Retrofit Lighting Controls Measures

Summary of Findings

FINAL REPORT

Massachusetts Energy Efficiency Program Administrators
Massachusetts Energy Efficiency Advisory Council
Prepared by: KEMA, Inc.
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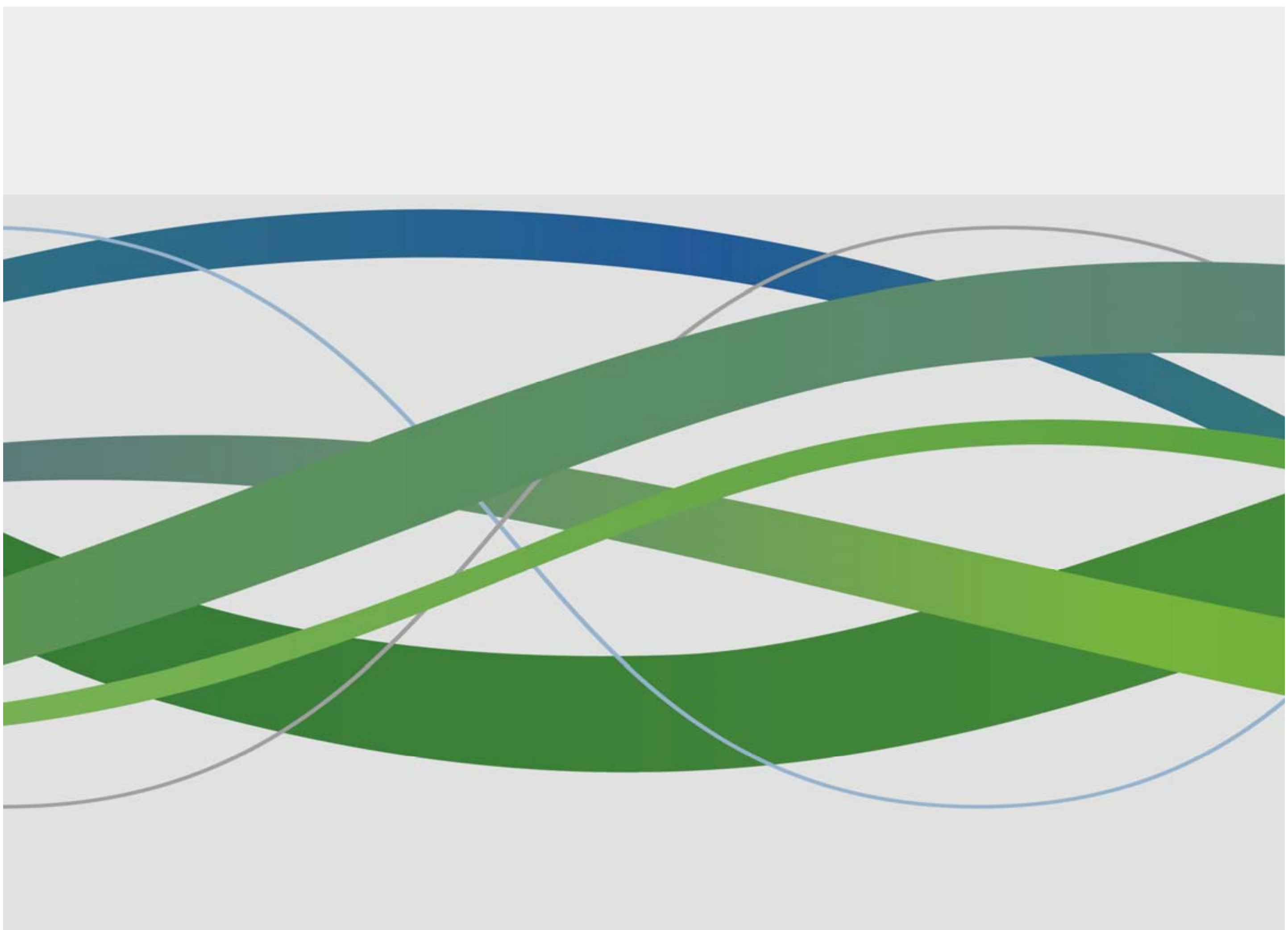

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1. Executive Summary

This document presents the summary of findings of DNV GL's research into the state of the market for C&I Retrofit Lighting Controls Measures in Massachusetts. The goals of this research are to provide the Massachusetts Program Administrators (PAs) with recommendations to improve the lighting controls options through the retrofit program, tracking methods, and to determine how lighting controls measures should be evaluated.

1.1 Evaluation Objectives

The results of this research include the following core objectives:

- Discover why program savings for the retrofit lighting controls market dropped off to about half its size between 2010 and 2011, and whether the program can reverse this decline
- Determine what kind of impact evaluation to conduct for Large C&I Retrofit Lighting Controls installations under MA-Large Commercial and Industrial Evaluation Contract (LCIEC) -study 22. The previous plan of an innovative pre-post metering study may prove either appropriate or overly ambitious, depending on the expected future growth or decline of the measure savings;
- Make recommendations for changes to future lighting controls measures to account for new market conditions, including how to track savings consistently. These recommendations may include new technologies and market segments to target, old technologies and market segments to leave behind, and existing technologies and market segments to reallocate resources to, and;
- Make recommendations for adjustments to savings estimation methods currently in use in the Massachusetts Technical Resource Manual (TRM).

The research addresses retrofit lighting controls installed under all PA C&I programs including Large C&I and Small Business, both Prescriptive and Custom. The focus will be on Large C&I, while data for the Small Business programs was also reviewed for comparison. Measures addressed include occupancy, daylight dimming, photo sensor controls, advanced/network controls and wireless controls. Though prescriptive programs utilize the algorithms from the TRM, hours of use reduction are site specific, not deemed. This is similar for custom lighting controls projects.

DNV GL conducted the following research activities.

- **Task 1**: Savings Estimation Literature Review
- **Task 2**: Market Assessment Literature Review
- **Task 3**: Tracking Data Review
- **Task 4**: Review of Previous MA-LCIEC Studies
- **Task 5**: Program Staff Interviews
- **Task 6**: Lighting Vendor / Distributor Interviews

1.2 Program Description

Commercial and Industrial lighting controls are supported by all electric utility sponsors of this study effort. Specifically, each sponsor administers a program that promotes the installation of lighting controls. These programs include C&I Large Retrofit in both Prescriptive and Custom tracks[1]. In addition to these programs, this review will look at the C&I Small Business programs.

Regardless of the application or setting of the control installation, the savings for prescriptive programs are guided by the calculations in the Massachusetts Technical Reference Manual (TRM). The TRM is a document, updated annually and used by regulatory agencies, customers, and other stakeholders to calculate savings from the installation of efficient equipment. The reference manual provides methods, formulas and default assumptions for estimating energy, peak demand and other resource impacts from efficiency measures. Custom programs receive savings determined on a project-by-project basis.

1.3 Summary of Findings

The following sections provide a high level overview of the key findings of the study.

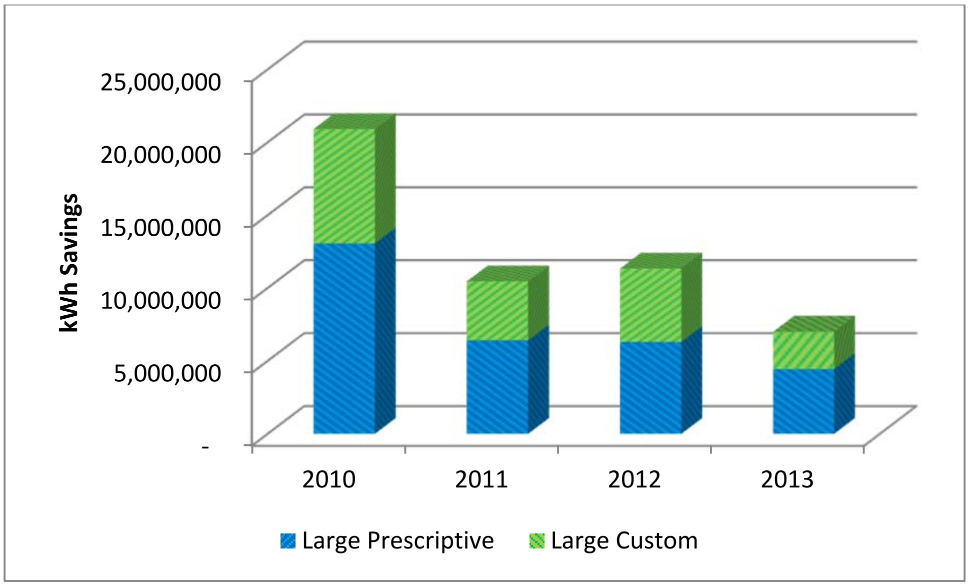
1.3.1 Massachusetts Lighting Controls Market Trends

DNV GL reviewed available tracking data to determine if the trends pointed out by the PAs can be explained by shifts in categorization, such as a shift from prescriptive to custom. It also looked to tease out trends within the data which may suggest whether reductions in the large C&I retrofit lighting controls program are occurring universally, or are confined to specific PAs or measure types. As shown in

[1] The MA PAs provide rebates for Large C&I lighting control retrofits in both their Prescriptive and Custom offerings. Prescriptive retrofits include occupancy sensors and daylight dimming controls in existing facilities that do not have pre-exisiting lighting controls. Custom retrofits generally include more complex control strategies, such as wireless, or whole building/networked controls.

Figure 1, the tracking data revealed a decline in retrofit lighting controls savings in the Large C&I program between 2010 and 2011 of about one half. The 2012 program year saw an increase of approximately 8% over the 2011 program year. However, 2013 saw large C&I lighting controls savings decrease to their lowest levels since 2010.

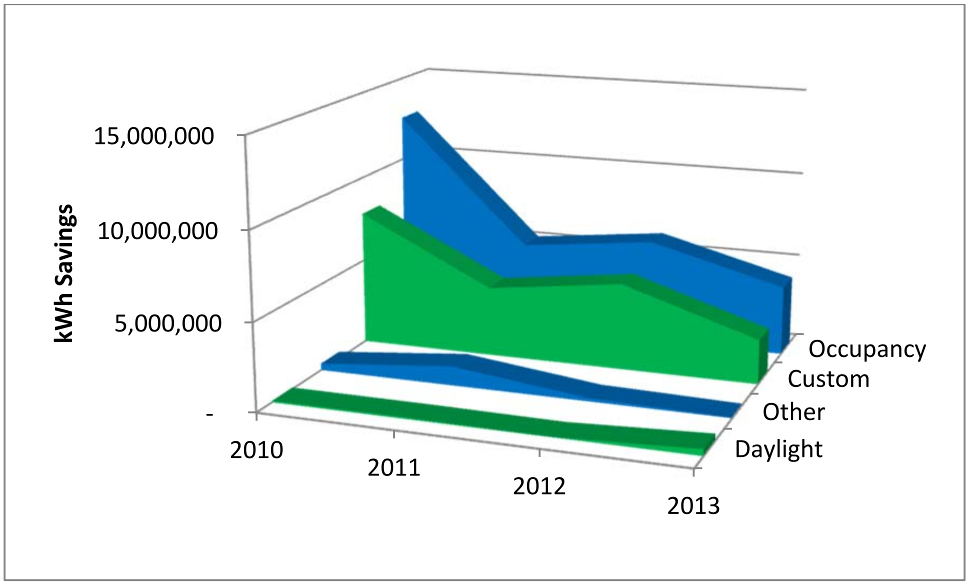
Figure 1: Retrofit Large C&I Lighting Controls Savings by Year



The data analysis showed that the decline occurred in both custom and prescriptive projects. Both custom and prescriptive lighting controls savings dropped more than 60% from 2010 to 2013 despite a small bounce back in 2012. The trend for custom projects is less trustworthy because it is possible that some of these projects include savings from both lighting systems and controls.

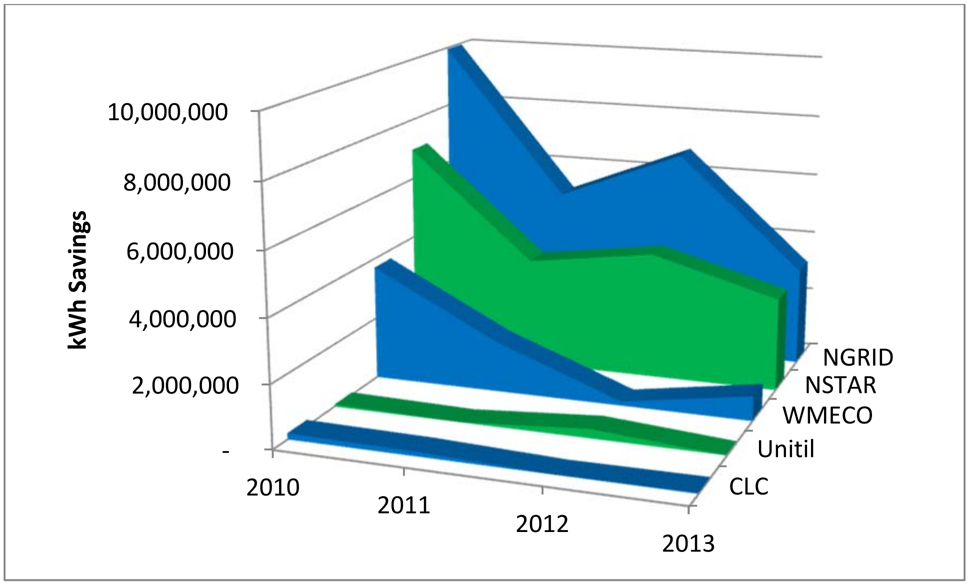
When reviewing the Large C&I savings by lighting control type in Figure 2, it was found that lighting controls savings are dominated by prescriptive occupancy sensors and custom projects. Both categories declined between 2010 and 2011, increased between 2011 and 2012, and declined again in 2013. Over the four year period, occupancy sensors decreased by about 70% while custom controls savings also decreased by about 70%. Daylighting represents a very small percentage of all lighting controls installations, but this technology did increase between 2012 and 2013.

