers by sending a summary letter thanking them for their purchase, and providing them a list of the bulbs that they purchased. This approach serves two purposes as it helps provide awareness about the program, and also provides customers with a record of their purchases, which can be referenced during future evaluations.
- It was found that the program implementers are also conducting a quality control (QC) check of the program using another third party vendor. It is expected that this third party QC

vendor will be making spot checks of approximately 10% of the installations each month. It is recommended that the QC vendor attempt to collect information such as facility and space type, installed quantity, pre-existing bulb type and wattage, and reported annual hours of use. This additional data can be used with the results of this impact evaluation on an ongoing basis to continue to update savings results for reporting and planning purposes. This approach can be applied for other upstream programs in Massachusetts and elsewhere as an ongoing check of the program, which may influence future changes.

- After several failed attempts to recruit customers into this evaluation early on, the evaluation team began offering monetary incentives to help improve participation rates. This strategy provided a small boost, but did not improve recruiting significantly. For C&I customers, time is usually more of a barrier for evaluation participation, and a small monetary incentive isn't always enough to overcome that. Program administrators should consider their customer base individually to determine if monetary incentives should be offered for evaluation participation in C&I upstream impact evaluations.
- Additionally, as part of impact evaluations, facility managers frequently request some kind of data or report of the monitoring results. Generally, PAs are happy to share site specific information with their customers once the evaluation report is finalized. It is recommended that the PAs provide a summary report for each customer it visits as part of the evaluation of these upstream programs. Evaluators can work with program staff to produce a high level, one-page summary of their customers' results that can be distributed to all evaluation participants. This will also help to strengthen the relationship between the PAs and their customers, and may help to improve participation in this type of evaluation.