Figure 2: Retrofit Large C&I Savings by Control Type



As shown in Figure 3, savings decreased for both of the large PAs (National Grid and NSTAR) between 2010 and 2013. The decreased savings for the large PAs between 2010 and 2011 bounced back partially in 2012, and dropped again in 2013. In 2013, National Grid Large C&I lighting controls savings decreased by 53% over 2012, and NSTAR decreased by 27% over 2012. These savings values are now 32% and 43% of 2010 savings, respectively. Lighting controls savings for WMECO dropped significantly between 2010 and 2012, but turned in a positive gain in 2013. CLC and Unitil claimed very few lighting control projects during these program years.

Figure 3: Retrofit Large C&I Controls Savings by PA



We do not have a clear answer at this time, based on this data, whether this trend reflects a market shift, a slowdown in the large C&I sector, changes in program planning, or other factors. Based on the research conducted in this study, and summarized in the sections below, we have some hypotheses of what may be driving the decline in savings. Table 1 presents a list of the potential reasons based on our research.

Table 1: Potential Reasons for Decline in Lighting Controls Savings

Potential Reasons for Decline	Evidence from this Study
Cost	MA-LCIEC Project 10[2] identified cost as a barrier to energy efficiency upgrades, while MA-LCIEC Project 1A[3] found that decreased costs and better performance would help boost controls savings in high bay applications. Though costs of controls haven't increased, costs for newer technologies such as wireless controls, remain higher.
Marketing	Interviews conducted with lighting contractors for MA-LCIEC Project 17[4] found that some of the smaller distributors may not be providing controls through the retrofit program, citing more marketing needed.
Rebates	MA-LCIEC Project 10 also noted that rebates for lighting controls do not have a large impact on the installation of controls.
Vendor Technical Awareness	PA interviews highlighted the issue surrounding vendor awareness and the ability for them to calculate energy savings and communicate those effectively to customers.
Saturation	Although most of the literature review and surveys concluded that there are still plenty of opportunities for lighting controls, some vendors did note that their impression is that occupancy sensors have been installed in many traditional commercial building types.

DNV GL also spoke with MA implementation program staff and MA implementation vendors to gather information on the recent trends in lighting controls installations.

Program Administrators were asked about the growth and decline of program sponsored lighting controls measures over the past several years. Respondents were asked to comment on each control type individually. The following bullets summarize the responses provided:

- Occupancy Sensors. This control type produced inconsistent responses. One respondent from a small PA stated that this measure type has produced a positive trend over time due to more customers becoming aware of control technologies. A second response from a large PA indicated that occupancy sensors are not as robust as they once were. This respondent indicated that there

[2] KEMA, Inc. Massachusetts Large Commercial & Industrial Process Evaluation. Prepared for the Massachusetts Energy Efficiency Program Administrators and the Massachusetts Energy Efficiency Advisory Council. July 2012.

[3] KEMA, Inc. HBL Market Effects Study Project 1A New Construction Market Characterization. Prepared for the Massachusetts Energy Efficiency Program Administrators and the Massachusetts Energy Efficiency Advisory Council. June 2011.

[4] KEMA, Inc. Process Evaluation of the Bright Opportunities Program. Prepared for the Massachusetts Energy Efficiency Program Administrators and the Massachusetts Energy Efficiency Advisory Council. June 2013.

are still opportunities, citing parking garages and high bay fluorescent or LED applications, but not as much in typical building applications due to possible saturation.

- Daylight Dimming. This type of control has never been very large due to challenges that are sometimes difficult to overcome. For example, it has been difficult for vendors to provide a strong methodology for how to quantify savings. It is also a more complex type of retrofit due to having to replace the entire lamp/ballast system, and is not attractive for existing buildings. This control type is better suited for new construction situations.

- Advanced/Network Controls. This technology typically includes whole building lighting controls, which are connected to a central control system, and can be programmed for optimal lighting control, including on/off and dimming. This is a newer technology that hasn't been fully integrated by some PAs yet. According to one large PA respondent, there appears to be an upward trend for this type of lighting control. There are some energy service companies (ESCOs) that are beginning to do a higher volume of these installations. However, there are some challenges due to the relatively high cost of this technology.

- Wireless Controls. Similar to advanced/network controls, wireless controls haven't been adopted by customers of some PAs yet. The noted advantage of wireless controls as compared to advanced/network controls is the cost. Wireless controls can communicate with a ballast to perform tasks such as dimming and task lighting, while avoiding having to run as much cable and wiring as needed for advanced/network controls.

Lighting vendors were asked if they noticed any industry trends over the past three years that would affect lighting controls installations within the large C&I retrofit programs. The following bullets provide a summary of the responses provided by vendors:

- Increase in installation of lighting controls for C&I buildings across all sectors.

- Trend of occupancy sensors is going towards more advanced technologies.

- Technology is changing with more converting to LEDs.

- Sensors are becoming more built in and network ready.

- One vendor noted that the cost of lighting controls is decreasing (cost was prohibitive for quite some time).

- Businesses are far more aware of what is available about things they can do to save energy.
- Impact of the building code updates (the utilities are reducing rebates due to code).

All lighting vendors surveyed report noticing changes in customers' level of understanding of the benefits of lighting control technologies over the past three years. Half the vendors indicate customers are asking more about advanced technology controls - especially daylight dimming controls.

1.3.2 Current and Expected Future State of Lighting Controls Market

To better understand whether the recent trends found for Massachusetts Large C&I Retrofit Lighting Control measures are occurring in other jurisdictions or nationally, DNV GL conducted a literature review of existing lighting control market potential studies and evaluations performed outside Massachusetts. DNV GL found that comprehensive research regarding trends seen in the lighting controls market and the expected market potential for occupancy sensors, daylight dimming, and photo sensor controls are rare. However, at a higher level, many of the reviewed studies did suggest that the retrofit lighting control market is not saturated and still offers a large opportunity for energy savings in commercial and industrial settings. A growing interest in wireless lighting controls and integrated systems, technologies currently not part of the prescriptive Massachusetts Large C&I Retrofit program, was also a reoccurring theme in many of the more recently published studies.

Interest in wireless lighting controls and integrated building systems has been growing in recent years. These technologies offer significant potential to address many of the barriers other control systems face, such as high costs and a lack of flexibility. The use of wireless lighting controls can reduce the barriers to adoption that exist for standard lighting control technologies. Wireless controls remove the need to run new wires to connect lighting systems therefore reducing installation time and costs. By being connected on a wireless network, lights can be controlled remotely as well which offers flexibility and additional operating options. As equipment costs decrease, this technology offers greater potential for controls installations.

It is likely that the reduced costs and additional control options would increase the adoption of these products over standard lighting controls in numerous retrofit applications, including existing buildings, street lighting, and parking garages. Current market trends indicate that demand for wireless controls will

increase the size of the lighting control market and sales of these controls will surpass hardwired controls.[5]
Trends also show growing interest in integrated systems. Integrated lighting systems allow additional flexibility: a remote operator can adapt conditions to current lighting needs, detect outages, and adjust lighting conditions

While there is a lack of quantitative information from other jurisdictions and at the national level regarding recent trends seen in retrofit lighting control programs that offer occupancy sensors, daylight dimming, and photo sensor controls, two major findings were uncovered in the literature review:

- Current market saturation for lighting controls is low but has more potential, and
- Substantial interest is growing in the market for wireless and integrated controls.

1.3.3 Recommendations for Program Expansion, Contraction and Future Marketing and Rebate Opportunities

1.3.3.1 High Potential Technologies

Interviews with program implementation staff, and lighting controls vendors highlighted some technologies in which the program may focus on in the future.

- **Advanced/Networked Lighting Controls** – Whole building, advanced/network lighting controls are becoming more prominent and cost effective as ESCOs are starting to implement these more frequently. This type of technology can be as sophisticated as lighting designers and programmers can make it. They can integrate the best of all lighting controls systems including, on/off scheduling, vacancy control, daylight dimming, and individual user controls. Though these types of systems are best suited for new construction types of projects, lighting vendors and designers should be encouraged, through program incentives, to look for opportunities to implement these complex systems in existing facilities where possible.

- **Wireless Controls -** Wireless controls are gaining in popularity as it allows the users to implement lighting controls without having to run the additional electrical wires necessary for traditional lighting controls. Wireless controls should be considered as a lower cost alternative to Advanced/Network controls in some retrofit applications.

[5] Spark Optoelectronics S&T, Global Lighting Controls Market Will Grow to 8 Billion Dollars by 2018, 2012

- **LED Lighting and Controls** – Many PAs and vendors surveyed noted the savings potential combining LEDs and lighting controls. There are many possible controls strategies offered with newer LED technology, including dimming capabilities. New LEDs with integrated controls offer increased lighting systems savings when combined in a package, or connected to an advanced system.

- **Daylight Dimming** – Many vendors suggested that customers are asking about daylight dimming controls more frequently. Vendors theorize that customers are becoming more comfortable with lighting controls systems, and are eager to learn more about how to make daylight dimming work in their facilities. It should be noted that some PA respondents thought that this was a challenging technology to implement due to the difficulties that some vendors have in explaining the savings and benefits for potential daylight dimming projects to their customers.

1.3.3.2 High Potential Sectors

The following represent some of the sectors in which the program may benefit from focusing more in terms of lighting controls opportunities. In addition to the specific sectors listed, spaces that are overilluminated, could benefit from more flexibility in light levels, while spaces with highly variable occupancy, are good candidates for lighting controls.

- **Offices** – There appear to be significant opportunities for lighting controls installations in office facilities. In addition to traditional occupancy/vacancy controls and daylight dimming controls, large offices would be good candidates for the more sophisticated types of controls, since they tend to have dedicated energy managers, and existing building automation systems.

- **Small business (<300 kW) -** There are opportunities for integral controls like common areas in multi-family buildings and hotels/motels. In this sector, one of the biggest advances is the advent of the dimming feature of LEDs.

1.3.3.3 Low Potential Technologies/Sectors

When asked if there were any technologies and/or sectors that the program shouldn't focus on as much, respondents generally stated that incentives should not be terminated or decreased for any technology or sector because there are still opportunities. However, some lighting vendors indicated that schools are difficult to implement effectively since some of them tend to have lower hours of use (i.e. less than 40 hours per week, and no summer operation).

1.3.3.4 Future Program Marketing and Rebate Opportunities

PAs and vendors were asked what they think the incentive programs could do to improve the number of retrofit lighting controls projects. In addition to vendors who unanimously suggested increasing incentives, the list below highlights some additional recommendations from PAs, vendors and DNV GL.

Many business are cautious about lighting system installations (i.e., how will it look, will it have right lumen output and color rendering properties). They suggest being able to try lighting controls for free for 30 days and if business doesn't like the system, have the technology taken out;

- Every lighting application should include an investigation of lighting controls at the site level. This would put more focus on lighting controls, and would require that vendors are better educated on the different technologies.
- Additional opportunities can come from training workshops reinforcing technical standards and savings quantifications. By providing these forums, program staff could be in a better position to assist vendors and future program participants on calculating baseline savings or redirect vendors to other retrofit control technologies to capture similar savings.
- Generate an energy savings calculation and presentation approach to show customers positive implications of installing lighting controls measure(s).
- Should keep all current incentives in place and just figure out way to implement specific incentives for advanced lighting controls. Consider increasing incentives for sites with 5,000 hours or more.
- Need to provide greater financial and technical assistance for more complex efficiency projects
- Need for more outside sales and account managers to contact and visit sites and bring in project expeditors to do implementation. Project expeditors are defined as PA authorized energy efficiency vendors. In buildings that appear to be good candidates for advanced controls, PAs may consider teaming with a lighting controls expert, who specializes in implementing advanced controls systems. Some project expeditors are not comfortable specifying lighting controls because they don't know how well they work;

1.3.4 Recommendations for Impact Evaluation and Savings Estimation Approach

DNV GL looked to gather the best information and methods currently available for calculating prescriptive lighting controls savings. The findings of this section focus mostly on occupancy sensors, since this technology currently dominates the prescriptive lighting controls savings in MA. The body of this report covers other technologies in addition to occupancy sensors.

DNV GL reviewed several sources, including the MA TRM, to be able to identify the best information and methods currently available for calculating prescriptive lighting controls savings. In addition to the MA TRM, the evaluation team reviewed the following studies:

- Focus on Energy Deemed Savings Manual[6]
- LBNL Meta Evaluation[7]
- Massachusetts SBDI Lighting Controls Evaluation[8]
- 2005 National Grid Lighting Controls Evaluation[9]
- Impact Evaluation of 2010 Prescriptive Lighting Installations[10]

1.3.4.1 Current Savings Estimation Approach from MA TRM

The calculation for prescriptive lighting controls savings essentially operates as a custom calculation. It calculates kWh savings using values obtained from the application, using the following formula:

$$\Delta kWh = (Controlled\ kW)(Hours_{base} - Hours_{EE})$$

$$\Delta kW = Controlled\ kW$$

Where

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[6] KEMA, Inc. *Business Programs: Deemed V1.0*. Prepared for State of Service Wisconsin. March, 2010.

[7] Erik Page & Associates, Inc. *A Meta-Analysis of Energy Savings from Lighting Controls in Commercial Buildings*. Prepared for the Ernest Orlando Lawrence Berkeley National Laboratory. September, 2011.

[8] The Cadmus Group: Small Business Direct Install Program: Pre/Post Lighting Occupancy Sensor Study. Prepared for the Massachusetts Utilities. October, 2012

[9] RLW Analytics. National Grid Lighting Controls Impact Evaluation FINAL REPORT: 2005 Energy Initiative, Design 2000plus and Small Business Services Programs. June, 2007.

[10] KEMA, Inc. Impact Evaluation of 2010 Prescriptive Lighting Installations. Prepared for the Massachusetts Energy Efficiency Program Administrators and the Massachusetts Energy Efficiency Advisory Council. June 2013.

Controlled kW = Controlled fixture wattage

$Hours_{base}$ = Total annual hours that the connected Watts operated in the pre-retrofit case.

$Hours_{EE}$ = Total annual hours that the connect Watts operate with the lighting controls implemented.

This equation calculates accurate savings estimates to the extent that the parameters entered into it are accurate. However, these parameters are drawn entirely from customer or vendor-reported information on the application, including *Hours of reduction.* and *.Controlled kW*. While *Controlled kW* is relatively easy to accurately estimate from product cut sheets of lamp and ballast configurations, *Hours (reduction)* is notoriously hard to estimate accurately. The program does not require the customer to perform any kind of M&V activities, so empirical data is rarely collected. This issue may compromise the accuracy of tracking savings estimates for retrofit lighting controls.

1.3.4.2 Percent Savings

DNV GL recommends that the program make a change to its current calculation methodology. We recommend that the program adopt the parameter Percent Savings (%Sav) for use in its lighting controls energy savings calculation going forward. This parameter, used by most other programs and research institutions, allows for a more intuitive calculation of savings for all lighting controls measures, including those which do not turn off lights completely such as daylight dimming. Using Percent Savings results in the following formula:

*ΔkWh = Controlled kW * 〚Hours〛_base * %Sav*

DNV GL compared occupancy sensor savings from each study by space type, as data were available. Percent reduction values were available from all studies but the National Grid study, and may be applicable to the Massachusetts TRM, which has default hours of operation estimates by building type in the appendix of the document, which can be multiplied by percent reduction to get to hours reduced by building type. However, since most MA PAs utilize site specific hours estimates in their savings calculations, an alternative approach would be to apply the percent reduction against evaluated MA site specific hours.

- DNV GL recommends using the weighted average values from the LBNL study, which is weighted by the total number of studies used for calculating percent reduction for each facility type. The percent savings value for occupancy sensors is 24%, and the percent savings value for daylight dimming is 28%. This recommendation should apply for all occupancy sensor and daylight dimming installations until a new large C&I lighting controls study is completed.

1.3.4.3 Coincidence Factors

Table 2 below shows the coincidence factor results from all occupancy sensor sources together. Coincidence factors are multiplied by the Controlled kW to estimate summer or winter peak kW reductions.

Table 2 – Occupancy Sensor CF Source Summary

Coincidence Factor	MA 2010 Prescriptive Lighting	National Grid Occupancy Sensor Large	National Grid Occupancy Sensor Small	SBDI Occupancy Sensor
Summer On-Peak	15.0%	30.4%	34.8%	17.0%
Winter On-Peak	13.3%	19.2%	28.0%	13.0%
Summer Seasonal Peak	14.3%	N/A	N/A	N/A
Winter Seasonal Peak	13.9%	N/A	N/A	N/A

The National Grid and SBDI studies are both less than ideal since the National Grid study was based on a small sample size, and the SBDI study is focused on small C&I, while this evaluation deals with large C&I. Note that the SBDI study was the only study to utilize pre/post metering, while the MA 2010 Prescriptive Lighting, and National Grid studies used post-only metering.

- DNV GL recommends that the program continues to use the CF values from the recent 2010 prescriptive lighting impact evaluation for all occupancy sensor installations until a new large C&I lighting controls study is completed..

1.3.4.4 Future Impact Evaluation

DNV GL reviewed several studies, savings estimation methods, and had detailed conversations with program staff and lighting controls vendors in an effort to understand the lighting controls market in MA. The results of this study show that there is some uncertainty of the future of lighting controls as more new technologies infiltrate the market, and customers are becoming more comfortable with controls strategies. However, it is clear that lighting controls will continue to be offered as a measure, and there will always be a need for accurate savings estimates. Recommendations for future impact evaluations include:

- DNV GL recommends that the PAs implement the above savings estimation methods and savings values until a new statewide lighting controls impact evaluation can be conducted. When it comes time for a new impact evaluation, DNV GL strongly suggests that the PAs consider a full pre/post metering approach. Pre/Post metering of lighting controls will be difficult to employ, but it offers the most rigorous approach for estimating the key savings parameters; percent savings and the coincidence factors.

2. Introduction

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DNV GL conducted the following research activities.

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4. Program Description

Commercial and Industrial lighting controls are supported by all electric utility sponsors of this study effort. Specifically, each sponsor administers a program that promotes the installation of lighting controls. These programs include C&I Large Retrofit in both Prescriptive and Custom tracks. In addition to these programs, this review will look at the C&I Small Business programs.

Regardless of the application or setting of the control installation, the savings for prescriptive programs are guided by the calculations in the Massachusetts Technical Reference Manual (TRM). The TRM is a document, updated annually and used by regulatory agencies, customers, and other stakeholders to calculate savings from the installation of efficient equipment. The reference manual provides methods, formulas and default assumptions for estimating energy, peak demand and other resource impacts from efficiency measures. Custom programs receive savings determined on a project-by-project basis.

5. Summary of Findings

The following sections present the findings of each individual task. Tasks 1 through 4 are covered in this summary, as well as a draft program staff interview guide.

5.1 Task 1: Savings Estimation Literature Review

This task looked to gather the best information and methods currently available for calculating prescriptive lighting controls savings. It presents these methods and provides an assessment as to their relevance with respect to the Massachusetts Large C&I Retrofit Lighting Controls program. The findings of this section is intended to help the program administrators decide whether the Large C&I Retrofit Lighting Controls impact evaluation, if undertaken, will require further data collection in order to make an accurate enough estimate of savings based on the current and future expected program size.

This section contains one subsection for each measure type, outlining and evaluating the currently used methodology, presenting industry best practices, and making recommendations for adjustments to program energy savings calculations.

5.1.1 Review of Current Methodology

The MA TRM currently offers a single calculation for Lighting Controls, which covers the following measures:

- Occupancy Sensing
    - Remote Mounted Occupancy Sensor
    - Occupancy Controlled Step Dimming System
    - Wall Mounted Occupancy Sensor
    - Wall Mounted Vacancy Sensor
    - High Bay Fluorescent (HIF) Occupancy Control Systems
- Daylight Dimming System

The calculation for these measures essentially operates as a custom calculation. It calculates kWh savings using values obtained from the application, using the following formula:

$$\Delta kWh = (Controlled\ kW)(Hours_{base} - Hours_{EE})$$

$$\Delta kW = Controlled\ kW$$

Where

Controlled kW = Controlled fixture wattage

$Hours_{base}$ = Total annual hours that the connected Watts operated in the pre-retrofit case.

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This equation calculates accurate savings estimates to the extent that the parameters entered into it are accurate. However, these parameters are drawn entirely from customer or vendor-reported information on the application, including *Hours* and *Controlled kW*. While *Controlled kW* is relatively easy to accurately estimate from product cut sheets of lamp and ballast configurations, *Hours (reduction)* is notoriously hard to estimate accurately. The program does not require the customer to perform any kind of M&V activities, so empirical data is rarely collected. This issue may compromise the accuracy of tracking savings estimates for retrofit lighting controls.

The program also applies a Realization Rate to savings estimates at the end of the program evaluation period. The realization rate for this measure includes HVAC Interaction. Summer and Winter coincidence factors (CF) are also applied to calculate summer and winter peak demand savings. The program determines coincidence factors based on the following time periods:

- Summer On-Peak: Average weekday from 1-5 PM, June - August.
- Winter On-Peak: Average weekday from 5-7 PM, December - January

Current CF values claimed by the various Program Administrators appear below in Table 3.

Table 3 – CF Values Currently in Use

PA	Measure	CF_{SP}	CF_{WP}
All	All	0.15	0.13

Note that WMECO uses custom CFs, which are based on a seasonal peak calculation methodology, not the on-peak definitions above.

In the following subsections, we review best practices and make recommendations for updates to parameters used in lighting control calculations for each prescriptive measure: occupancy sensors and daylight dimming controls.

5.1.2 Occupancy Sensors

This review will distinguish savings by space type. For measures which do not turn lighting all the way off (such as hi-lo control), controlled lighting wattage should only include the wattage by which the lighting power is reduced. Note that the review of 2010 through 2011 program tracking data did not find any vacancy sensors, which are a manual on and auto off control, claimed as such. Therefore, this review does not include an evaluation of vacancy sensors.

5.1.2.1 Best Practices

This section contains a review of industry best practices for calculating occupancy sensor energy (kWh) and demand (kW) savings. The following studies will be summarized below:

- Focus on Energy Deemed Savings Manual[11]
- LBNL Meta Evaluation[12]
- Massachusetts SBDI Lighting Controls Evaluation[13]
- 2005 National Grid Lighting Controls Evaluation[14]
- Impact Evaluation of 2010 Prescriptive Lighting Installations[15]

5.1.2.1.1 Focus on Energy Deemed Savings Manual

The Focus on Energy evaluation is based on a comparison of two sources, the EPA and EPRI. It is unclear what the scope of both studies included, but both present dedicated results for occupancy sensors, and is included here for completeness. The EPA data[16] remains publicly available, while the EPRI data is not publicly available at this time. Percent savings results are shown below in Table 4.

Table 4 – Focus on Energy Occupancy Sensor kWh Percent Savings Results

Application	Percent Savings		
	From EPA	From EPRI	Value Chosen
Private office	13–50%	25%	25%
Open office			20%
Classroom	40–46%		40%
Conference room	22–65%	35%	35%
Break room			35%
Restroom	30–65%	40%	40%
Corridor	30–80%		50%
Storage area	45–80%		50%
Hotel meeting room		65%	65%
Warehouse			50%
Average			**41%**

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[11] KEMA, Inc. *Business Programs: Deemed V1.0*. Prepared for State of Service Wisconsin. March, 2010.

[12] Erik Page & Associates, Inc. *A Meta-Analysis of Energy Savings from Lighting Controls in Commercial Buildings*. Prepared for the Ernest Orlando Lawrence Berkeley National Laboratory. September, 2011.

[13] The Cadmus Group: Small Business Direct Install Program: Pre/Post Lighting Occupancy Sensor Study. Prepared for the Massachusetts Utilities. October, 2012

[14] RLW Analytics. National Grid Lighting Controls Impact Evaluation FINAL REPORT: 2005 Energy Initiative, Design 2000plus and Small Business Services Programs. June, 2007.

[15] KEMA, Inc. Impact Evaluation of 2010 Prescriptive Lighting Installations. Prepared for the Massachusetts Energy Efficiency Program Administrators and the Massachusetts Energy Efficiency Advisory Council. June 2013.

[16] http://www.esource.com/BEA/demo/BEA_esource/PA_10.html

5.1.2.1.2 LBNL Meta Evaluation

Similar to the scope of this MA Lighting Controls study, the LBNL Meta evaluation looked at a number of different sources and compared the results based on their merit. This was accomplished by filtering out studies that included savings data from both lighting systems and controls combined, removing data points that were based on a savings fraction of total building energy and those that represented a non-comparable savings type. Additionally, it removed any savings that did not come from actual installations (i.e. simulations were not included). Of the remaining studies that included actual installations, 65% of the savings estimates came from monitoring the post and estimating the baseline. Approximately 28% of the savings estimates came from monitoring both the baseline and post conditions. It is unclear how the remaining savings estimates were generated. It may present the most reliable energy savings estimates for lighting controls savings nationwide. The sources used in this study are attached in Appendix C. Table 5 below shows the percent savings results from this meta-analysis following the filtering process described above. "n" refers to the number of studies considered in the meta-analysis for that space type. It appears that the percent savings values represent the straight average of all sources used.

Table 5 – LBNL Occupancy Sensor kWh Percent Savings Results

Building Type	n	% Savings
Office	23	22%
Warehouse	4	31%
Lodging	2	45%
Education	5	18%
Public assembly	2	36%
Health care outpatient	1	23%
Other	1	7%

5.1.2.1.3 Massachusetts SBDI Lighting Controls Evaluation

The MA SBDI Lighting Controls evaluation based its results on 203 lighting logger installations for small business customers in Massachusetts. The savings estimates from this study are based on occupancy sensor-specific pre-post metering, which is the crème-de-la-crème of lighting controls evaluation methods. While these results don't directly apply to the Large C&I program, as large businesses often operate differently than small ones, the quality of the results, and the fact that they originate in MA, requires they be considered. Percent savings results are shown below in Table 6.

Table 6 – SBDI Occupancy Sensor kWh Percent Savings Results

Space Type	Loggers	Percent Savings
Active Storage	27	68%
Atrium	1	-2%
Classroom/Lecture/Training	20	17%
Conference/Meeting/Multipurpose	10	22%
Corridor/Transition	5	69%
Dining Area	8	14%
Dressing/Locker/Fitting Room	1	31%
Electrical/Mechanical	4	54%
Exterior	2	54%
Food Preparation	3	-29%
Inactive Storage	8	24%
Laboratory	2	1%
Lobby	1	-3%
Lounge/Recreation	7	35%
Office - Enclosed	49	14%
Office - Open	16	-1%
Restrooms	39	42%
TOTAL	**203**	**37%**

These results show a range of values, some having more confidence than others based on the sample size. Some values show highly positive results and others negative results. Negative values are the result of lighting being on more than without controls. Both types of results can occur in specific space types which are especially well or poorly suited to occupancy sensor installation.

Table 7 below shows coincidence factor results from this evaluation.

Table 7 – SBDI Occupancy Sensor CF Results

Utility	CF_{SP}	CF_{WP}
CLC	-3%	5%
National Grid	22%	13%
NSTAR	6%	12%
Unitil	80%	38%
WMECO	11%	6%
Statewide	17%	13%

The CF results show the same trends as the percent savings results do, which is primarily positive results but one negative depending on circumstances. CF results from this study are not as useful as the percent savings results, as they cannot be directly applied to space type.

5.1.2.1.4 2005 National Grid Lighting Controls Evaluation

This National Grid Lighting Controls evaluation based its results on site visits with 25 Large C&I and 15 Small Business National Grid customers in Massachusetts. Site visits included interviews, inspections, and short-term, post-only, logger data collection. It found the following results, shown in Table 8.

Table 8 – Results from 2005 Mass. LC Evaluation for Occupancy Sensors

Parameter	Large C&I	Small Business
ΔHrs	2,040	1,577
CF_{SP}	30.4%	28.0%
CF_{WP}	19.2%	34.8%

5.1.2.2 Impact Evaluation of 2010 Prescriptive Lighting Installations

This statewide prescriptive lighting impact evaluation included results from 26 Large C&I on-sites in Massachusetts. Site visits included interviews, inspections, and short-term, post-only, logger data collection. The results from the study are shown in Table 9 below.

Table 9 – Results from 2010 Mass. Large C&I Impact Evaluation

Parameter	Value
Hours of Use Reduction Realization Rate	77.9%
CF_{SP}	15.0%
CF_{WP}	13.3%

The current MA TRM uses these Large C&I CF results to calculate savings for all MA PAs.

5.1.2.3 Recommendations

5.1.2.3.1 Percent Savings

Table 10 below shows the hours reduction results from all the sources compiled together. This table is divided into two sections: one section for hours reduced, and another for percent reduction. Percent reduction is available from all studies but the National Grid study, and may be applicable to the Massachusetts TRM, which has default hours of operation estimates by building type in the appendix of the document, which can be multiplied by percent reduction to get to hours reduced by building type. However, since most MA PAs utilize site specific estimates in their savings calculations, an alternative approach would be to apply the percent reduction against the site specific hours of operation from the application. Any value with a sample (n) less than 5 is removed from consideration.

Table 10 – Occupancy Sensor kWh Percent Savings and Hours Reduced Source Summary

	Mass. SBDI	**Focus**	**LBNL**	**Mass. SBDI**	**National Grid LCI**	**National Grid SBS**
Space Type	**Percent Reduction**			**Hours Reduced**		
Active Storage / Warehouse	68%	50%	31%	2,896		
Classroom/Lecture/Training	17%	40%	18%	316		
Conference/Meeting/Multipurpose	22%	35%		437		
Corridor/Transition	69%	50%		4,806		
Dining Area	14%	35%		364		
Electrical/Mechanical	54%			592		
Inactive Storage	24%	50%		127		
Lounge/Recreation	35%			1,129		
Office - Enclosed	14%	25%		278		
Office - Open	-1%	20%	22%	-14		
Restrooms	42%	40%		1,609		
Retail (other than mall)						
Health care outpatient			23%			
Lodging			45%			
Public assembly			36%			
Hotel meeting room		65%				
TOTAL	**37%**	**41%**	**24%**	**1,022**	**2,040**	**1,577**

Here we see that values for some sectors seem to correlate strongly between studies, while others do not correlate well. The most striking difference is Office – Open, for which the SBDI evaluation found a negative value (n=16) but the two other studies found a significant positive value. This may result from the difference between small and large C&I, be a fluke of the sample, or occur for another unknown reason. The overall average value for the LBNL study may be low because of its lack of values for certain space types such as corridor, which can have large savings.

DNV GL recommends using the LBNL overall weighted average reduction of 24% for energy savings, which is weighted by the total number of studies used for calculating percent reduction for each facility type from Table 5 above. This value is based on a number of actual installations, most with metering, and some with baseline metering. DNV GL recommends that this value is applied to site specific estimates of annual hours of operation to calculate annual energy savings. This recommendation should apply for all occupancy sensor installations until a new large C&I lighting controls study is completed.

5.1.2.3.2 Coincidence Factors

Table 11 below shows the coincidence factor results from all occupancy sensor sources together. Only one of the studies offered these percentages by building type, so they are shown aggregated here.

Table 11 – Occupancy Sensor CF Source Summary

Coincidence Factor	MA 2010 Prescriptive Lighting	National Grid Occupancy Sensor Large	National Grid Occupancy Sensor Small	SBDI Occupancy Sensor
Summer On-Peak	15.0%	30.4%	34.8%	17.0%
Winter On-Peak	13.3%	19.2%	28.0%	13.0%
Summer Seasonal Peak	14.3%	N/A	N/A	N/A
Winter Seasonal Peak	13.9%	N/A	N/A	N/A

The National Grid and SBDI studies are both less than ideal since the National Grid study was based on a small sample size, and the SBDI study is focused on small C&I, while this evaluation deals with large C&I. Note that the SBDI study was the only study to utilize pre/post metering, while the MA 2010 Prescriptive Lighting, and National Grid studies used post-only metering. DNV GL recommends that the program continues to use the CF values from the recent 2010 prescriptive lighting impact evaluation for all occupancy sensor installations until a new large C&I lighting controls study is completed.

5.1.3 Daylight Dimming System

This section contains a review of industry best practices for calculating interior daylight dimming sensor energy (kWh) and demand (kW) savings. This review will distinguish savings by space type. We only found one independent study which distinguished savings for daylight dimming from occupancy sensor savings.

5.1.3.1 Best Practices

5.1.3.1.1 LBNL Meta Evaluation

The LBNL Meta evaluation is based on a review similar in scope to this MA lighting controls study, in that it looked at a number of different sources and compared the results based on their merit. It may present the most reliable energy savings estimates for lighting controls savings nationwide. The sources used in this study are attached in Appendix C. Table 12 below shows the percent savings results from this meta-analysis. "n" refers to the number of studies considered in the meta-analysis for that space type.

Table 12 – Daylight Dimming kWh Percent Savings Results

Building Type	n	Percent Savings
Office	18	27%
Warehouse	1	28%
Education	7	29%
Retail (other than mall)	3	29%
Public assembly	1	36%
Average		**28%**

5.1.3.2 Recommendations

5.1.3.2.1 Percent Reduction

DNV GL recommends that the program adopt the weighted average savings shown above in Table 12, which is weighted by the total number of studies used for calculating percent reduction for each facility type. Daylight dimming currently makes up a small portion of the programs' energy savings; however, if the PAs hope to expand the daylight dimming program, they may consider performing a study to look at savings for daylight dimming percent savings in MA.

5.1.3.2.2 Coincidence Factors

DNV GL was unable to find any studies which look at coincidence factor for daylight dimming. Again, if the program is looking to expand in daylight dimming applications, the PAs should consider implementing a study to look at CFs for daylight dimming measures.

5.1.4 MA TRM Recommendations

DNV GL recommends that the program make a change to its current calculation methodology. We recommend that the program adopt the parameter Percent Savings (%Sav) for use in its lighting controls energy savings calculation going forward. This parameter, used by most other programs and research institutions, allows for a more intuitive calculation of savings for all lighting controls measures, including those which do not turn off lights completely such as daylight dimming. Using Percent Savings results in the following formula:

$$\Delta kWh = Controlled\ kW * Hours_{base} * \%Sav$$

5.2 Task 2: Market Assessment Literature Review

To better understand whether the recent trends found in the Massachusetts Large C&I Retrofit Lighting Control programs are occurring in other jurisdictions or nationally, DNV GL conducted a literature review of existing lighting control market potential studies and evaluations performed outside Massachusetts. DNV GL found that comprehensive research regarding trends seen in the lighting controls market and the expected market potential for occupancy sensors, daylight dimming, and photo sensor controls are rare. However, at a higher level, many of the reviewed studies did suggest that the retrofit lighting control market is not saturated and still offers a large opportunity for energy savings in commercial and industrial settings. A growing interest in wireless lighting controls and integrated systems, technologies currently not part of the Massachusetts Large C&I Retrofit Lighting Control program, was also a reoccurring theme in many of the more recently published studies.

The detailed findings from the market assessment literature review are discussed in the following sections. As the intent of this task was to understand the lighting control market, with emphasis on technologies currently offered in the Massachusetts Large C&I Retrofit Lighting Control programs, the discussion starts with information on general trends and then discusses occupancy sensors, daylight dimming, and photo sensor controls. As the research also uncovered a growing interest in new control technologies, a section on wireless controls and integrated systems is also included.

5.2.1 General Trends in Lighting Controls

5.2.1.1 Market Saturation and Potential

The 2010 U.S. Lighting Market Characterization study conducted by the Energy Efficiency and Renewable Energy program at the United States Department of Energy highlighted the need to focus program efforts on commercial lighting as it showed that 50% of the electricity used nationally for lighting is from commercial buildings (EERE 2012). Industrial and outdoor lighting consume an additional 8% and 17% of electricity used for lighting. Likewise, according to the most recent Commercial Buildings Energy Consumption Survey (CBECS), lighting accounts for roughly one third of total commercial electricity consumption (United States Department of Energy n.d.). However, since 2001, the efficiency of installed bulbs in the commercial sector has increased and although commercial floor space and average operating hours have increased, the total energy used for lighting has decreased (EERE 2012).

Many studies indicated that despite the improvements in bulb efficiencies there is still a large opportunity for the retrofit lighting control market in commercial and industrial facilities. The 2003 CBECS showed that a very small percentage of commercial buildings had any form of automated lighting control; 2% had daylight dimming systems and 1% used energy management systems or other controls on the lighting system (United States Department of Energy n.d.). While the penetration of lighting controls has increased since 2003 nationally, today only 12% of bulbs in commercial facilities are operated with lighting controls such as dimmers, occupancy sensors, timers, and light sensors and another 18% of bulbs are controlled through the use of EMS (EERE 2012)[17]. The saturation for automated controls is still low and the majority of lighting systems are still controlled by manual switches only. A baseline study in Pennsylvania estimated that 75% of the state's commercial and industrial floor space is lit by bulbs controlled only with manual on/off switches (Nexant 2012). Similarly, in Michigan, 98% of commercial buildings still use manual switches, and only 6% have installed occupancy sensors (Cadmus 2011). An analysis of retrofit lighting data in California also indicated that lighting control retrofits were still rare, and when installed, most projects only include the area controls required by Title 24.

The National Electrical Manufacturers Association (NEMA) has long argued that lighting controls have greater potential for savings than increases in bulb efficacies and that the addition of lighting controls into lighting standards will lead to increased savings (Department of Energy 2011). A meta-analysis of savings for lighting controls conducted by LBNL suggests potential savings of 24% for occupancy sensors and 28% for daylight dimming (LBNL 2011). Likewise, a recent market potential study in Maine estimated that 37.4% of potential savings in industrial lighting and 27.8% of potential savings in commercial lighting can be achieved through the installation and use of controls. Yet, despite the growing interest in saving energy and the known potential savings from these technologies, the retrofit lighting control market still experiences low saturation across the nation.

5.2.2 Currently Offered Technologies

5.2.2.1 Occupancy Sensors

Occupancy sensors are the most popular automated lighting control solution in the country. They currently represent 30% of the lighting control market in commercial facilities and are growing in the industrial sector as well (BSIRA 2010). 8.2% of all commercial and industrial floor space in Pennsylvania is lit by lighting controlled with occupancy sensors (Nexant 2012), though nationally the

[17] The 2010 U.S. Lighting Market Characterization study did not report on lighting controls in the industrial sector or for outdoor lighting.

penetration does vary by building type, with schools and universities being some of the largest adopters (Lighting Control Association). California has also considered making occupancy sensors mandatory for warehouse and library aisles (California Utilities Statewide Codes and Standards Team 2011).

This technology has a potential savings of 24% for lighting systems with no automated controls. Occupancy sensors account for 27.8% of lighting energy savings potential in the Maine commercial sector and 13.6% of the industrial lighting energy savings potential (Cadmus 2012).

The literature review also uncovered barriers to the adoption of occupancy sensors. Among users of occupancy sensors, false on/off switching and delays are the biggest complaint (Lighting Control Association n.d.). The installation of hardwired occupancy sensors in existing buildings also requires rewiring, a large initial cost than can be prohibitive and make occupancy sensors a less attractive control strategy, especially in office spaces with numerous subdivisions (California Utilities Statewide Codes and Standards Team 2011). It is possible that because of these barriers, interest in occupancy sensors has waned while interest in alternative control types has piqued as users look for more affordable and versatile options.

5.2.2.2 Daylight Dimming

Daylight dimming controls are less common than occupancy sensors. In 2003, 2% of commercial buildings had daylighting controls (United States Department of Energy). In Pennsylvania, daylighting sensors are used to control lighting on less than 1% of all commercial and industrial floor space (Nexant, 2012). Nationally, light sensors, including daylight dimming and photo sensor (on/off) controls, are found in less than 1% of commercial facilities and is installed more frequently on HID lighting than other types of bulbs (EERE, 2012). Moreover, it was noted that the use of architectural daylighting is the least important trend in lighting controls but is expected to increase as more architects adopt daylighting design in their practices (Lighting Control Association).

Currently, daylight dimming faces numerous barriers to adoption. While daylight dimmers are expected to save an average of 28%, actual savings do not meet expected savings due to ineffective designs, user misuse, failure to properly calibrate controls, and poor documentation and specifications (The Weidt Group). Initial cost is another major barrier for daylight controls that also inhibits its adoption (Lighting Control Association).

5.2.2.3 Photo Sensor Controls

Similar to daylight dimmers which also use light sensors, photo sensor (on/off) controls are also not found in many commercial and industrial facilities. Photo sensor (on/off) controls differ from daylight dimmers by turning lights completely on or off depending on availability of ambient light. As discussed in the previous section, less than one percent of commercial facilities have light sensors installed on their lighting systems. Although photo sensor controls have not penetrated the built environment, they are becoming a popular strategy for street lighting and parking garages. Standard controls on street lights use photo sensors to turn the lights on at dusk and off at dawn, but new technologies are being piloted that will allow for further control of these lights. The current trends are showing streetlight operators are interested in using these new technologies with LED street lighting as HID bulbs do not allow for dimming (NEEA, 2011).

Photo sensor controls also have shortcomings that have impacted the adoption of this technology. Many building operators cite photo sensor controls as complex systems that are difficult to calibrate and manage. Many photo sensors have been installed incorrectly, in part due to the complexity of the systems. As a result, photo sensor controls are often disabled or do not operate as expected. In functioning systems, photo sensor controls save 53% of expected savings (Herschong Mahone Group, 2006). Furthermore, costs for photo sensor controls is also a barrier, though research done by the California Utilities Statewide Codes and Standards Team shows that the technology is cost effective if the product functions properly (California Utilities Statewide Codes and Standards Team, 2011).

5.2.3 New Technologies

Interest in wireless lighting controls and integrated building systems has been growing in recent years. These technologies offer significant potential and address many of the barriers other control systems face, such as high costs and a lack of flexibility. A recently developed wireless integrated lighting control system with photo sensors and occupancy sensors is expected to save between 40% of baseline lighting energy in offices (PIER).

The use of wireless lighting controls can reduce the barriers to adoption that exist for standard lighting control technologies. Wireless controls remove the need to run new wires to connect lighting systems therefore reducing installation time and costs. Installation times for wireless control systems are expected to be 50% less than standard controls (PIER). By being connected on a wireless network, lights can be controlled remotely as well which offers flexibility and additional operating options. Using wireless controls would allow the lighting system to connect to smart meters and be controlled by users' smart phones and tablets (Peter Rand).

It is likely that the reduced costs and additional control options would increase the adoption of these products over standard lighting controls in numerous retrofit applications, including existing buildings, street lighting, and parking garages. Current market trends indicate that demand for wireless controls will increase the size of the lighting control market and sales of these controls will surpass hardwired controls (SPARK OPTOELECTRONICS S&T, 2012). Currently, in California, 17% of retrofit projects over the past two years are using wireless lighting controls (California Utilities Statewide Codes and Standards Team, 2011) and are expecting a 2 to 5 year payback period without incentives (PIER).

Trends also show growing interest in integrated systems, which are lighting controls integrated with building automation systems. The 2010 U.S. Lighting Market Characterization study suggested rapid growth in open source lighting, which is software that can provide building operators the ability to monitor and adjust lighting over the internet (EERE, 2012). California's lighting action plan highlights the need to reduce lighting control costs and to establish integration protocols for lighting systems with all building systems and smart grid (Engage 360, 2011). Integrated lighting systems allow additional flexibility: a remote operator can adapt conditions to current lighting needs, detect outages, and adjust lighting conditions based on occupant preferences. While costs for integrated, networked street lighting systems are still high, it is expected that these costs will drop as the technology advances in popularity and manufacturers recognize economies of scale (NEEA, 2011).

Various case studies in California have shown the benefits of wireless and integrated lighting systems. An integrated lighting system installed at a college in Oakland utilized wireless controls and gave users the ability to take advantage of daylight dimming, occupancy sensors, and scene control for operators. Scene control refers to switching between lighting "scenes," which are programed to provide varying lighting scenarios for unique functions and occupancy. Logging data obtained from this project estimates a savings of 54% over the baseline lighting. (California Energy Commission's Public Interest Energy Research Program, 2012). Another case study conducted by PIER highlights the benefits of using wireless, adaptive controls in commercial hallways, areas that are often lit 24 hours a day despite their infrequent use. By using the wireless, adaptive controls, hallway lighting in an Oakland office building was dimmed to the minimum level when not needed, and increased when wireless occupancy sensors detected motion. The use of wireless controls decreased the cost of this project and the expected payback period without incentives would have been 3 years and 4 months. It is expected that the new controls will reduce the energy use of these lights by 86%. (California Energy Commission's Public Interest Energy Research Program, 2012)

5.2.4 Conclusions

While there is a lack of quantitative information from other jurisdictions and at the national level regarding recent trends seen in retrofit lighting control programs that offer occupancy sensors, daylight dimming, and photo sensor controls, two major findings were uncovered in the literature review: current market saturation for lighting controls is low but has more potential and substantial interest is growing in the market for wireless and integrated controls. Task 3: Tracking Data Review

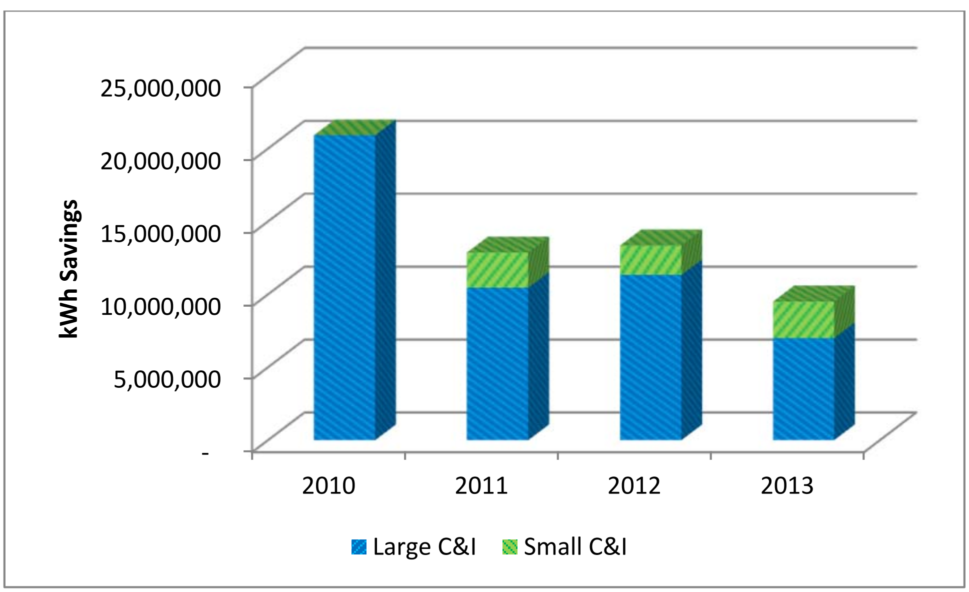
DNV GL reviewed available tracking data to determine if the trends pointed out by the PAs can be explained by shifts in categorization, such as a shift from prescriptive to custom. It also looked to tease out trends within the data which may suggest whether reductions in the installation of large C&I retrofit lighting controls are occurring universally, or are confined to specific PAs or measure types.

DNV GL currently has access to program tracking data for Large C&I for the years 2010 through 2013, and for Small C&I for 2011 and 2013.

5.2.5 Data Analysis

Figure 4 shows the overall kWh savings for lighting control measures for Large and Small C&I between 2010 and 2013, organized by installation date. Note that Small C&I data begins in 2011.

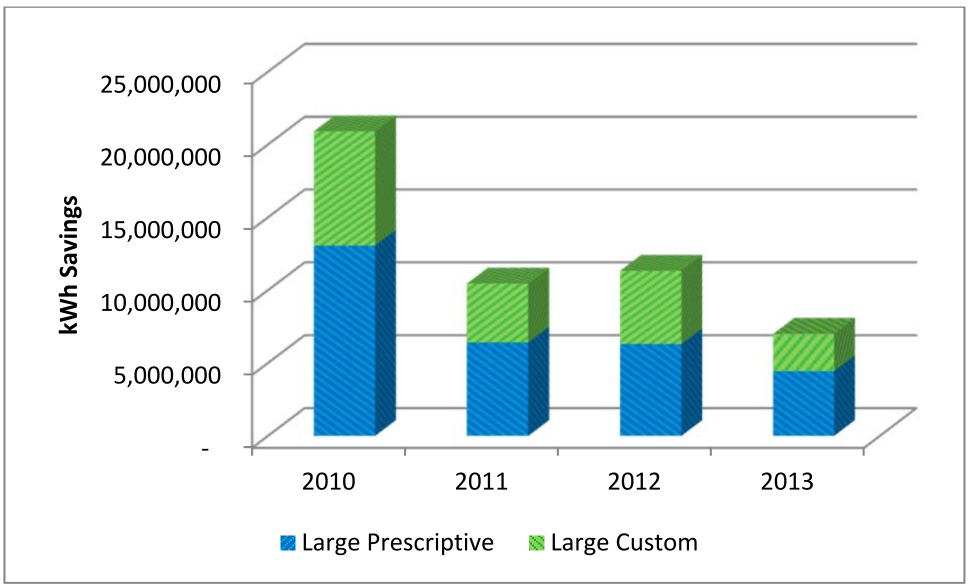
Figure 4: Retrofit Lighting Controls Savings



As discussed above, we see here a decline in savings in the Large C&I program between 2010 and 2011 of about one half. However, the 2012 program year saw an increase of approximately 8% over the 2011 program year, which was due to an increase in Custom installations. Program year 2013 saw another drop to its lowest levels since 2010.

Figure 5 shows the Large C&I data broken up by custom and prescriptive tracks. Note that the data for custom projects is incomplete and may be misleading, as many projects contain both lighting and lighting controls and the databases do not distinguish between them. Custom projects included below contain words in the measure description that indicate that lighting controls are included.

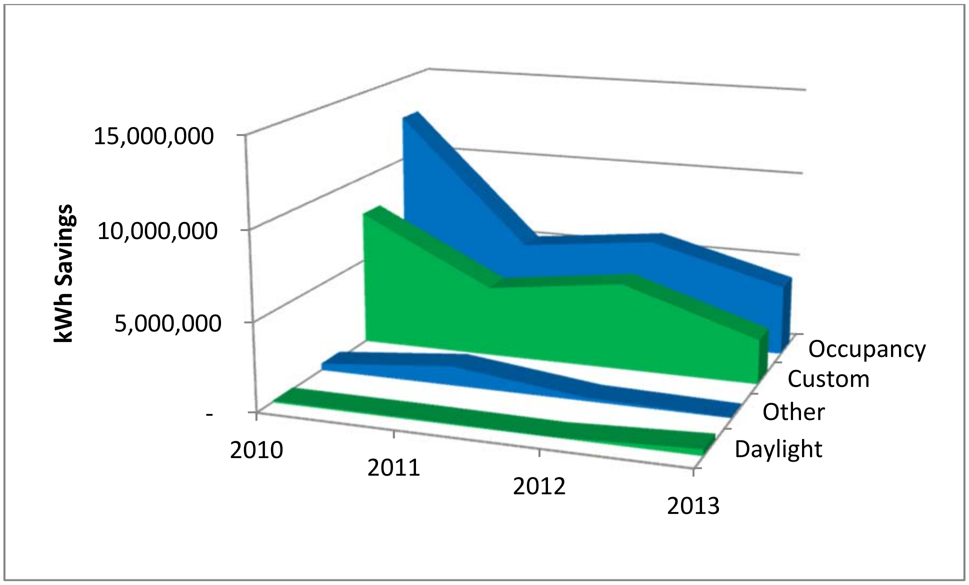
Figure 5: Savings by Custom and Prescriptive (Large C&I)



The data analysis showed that the decline occurred in both custom and prescriptive projects. Both custom and prescriptive lighting controls savings dropped more than 60% from 2010 to 2013 despite a small bounce back in 2012. The trend for custom projects is less trustworthy because it is possible that some of these projects include savings from both lighting systems and controls.

Figure 6 shows savings by measure type for Large C&I. These measure types were determined by searching in the measure descriptions for terms such as "occupancy," "daylight," "motion," etc.

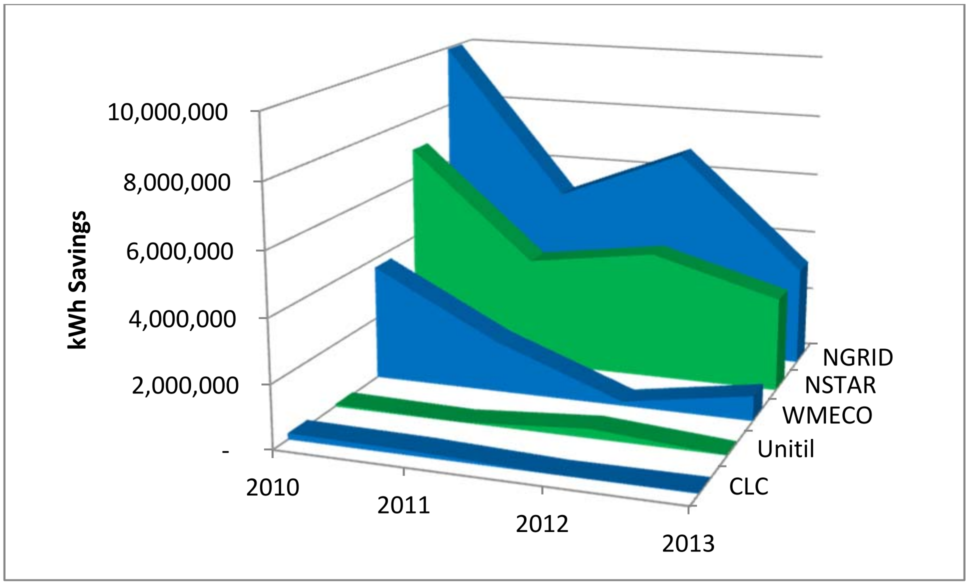
Figure 6: Savings by Measure Type (Large C&I)



Here we see that lighting controls savings are dominated by occupancy sensors and custom projects. Both categories declined between 2010 and 2011, increased between 2011 and 2012, and declined again in 2013. Over the four year period, occupancy sensors decreased by about 70% while custom controls savings also decreased by about 70%. Daylighting represents a very small percentage of all lighting controls installations, but this technology did increase between 2012 and 2013.

Figure 7 shows Large C&I savings by PA between 2010 and 2013. The decreased savings for the large PAs between 2010 and 2011 bounced back partially in 2012, and dropped again in 2013. In 2013, National Grid Large C&I lighting controls savings decreased by 53% over 2012, and NSTAR decreased by 27% over 2012. These savings values are now 32% and 43% of 2010 savings, respectively. Lighting controls savings for WMECO dropped significantly between 2010 and 2012, but turned in a positive gain in 2013. CLC and Unitil claimed very few lighting control projects during these program years.

Figure 7: Savings by PA (Large C&I)



5.2.6 Summary

Based on the data shown above, the savings decline between 2010 and 2013 appears to span all the large PAs, and occurs primarily in prescriptive occupancy sensor projects. Custom projects also show a decline, but this trend is less reliable because custom projects cannot confidently be divided between lighting systems and lighting controls. Both prescriptive occupancy sensors and custom lighting controls savings increased somewhat between 2011 and 2012, but fell again in 2013. Daylighting controls do not make up a significant portion of the program, but they also saw a mild decline.

We do not have a clear answer at this time, based on this data, whether this trend reflects a market shift, a slowdown in this economic sector, changes in program planning, or other factors.

5.3 Task 4: MA-LCIEC Literature Review

DNV GL reviewed past MA-LCIEC reports to determine whether any information about the retrofit lighting control market could be found in the studies or the results of other surveys and interviews conducted with lighting market actors. Specifically, DNV GL reviewed the following lighting related projects:

- Project 1A: High Bay Lighting Market Effects
- Project 10: Process Evaluation
- Project 12: Commercial and Industrial Lighting Impact Evaluation

Initial lighting contractor survey results from project 17: Upstream Lighting, were reviewed for inclusion in this research as well.

The results of the MA-LCIEC literature review are discussed in the following sections. As the intent of this task was to understand the lighting control market, with emphasis on technologies currently offered in the Massachusetts Large C&I Retrofit programs, the discussion starts with information on general trends and then discusses information found regarding occupancy sensors, daylight dimming, and photo sensor controls. A final section discusses any additional findings from this review.

5.3.1 General Trends in Lighting Controls

5.3.1.1 Market Saturation and Potential

The data available in past MA-LCIEC studies indicates that the lighting control market in Massachusetts is not yet saturated and more can be done to increase the adoption of these products. In Project 12, evaluators found several retrofit lighting projects where controls would have been feasible, but were not installed. This project concluded that the PAs should look for more savings opportunities from lighting controls. Likewise, in recent contractor surveys conducted for project 17, DNV GL got a variety of responses regarding market saturation and potential, but the general findings indicate that the market for lighting controls is not saturated and is now increasing.

5.3.1.2 Barriers to Adoption

Since none of the MA-LCIEC studies focused specifically on lighting controls, there was a limited amount of information on barriers for these specific technologies. However, general barriers that do impact lighting control adoption include costs and awareness. Project 10 identified costs as the largest barrier to the adoption of energy efficiency measures. 61% of recent program participants specified this as a barrier to implementing energy efficiency improvements. Manufacturers interviewed during project 1A also indicated that with a decrease in costs and better performance, controls would provide a large benefit to HID bulb savings in high bay lighting (HBL) applications.

The Project 10 study determined that 51% of vendors were aware of prescriptive lighting rebates and 33% were aware of custom lighting rebates. The Project 17 contractor surveys also highlighted market actor awareness. In total, 63% [18] of the surveyed contractors install lighting controls in retrofit applications. One of these respondents indicated that awareness of lighting controls is increasing and another suggested that more marketing should be done on the commercial side and thought that small distributors may not be providing lighting controls through the retrofit program. Another respondent suggested that the market has started to shift towards more frequent installations of controls with lighting retrofits.

Project 12 also highlighted the need for better project documentation for custom projects. It is possible that in the 2010 program year in question, lighting controls could have been installed through a custom program but the quantities and types were not always noted correctly in the documentation or tracking data. This study suggested all PAs focus on better documentation and record keeping to ensure that the correct products are being tracked and considered for savings calculations.

5.3.2 Technology-specific trends

A review of past MA-LCIEC studies did not provide much product-specific information. Project 1A did determine that HBL end users more frequently installed lighting controls during a high bay lighting project. 43% of HBL end users in Massachusetts installed occupancy sensors on their HBL systems during a HBL project compared to only 12% in the studies comparison area[19]. Likewise, 26% of HBL end users in Massachusetts installed daylighting controls at the time of a HBL retrofit. In the comparison area, only 3% of end users installed daylighting controls on the HBL systems. In both regions, only 5% of projects included photo sensors.

Project 10 found that occupancy sensors were installed in a larger number of projects implemented by participating vendors, but that rebates did not have a large impact on the installation of lighting controls. This study found that 80% of participating vendors do install occupancy sensors and 63% of their eligible projects specify occupancy sensors. These vendors believe that without rebates, 58% of their projects would still have installed occupancy sensors. On the other hand, only 63% of non-participating vendors install occupancy sensors and 48% of their eligible projects ultimately specify and install this technology.

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[18] 19 contractors were asked whether they installed lighting controls. 12 indicated that they do install lighting controls in retrofit applications.

[19] The comparison area used in Project 1A included South Carolina, Georgia, Alabama, and Mississippi

5.3.3 Other Technologies

Lighting contractors surveyed in project 17 mentioned three new control technologies that are starting to infiltrate the market: vacancy sensors, wireless/digital controls, and integrated systems.

Two contractors mentioned a shift in the market from occupancy sensors to vacancy sensors. One indicated that their business now specifies vacancy sensors instead of occupancy sensors as these controls can achieve greater savings.

Four contractors mentioned wireless or digital control systems as a trend in the retrofit portion of their lighting control installations. One of these contractors indicated that digital controls make the installation process much easier. Another indicated that it has been easier in the past to just sell bulbs since occupancy sensors require rewiring. Wireless controls may be able to penetrate the market in places where installation costs are prohibitive.

Finally, one contractor mentioned integrated controls (i.e. T5-HO with integrated occupancy sensor) as a new trend in the lighting control market.

5.3.4 Conclusions

The lighting control market has not been covered extensively in any of the past MA-LCIEC studies so only a limited amount of information about trends in this market existed. Overall, the review indicated that the market is not yet saturated and is growing and expanding to include new technologies. Barriers that typically affect other types of energy efficiency improvements, high costs and awareness, also impact the lighting control market, but the new technologies have the potential of addressing some of the common barriers.

5.4 Task 5: Program Staff Interviews

Following the completion of the prior tasks, DNV GL began interviewing PA program implementation staff that provided valuable feedback on both the current state of the lighting controls installations through the retrofit programs as well as any new technologies. Part of the effort was to better understand the reasons why installation rates have declined significantly over the past few years.

The survey, see Appendix 6, was designed to gather information on the following topics:

- Program background including prescriptive lighting program design and implementation strategies;
- Recent changes in industry trends including:
  - PA observations and perspectives on customer motivations and barriers;
  - PA observations and perspectives on installation vendor motivations, barriers and inhibitions; and,
- Future actions to identify additional opportunities to increase participation rates, specifically among engaged customers, with regards to lighting control technologies.

The questions were framed to be primarily open-ended, to enable staff to raise any issues of relevance. DNV GL interviewed four PA program implementers, including two from National Grid, and one each from CLC and Unitil, between May 3 and May 7, 2013. The program implementers participating in the survey were identified as subject matter experts, at their respective participating PA, regarding large C&I energy efficient retrofit implementation. The survey respondents were of varying levels of industry tenure and could be categorized as having approximately 6 months to over 10 years of experience.

5.4.1 Program Background

Retrofit lighting control technologies available to large C&I utility customers offered by the Massachusetts PAs include the following:

- Remote mounted occupancy sensors;
- Daylight dimming controls and/or occupancy sensors;
- Wall mounted occupancy sensors;
- Photocell sensors;
- High bay fluorescent occupancy control systems; and,
- Integral occupancy sensor controls for stairwell fluorescent fixtures.

Most program implementers could not recall when their respective utility began offering rebates for lighting control retrofits however, all agreed; lighting controls are a legacy component of the lighting retrofit program.

Respondents were knowledgeable as to what prescriptive lighting control retrofit options were available at their respective company. The prescriptive lighting control offerings were the same across all PAs according to the respondents. Given the opportunity to discuss further what lighting control technologies where supported by their company through custom retrofits several respondents indicated that there was room to capture energy savings through custom retrofits. Most respondents indicated that whole facility lighting controls using advanced technology and wireless sensors were an opportunity for custom lighting retrofits. One PA mentioned that an advanced lighting program is currently being developed for the state. This program would include sophisticated controls with wireless sensors and building-wide lighting systems.

5.4.2 Recent Changes

Respondents were asked if the types of lighting controls supported by the PAs have changed over time. Most respondents stated that their offerings have changed over the past several years. Specifically, daylight harvesting was added to the prescriptive program. It was noted that controls can be more application specific, and placed at the fixture level, which can drive deeper energy savings. One more recent shift was the PAs' move to promote vacancy sensors, which are a manual on and auto off control, over occupancy sensors in an effort to mimic what has been done in California with Title 24, which mandates vacancy sensors. Currently, vacancy sensors are on the same application as occupancy sensors. Additionally, one respondent from a small PA noted that their program offerings increased as the prescriptive lighting controls program went to a statewide model.

When surveyed about energy efficiency measures and trending technologies, with regards to large C&I sector type and customer preference, program implementers overall agreed commercial office space, educational facilities, and warehouses were among the most likely sectors to adopt lighting control retrofits. Table 13shows the existence of lighting control measures as discussed by the PAs within each sector type.

Table 13: Implemented Lighting Control Measures by Participant Sector Type

Sector Type	Occupancy Sensors	Daylight Diming	Advanced/Network Controls	Wireless Controls	Photocell Sensors
Leased office space	x	x			
Owned office space	x		x	x	
Educational facilities	x	x	x		
Retail - box stores	x	x			
Warehouses	x				
Exterior space		x		x	x

Program Administrators were asked about the growth and decline of program sponsored lighting controls measures over the past several years. Respondents were asked to comment on each control type individually. The following bullets summarize the responses provided:

- Occupancy Sensors. This control type produced inconsistent responses. One respondent from a small PA stated that this measure type has produced a positive trend over time due to more customers becoming aware of control technologies. A second response from a large PA indicated that occupancy sensors are not as robust as they once were. This respondent indicated that there are still opportunities, citing parking garages and high bay fluorescent or LED applications, but not as much in typical building applications due to possible saturation.

- Daylight Dimming. This type of control has never been very large due to challenges that are sometimes difficult to overcome. For example, it has been difficult for vendors to provide a strong methodology for how to quantify savings. It is also a more complex type of retrofit due to having to replace the entire lamp/ballast system, and is not attractive for existing buildings. This control type is better suited for new construction situations.

- Advanced/Network Controls. This technology typically includes whole building lighting controls, which are connected to a central control system, which can be programmed for optimal lighting control, including on/off and dimming. This is a newer technology that hasn't been fully integrated by some PAs programs yet. According to one large PA respondent, there appears to be an upward trend for this type of lighting control. There are some energy service companies (ESCO) that are beginning to do a higher volume of these installations. However, there are some challenges due to the relatively high cost of this technology. As more manufacturers enter the market, and more modulation and wireless options become available, it may increase customers' willingness to go this route, and prices may drop due to increased competition.

- Wireless Controls. Similar to advanced/network controls, wireless controls haven't been adopted by customers of some PAs yet. The noted advantage of wireless controls as compared to advanced/network controls is the cost. Wireless controls can communicate with a ballast to perform tasks such as dimming and task lighting, while avoiding having to run as much cable and wiring as needed for advanced/network controls.

5.4.2.1 Industry Trends

Respondents were asked if they have noticed any recent industry trends that would affect lighting controls retrofits within large C&I facilities. Two of the four respondents noted the growth of the LED market, and addressable LED systems ability to produce savings via daylight harvesting and network controls. Additionally, whole building network controls are becoming more prominent and cost effective, which should move more customers in that direction.

5.4.2.2 Motivations and Barriers

Table 14 summarizes customer motivations and barriers as reported by PA respondents. The topics are further explored in the sections below.

Table 14: Motivations/Barriers of Customers, Vendors, Administrators and Technology

	Motivation		Barrier	
Customers	Small PAs	Large PAs	Small PAs	Large PAs
Customer Knowledge	X	X	X	X
Customer Skepticism			X	X
Customer as Tenant in Leased Building				X
Eager to Adopt New Technology		X		
Physical Design of Existing Building			X	
Economy/Cost			X	
Vendors				
Vendor Knowledge of Controls Systems and Savings Potential			X	X
Administrators				
Raising Customer Awareness of Controls Technology	X	X		
Raising Vendor/Contractor Awareness of Controls Technology			X	X
Limited Staff and Time to Educate Vendors			X	
Technology				
Growth of LED Market	X	X		
Controls Compatibility with LEDs			X	

5.4.2.2.1 Customer Motivations and Barriers

Respondents were asked to address why lighting control retrofits were a challenge to large C&I customers. One typical response was physical design restrictions of the facility structure prohibiting retrofit upgrades from being effective. Unless the facility was directly owned by the customer and undergoing a full facility renovation, installing hardwired and wireless network control technology was cost prohibitive.

Utility customers were reported to have more awareness, knowledge, and enthusiasm about certain lighting control technologies such as occupancy sensors and daylight dimming/occupancy sensors, however PAs are seeing a widening gap between the educational awareness of earlier generation lighting control measures and evolving technology. Several respondents commented that utility customers that are early adopters of technology are more willing to adopt newer lighting control technology; whereas customers that are slower to adopt newer technology, yet still enthusiastic, are observed to succumb to technology stigmas such as; "not wanting to wave their arms around to turn the lights back on."

Custom retrofit lighting control implementation proved to be a barrier for customers. Respondents indicated that little effort was being made to explore lighting control opportunities through the custom approach. Even if opportunities for custom lighting retrofit controls were identified by PAs, if vendors were not knowledgeable, didn't supply specific technologies, or were unfamiliar with installation specifications, energy savings opportunities were lost.

Other areas for lost savings were identified as small retrofit upgrades where it didn't seem cost effective to hire a consultant to quantify the controls savings.

The PAs have identified that customer barriers do not always reside with the customer and that a further gap in educational awareness resides with vendors, distributors and implementation contractors.

5.4.2.2.2 Vendor, Distributor, and Installation Contractor Motivations and Barriers

Lack of consistent training and education was a common theme among the PAs as they further identified barriers with regards to retrofit lighting controls. Differences in vendor/customer relationship were observed between the utility territories. Some administrators responded that program participants work through Energy Service Companies (ESCO's), other customers work with local area vendors and may not be exposed to current lighting control technologies in the market place because the vendor may not offer or endorse the technology.

Occasionally, vendors cannot provide a strong methodology on how to quantify energy savings and that lighting control technology may be difficult to promote to utility customers and if large reductions are not present it may not be worth the time of the vendor. According to respondents, additional energy savings opportunities are gained or lost dependent on the vendor and their level of knowledge and experience. This seems to be a great opportunity to help educate vendors, as savings estimates for this type of upgrade are relatively simple.

5.4.3 Future Actions

Opportunities identified by respondents indicate that whole building, advanced lighting control retrofits will become more of the norm as technology becomes more prominent in the market place and more affordable. Currently, there is a steep slope when considering whole building, advanced lighting controls due to constraints of existing building design, and high costs. The PAs report new modulation and wireless controls that may help the PAs push these whole building retrofits to their customers. [20]Light emitting diodes (LED's) were mentioned as being at the forefront of advancing technology within the market place and could be a factor to replacing compact fluorescents (CFL's) due to their control capabilities.

The PAs identified their own program as an area for improvement. The smaller PA respondents mentioned having large workloads and being understaffed. This makes it difficult to allow for sufficient time to spend with customers identifying lighting control opportunities within their territory.

One of the smaller PAs noted that if given the opportunity to develop educational training programs for vendors and customers, they would embrace the chance to do so. Other PAs have had opportunities to engage with customers and vendors at training events but report a lack of follow up by program staff. This appears to be an issue regarding time available for all PAs to be able to dedicate to lighting controls or other more complicated measures. One suggestion from one of the small PAs was that every lighting application should include an investigation of lighting controls at the site level. This would put more focus on lighting controls, and would require that vendors are better educated on the different technologies.

Additional opportunities can come from training workshops reinforcing technical standards and savings quantifications. By providing these forums, program staff could be in a better position to assist vendors and future program participants on calculating savings or redirect vendors to other retrofit control technologies to capture similar savings.

5.5 Task 6: Lighting Vendor Interviews

Following the PA implementer interviews, DNV GL interviewed vendors/Project Expeditors involved in lighting controls implementation that provided valuable feedback on utility programs and how program incentives influence the lighting controls business. These in-depth interviews were conducted to better understand how lighting controls are being addressed by the utilities in major retrofits in Massachusetts.

The interview guide, see Appendix 6,, was designed to gather information on the following topics:

- Overview of business activities involving lighting and lighting controls;

[20] Light emitting diodes (LED's) were mentioned as being at the forefront of advancing technology within the market place and could be a precursor to replacing compact fluorescents (CFL's) due to their control capabilities

- Recent industry trends of lighting controls;
- Lighting vendor observations and perspectives on customer understanding and acceptance of lighting control technologies;
- Lighting vendor observations and perspectives on customer and distributor/contractor motivations and barriers to installing lighting controls;
- Future actions to identify areas of improvement for incentive programs and to identify technologies and sectors that provide the greatest opportunity for energy savings.

Like Task 5, the questions for the Task 6 survey were framed to be primarily open-ended to enable lighting vendors to elaborate on issues of significance. DNV GL interviewed six lighting vendors between October 24 and November 5, 2013. The vendors participating in the survey were identified as subject matter experts regarding C&I businesses use of lighting controls by their respective Program Administrators. All vendors providing feedback for this Massachusetts Lighting Controls Implementation Vendor Survey also supplied comments to the Massachusetts Project 19 Mid-size Customer Needs Assessment. The lighting vendor respondents were high ranking staff at their respective firms (e.g., President/Founder, Vice President and Director of Business Development). The six lighting vendor businesses we interviewed ranged in size from one employee to over 100 staff and in sales from under $500,000 to over $50 million.

5.5.1 Overview of Lighting Control Vendor Business

Lighting vendors were asked what percent of their business was associated with a number of different lighting services. Table 15 shows for the six vendors interviewed that business associated with lighting installation and design outweighed business involving lighting financing, commissioning and maintenance.

Table 15: Percent of Vendor Business Associated with Different Lighting Services

Lighting Service	Average % of Business Associated with Service	Range
Lighting Installation*	54%	15% to 85%
Lighting Design*	31%	3%to 85%
Lighting Finance	13%	0% to 70%
Lighting Commissioning	7%	1%to 10%
Lighting Maintenance**	1%	0% to 5%

*Every lighting vendor surveyed had business associated with lighting installation and design
**Only one lighting vendor surveyed had business associated with lighting maintenance

Lighting vendors were asked what percentage of their work in Massachusetts involves replacing or remodeling indoor lighting systems in existing commercial and industrial buildings. Responses ranged from 30% to 100% with the number of projects ranging from 20 to 1,700.

Table 16 indicates that the vendors interviewed installed lighting in many different building types over the last year.

Table 16: Overview of Building Types where Vendors are Installing Lighting

Building Type	# of Vendors Installing Lighting in the Last Year (n=6)
Office	6
School	6
Warehouse	6
Manufacturing	6
Retail	5
College	5
Hotel	4
Hospital	4
Health Facility	4
Restaurant	3
Grocery	2
Religious	2
Other*	3

*Other includes municipal, parking garage and multi-family buildings

Lighting vendors were asked for an estimate of the number of total fixture units they installed in existing commercial/industrial buildings in Massachusetts in the last year with 1) automated lighting controls and 2) manual switches. Of the six vendors interviewed, half indicated installing more than 10,000 automated lighting controls. On the other hand, half the vendors reported installing no manual switches last year and no vendor mentioned installing more than 10,000 manual switches. A summary of the responses are included in Table 17.

Table 17: Vendor Fixture Installations with Automated Lighting Controls and Manual Switches

Number of Fixtures Installed	Automated Lighting Controls (n=6)	Manual Switches (n=6)
0	0	3
1 to 500	1	1
501 to 1,000	1	0
1,001 to 5,000	1	1
5,001 to 10,000	0	1
10,001 to 50,000	1	0
>50,000	2	0

Lighting vendors indicated a number of ways they determine if a space is appropriate for controls. The following bullets show how vendors make that determination by focusing on the physical characteristics of the room, how often the space is occupied, hours of operation of the space, and the potential for daylighting. Details for their responses include:

- Physical characteristics of space
  - Look if existing sensors are already in the room - if not, assess opportunity;
  - Review physical characteristics and conduct cost benefit -- Example: If have restroom and light switch is in hallway it becomes not logistical or cost effective to move the switch (and the resulting control) into the restroom itself...requires more work (product, labor, cost) and frequently doesn't make sense;
  - Look for obstructions to see what sensor technology is most appropriate;
  - Look to see if current space is over lit.
- How often space is occupied
  - Determine how often the space is occupied;
  - Look at existing occupancy of the space (opt for controls if space not used consistently);
  - Find out the activity levels of the space.

- Hours of operation of space
    - Find out current hours of operation (sometimes hours aren't long enough to justify sensor installation);
    - Consider time of day timer panels: Can be a good solution when a building opens and closes on a regular schedule (e.g., Retail store -- have sensors set for half hour before store opens and half hour after store closes).
- Opportunities for daylighting
    - Look to see if current space has sunlight exposure.
- Other factors to determine if space is appropriate for controls
    - Find out concerns client has about sensors;
    - Look at existing load of room to make determination if controls needed.

Lighting vendors were asked to provide an estimate of the percentage of fixtures for different control technologies installed in commercial and industrial buildings over the past year. Table 18 shows, on average, almost half of buildings (49%) had occupancy sensors and over a third (34%) had manual switching. Very few buildings had manual dimming installed. With the exception of manual dimming, it is interesting to note the wide range of responses provided by the vendors for the different technologies.

Table 18: Percentage of Different Lighting Control Fixtures Installed in C&I Buildings

Control Technology	Average (n=6)	Range (n=6)
Occupancy sensors	49%	20% to 95%
Manual Switching	34%	0% to 80%
Advanced/ Network Control	20%	0% to 100%
Wireless Controls	19%	0% to 95%
Daylighting controls	15%	0% to 60%
Manual Dimming	2%	0% to 5%

Lighting vendors were asked if they observed more, less or the same amount of automated lighting controls installations than in the past. All six vendors surveyed stated seeing more (if not much more) automated lighting controls now compared to the past. All six vendors surveyed also indicated the increase in automated lighting controls has occurred more in large (>300 kW) compared to small (<300 kW) commercial and industrial facilities, for reasons that include:

- "Small commercial program vendors can't spend time doing advanced controls because the margins are so low…they need to get in and out as quickly as possible."
- "Large far exceeds the small due to capital budget allowances"
- "There is more new construction, renovation and retrofit with larger facilities."
- "A larger facility is likely to have more people designated for energy conservation (e.g., facility manager whose job is to reduce energy consumption)."
- "The traditional lighting control systems tend to have expensive start-up cost, so with small facility with just 100 fixtures or less, the start-up cost is high relative to a large facility with more fixtures."

Lighting vendors were asked to provide their perspective on trends taking place since 2006 for different lighting technologies. The following bullets provide a summary of the responses provided by lighting vendors for whether they thought sales of different technologies increased, decreased or stayed the same and their reasoning for the trend.

Occupancy sensors

- Reasons for Increase (n=5)
    - More people are aware of the technology;
    - More businesses are concerned with energy consumption;
    - More and more code rules mandating occupancy sensors;
    - Decreased costs for this technology (since installed cost decreasing, ROI is increasing).
- Reasons for Decrease (n=1)
    - Because many occupancy sensor have already been installed (saturation).

Daylight Dimming

- Reasons for Increase (n=6)

- Decreased costs for this technology (since installed cost decreasing, ROI is increasing);
- Increase in customer knowledge (e.g., more awareness by facility managers to save as much as they can and be as green as they can);
- Other technologies have already been employed, so need to find something else to garner savings;
- LEDs lend themselves to dimming;
- Seeing more frequently in new construction;
- Growing due to code requirements.

Manual Switches

- Reasons for Decrease (n=6)
  - There is a movement to automation (i.e., manual switches being replaced by automatic switches) - moving forward, there will be more and more controls to lighting (with more controls there is less need for manual switching);
  - More sensors are being installed in new construction and retrofit projects;
  - More people are concerned with energy consumption.

Manual Dimming

- Reasons for Increase (n=3) [Has stayed the same (n=2); Don't know (n=1)]
  - Being installed more often in new construction and retrofit projects (more controllable systems are being installed and manual dimming going along with that);
  - Due to increase in penetration of LEDs;
  - Systems becoming less expensive.

Advanced Network Controls

- Reasons for Increase (n=6)

- More available options;
- More pressure to conserve energy;
- Growing due to code requirements;
- Decreased costs for this technology (since installed cost decreasing, ROI is increasing);
- Increase in customer knowledge (customers asking about advanced controls more frequently);
- Need to employ more sophisticated technology to find more savings;
- The introduction of all the newer LED systems lends themselves to be more compatible with wireless networking. Seems every company out there is coming out with wireless controls.

Wireless Controls

- Reasons for Increase (n=6)
    - Being used more often in retrofit applications;
    - Improving technology (when first came out, it caused more problems than it did good);
    - Increase in customer knowledge (customers asking about wireless controls more frequently);
    - Need to employ more sophisticated technology to find more savings;
    - Decreased costs for this technology (since installed cost decreasing, ROI is increasing);
    - Reduced labor costs from an installation point of view and can put in areas where a hardwired solution would be impractical (e.g., challenging to run hardwire through concrete – cost prohibitive).

Besides providing feedback on occupancy sensors in general, lighting vendors were also asked to describe sales trends for a number of specific occupancy sensor technologies over the past several years and whether they thought the technologies had peaked in sales/installations. The following bullets provide a summary of the responses provided by lighting vendors.

- High bay fixture mounted occupancy sensors: Despite all vendors (n=6) signifying an increase in sales over the past several years, many indicate that sales of high bay fixture mounted occupancy sensors have reached its peak due to significant market penetration. Even though there is still need for high bay fixture mounted occupancy sensors, the market is thought to be pretty saturated for this technology.

- High bay space occupancy sensors: Almost all vendors (n=5) indicate sales have increased over the past several years. High bay space occupancy sensors are not as common as high bay fixture mounted occupancy sensors and with setting levels based on area and not individual fixtures, it is thought this technology has strong growth potential. The one vendor signifying a decrease in sales over the past several years noted the reason for the slight downward trend is because he is often finding updated technology with high bay space occupancy sensing already in place when going into facilities.

- Office Occupancy Sensors: Even though all vendors (n=6) indicate sales have increased over the past several years, most note that office occupancy sensors are reaching their peak due to the market becoming saturated with this technology. One vendor mentioned that while sales for wall mounted units are relatively flat, sales are increasing for space units.

All vendors surveyed signaled they expect the trend for increased installation of lighting controls to continue. There is a trend toward newer and more advanced technology – when a lighting technology first comes out, it tends to be expensive -- but over time the price comes down and the quality improves. Even though some control technologies have gotten saturated, the overall trend for the installation of lighting controls is likely to continue to increase.

5.5.1.1 Industry Trends

Lighting vendors were asked if they noticed any industry trends over the past three years that would affect lighting controls installations within the large C&I retrofit programs. The following bullets provide a summary of the responses provided by vendors:

- Increase in installation of lighting controls for C&I buildings across all sectors.
- Trend of occupancy sensors is going towards more advanced technologies.
- Technology is changing with more converting to LEDs, and not always involving controls.

- Sensors are becoming more built in and network ready.
- One vendor noted that the cost of lighting controls is decreasing (cost was prohibitive for quite some time).
- Businesses are far more aware of what is available about things they can do to save energy.
- Impact of the building code updates (the utilities are reducing rebates due to code).

All six lighting vendors surveyed report noticing changes in customers' level of understanding of the benefits of lighting control technologies over the past three years. Half the vendors indicate customers are asking more about advanced technology controls - especially daylighting. A couple reasons for the increased level of customer understanding is thought to be driven by meeting energy code requirements and the desire to be known as a green company (e.g., obtaining LEED certification). A number of vendors note that small or medium size customers may be aware of available control technologies, but not as high a percentage as larger businesses as larger businesses are more likely to have a dedicated energy manager engaged at keeping up-to-date with new lighting trends in the marketplace.

All six lighting vendors surveyed also report noticing changes in customers' level of acceptance of automated lighting controls for their facilities. Vendors point out an increase in customers seeking the following technologies for their business:

- Automated lighting controls (mentioned 3 times)
- Daylight dimming (mentioned 2 times)
- Controls tied to EMS systems
- Controls associated with LED lighting
- Advance network controls

Three of the six lighting vendors conveyed having experienced businesses being skeptical of certain types of retrofit lighting controls, for reasons that include:

- A bad reputation hangover from the first generation of sensors;
- Facility managers having to deal with complaints from callbacks related to lighting controls (e.g., "Hey, my light just went down!");

- Frustration with simple occupancy controls(e.g., lighting going out in conference room).

Lighting vendors were asked if they noticed customers holding off on purchases while waiting for new products to come out. A couple vendors noted that customers are waiting for pricing to come down for LED lighting -- coming to a point where companies doing big renovations are strongly considering LEDs, whereas two years ago that was not the case because wasn't cost effective. As a result, companies may be waiting on installing any kind of control until they go to LEDs.

Besides holding out for new products to come out, lighting vendors were also asked if they experienced their customers delaying projects for other reasons recently. All six vendors interviewed mention having customers who are postponing projects due to budget constraints. Many businesses experience having energy efficient projects compete with capital improvement projects for implementation (e.g., "If you are a CEO with $4 million to spend on projects and have 15 to consider…likely can only pursue a few of them").

5.5.1.2 Motivations and Barriers

Lighting vendors were asked to identify motivations and barriers that respectively encourage or discourage their customers to adopt more energy-efficient lighting control technologies.

5.5.1.2.1 Customer Motivations and Barriers

Lighting vendors provided various responses for the primary drivers for installation of lighting controls that receive program incentives. Vendors suggest the motives for pursuing lighting controls that receive program incentives include:

- Make it easy to participate in the program if installing something that is custom;
- Offer higher incentives or lower cost to install control systems.
- Have knowledgeable installers (These are the people who are selling the lighting controls - complicated lighting control solutions are often not pursued by customers because vendors don't know how to employ them).

Lighting vendors were asked if they see a shift in a particular market segment towards advanced lighting controls. Vendors signaled the following segments being able to make more frequent use of lighting controls:

- Retail and grocery stores (especially if part of a chain -- chains can own hundreds of stores and tend to get into advanced controls to see what is going on with each building, room and fixture. If a fixture is out, can be monitored from a computer);
- Offices (this segment tends to have a more educated consumer base that is knowledgeable about energy efficiency);
- Colleges/universities;
- Municipal buildings (e.g., recreation centers).

Almost all lighting vendors surveyed (n=5) note that financing is a barrier that can prevent their customers from pursuing energy-efficient lighting control technologies. Speaking about budget constraints, a vendor conveyed that most customers like the idea of controls and if they have money available, they want to include them in their lighting projects. Other barriers to pursuing lighting controls mentioned by vendors include:

- Payback (longer payback because of the expense involved);
- The increase in complication to install controls;
- The added time the vendor has to spend installing the control technology;
- Callbacks (the more sophisticated the systems, the more likely callbacks occur);
- Skepticism that controls work properly (have to feel comfortable that when controls are installed won't have a bunch of unhappy employees) ;
- Not prioritizing energy-efficient lighting control technologies (businesses tend to have more pressing matters than looking into lighting and installing control systems);
- Absence of high electricity bills (customers aren't as driven to pursue energy efficiency projects if expenses aren't prohibitive).

Lighting vendors were asked how well they think the incentive program is doing at addressing customer motivations and inhibitions for purchasing efficient lighting control technologies. While a couple vendors noted the program is doing a fine job offering incentives and having most businesses doing large retrofits being aware of incentive programs, many vendors indicated the program could do better at addressing customer motivations. The following bullets summarize the responses provided:

- Don't think advanced controls have been penetrated in the marketplace -- Had recent meeting with utility and pulled data and found that very low percentage of controls compared to overall lighting was being installed;
- Control systems have only penetrated about 2% of the marketplace, so would seem a fair amount of opportunity to push further;
- The program could do better - going by the numbers, the majority of the incentives are associated with lamp, ballasts, kits and fixtures - not controls;
- Need for more attractive incentives – the program is not really addressing customers in a way that is meaningful for them to take advantage of opportunities;
- The utilities are not really addressing customer skepticism of controls…leaving that up to vendors to address with customer to warrant the systems work properly.

5.5.1.2.2 Distributor and Vendor Motivations and Barriers

In addition to being asked about customers, lighting vendors were asked how well they think the incentive program is doing at addressing distributor and vendor motivations and inhibitions for purchasing efficient lighting control technologies. While one vendor conveyed the program is doing a good job coming up with new and creative ideas so that distributors and contractors can be more involved, most of the other vendors expressed the program could be better. The following bullets summarize the responses provided:

- The program can be challenging for the average contractor – the average contractor can't be bothered with pain of doing paperwork and going through the utility process;
- Don't see a lot of emphasis from the utility to promote these technologies. Don't know how much utilities are talking to distributors about program incentives;
- If utilities want to expand the market, the incentives need to be increased.

5.5.2 Future Actions

Lighting vendors were asked which measures they think have the most potential to provide energy savings in the retrofit lighting controls market. Half the vendors surveyed (n=3) note that daylighting has a great potential for energy savings. Other measures mentioned include wireless controls, automated fixtures sensors for stairwells, EMS that could either dim or turn off at certain times of day and time of day controls. Vendors indicate the utility could offer higher incentives to support these measures. Other recommendations by vendors to support technologies that offer strong potential for energy savings include:

- Make incentive more based on kilowatt hours of savings instead of prescriptive for the device;
- Generate an energy savings calculation to show customers positive implications of installing measure(s);
- Offer shorter payback ("Payback drives most projects -- quick paybacks get a lot of attention, whereas project with slower payback is likely to get nixed or pushed to bottom of the barrel").
- Put onus on contractor to install controls and have incentive structure to promote lighting controls installation.

Lighting vendors were asked in what C&I sectors, if any, they saw the potential for increasing incentive program-sponsored installations of retrofit lighting controls. While a couple vendors noted that there is equal opportunity for all sectors across the board, other vendors specified the following C&I sectors they thought have the potential for increasing incentives for retrofit lighting control projects:

- Offices: Hours are lower in general than manufacturing facilities with numerous shifts (payback for office with just one shift may be longer and could use the help of increasing the incentive program);
- Retail and grocery chain stores: Good candidate for advanced controls and EMS where operators can control each store with just one computer;
- Small business (<300 kW): There are opportunities for integral controls like common areas in multi-family buildings and hotels/motels. In this sector, one of the biggest advances is the advent of the dimming feature of LEDs.

In addition to being asked to indicate sectors they saw the potential for increasing program incentives of retrofit lighting controls, lighting vendors were asked if they think there are technologies or sectors that incentive programs should stop focusing on, based on the market being saturated or for other reasons. While most of the vendors surveyed conveyed that incentives should not be stopped or decreased for any technology/sector because there are still opportunities, a couple of vendors inferred incentives geared to schools may want to be reconsidered for the following reasons:

- Doesn't make sense for facilities, such as schools, with low hours of use (i.e., less than 40 hours per week which can translate to only around 1,500 hours per year). Schools are hard to implement more expensive technologies because of the hours.
- Programs have focused heavily on schools over the recent years - Payback scenarios are better for other commercial buildings when taking into consideration that hours of operations for schools tend to be low and tend to be off peak, especially over the summer. There is the need to recognize that control costs tend to be the same at schools compared to other commercial buildings, but hours of operation tend to be twice as much at other commercial buildings, which gives twice as much savings for same amount of money.

Finally, lighting vendors were asked what they think the incentive program could do to improve the number of completed installations of lighting controls retrofit projects. All six vendors surveyed indicated the desire for better incentives (especially regarding on-bill financing) – the thought being, the higher the incentive, the more likely businesses will be to pursue lighting controls. Additional suggestions to improve the program provided by vendors include:

- Many business are cautious about lighting system installations (i.e., how will it look, will it have right lumen output and color rendering properties). Suggest being able to try lighting controls for free for 30 days and if business doesn’t like the system, have the technology taken out;
- Have a prerequisite that in order to obtain lighting incentive, have to also install a control system;
- Step up incentives for customer with operation of at least 5,000 hours and then increase the incentive for more hours;
- Should keep all current incentives in place and just figure out way to make incentives for advanced lighting controls more attractive;

- Incentives should encompass all lighting control technologies – "the more the merrier - will turn more jobs with more incentives";
- Need to provide greater financial support for technical assistance more complex efficiency projects;
- Have incentives that are driven by kilowatt hours of savings vs. unit incentives;
- Need for more outside sales and account managers to contact and visit sites and bring in project expeditors to do implementation;
- The speed at which incentives are approved has lengthened greatly. Speedy approval of incentives is a key driver for getting a customer to engage - have seen a significant slowdown that hurts sales;
- Would be helpful if people who are experts in advanced controls come out with project expeditors to spec out systems. Some project expeditors are not comfortable specifying lighting controls because they don't know how well they work;
- Realize that utilities have their work cut out for them with a substantial budget increase it is more difficult to spend the budget every year - Think lighting controls is one of the better places they can concentrate their efforts.

6. Conclusions and Recommendations

We do not have a clear answer at this time, based on the program tracking data, whether the reduction in lighting controls savings reflects a market shift, a slowdown in this economic sector, changes in program planning, or other factors. Based on the research conducted in this study, we have some hypotheses of what may be driving the decline in savings. Table 19 presents a list of the potential reasons based on our research.

Table 19: Potential Reasons for Decline in Lighting Controls Savings

Potential Reasons for Decline	Evidence from this Study
Cost	MA-LCIEC Project 10[21] identified cost as a barrier to energy efficiency upgrades, while MA-LCIEC Project 1A[22] found that decreased costs and better performance would help boost controls savings in high bay applications. Though costs of controls haven't increased, costs for newer technologies such as wireless controls, remain higher.
Marketing	Interviews conducted with lighting contractors for MA-LCIEC Project 17[23] found that some of the smaller distributors may not be providing controls through the retrofit program, citing more marketing needed.
Rebates	MA-LCIEC Project 10 also noted that rebates for lighting controls do not have a large impact on the installation of controls.
Vendor Technical Awareness	PA interviews highlighted the issue surrounding vendor awareness and the ability for them to calculate energy savings and communicate those effectively to customers.
Saturation	Although most of the literature review and surveys concluded that there are still plenty of opportunities for lighting controls, some vendors did note that their impression is that occupancy sensors have been installed in many traditional commercial building types.

Program Administrators were asked about the growth and decline of program sponsored lighting controls measures over the past several years. Respondents were asked to comment on each control type individually. The following bullets summarize the responses provided:

- Occupancy Sensors. This control type produced inconsistent responses. One respondent from a small PA stated that this measure type has produced a positive trend over time due to more customers becoming aware of control technologies. A second response from a large PA indicated that occupancy sensors are not as robust as they once were. This respondent indicated that there are still opportunities, citing parking garages and high bay fluorescent or LED applications, but not as much in typical building applications due to possible saturation.

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[21] KEMA, Inc. Massachusetts Large Commercial & Industrial Process Evaluation. Prepared for the Massachusetts Energy Efficiency Program Administrators and the Massachusetts Energy Efficiency Advisory Council. July 2012.

[22] KEMA, Inc. HBL Market Effects Study Project 1A New Construction Market Characterization. Prepared for the Massachusetts Energy Efficiency Program Administrators and the Massachusetts Energy Efficiency Advisory Council. June 2011.

[23] KEMA, Inc. Process Evaluation of the Bright Opportunities Program. Prepared for the Massachusetts Energy Efficiency Program Administrators and the Massachusetts Energy Efficiency Advisory Council. June 2013.

- Daylight Dimming. This type of control has never been very large due to challenges that are sometimes difficult to overcome. For example, it has been difficult for vendors to provide a strong methodology for how to quantify savings. It is also a more complex type of retrofit due to having to replace the entire lamp/ballast system, and is not attractive for existing buildings. This control type is better suited for new construction situations.

- Advanced/Network Controls. This technology typically includes whole building lighting controls, which are connected to a central control system, and can be programmed for optimal lighting control, including on/off and dimming. This is a newer technology that hasn't been fully integrated by some PAs yet. According to one large PA respondent, there appears to be an upward trend for this type of lighting control. There are some energy service companies (ESCOs) that are beginning to do a higher volume of these installations. However, there are some challenges due to the relatively high cost of this technology.

- Wireless Controls. Similar to advanced/network controls, wireless controls haven't been adopted by customers of some PAs yet. The noted advantage of wireless controls as compared to advanced/network controls is the cost. Wireless controls can communicate with a ballast to perform tasks such as dimming and task lighting, while avoiding having to run as much cable and wiring as needed for advanced/network controls.

Lighting vendors were asked if they noticed any industry trends over the past three years that would affect lighting controls installations within the large C&I retrofit programs. The following bullets provide a summary of the responses provided by vendors:

- Increase in installation of lighting controls for C&I buildings across all sectors.

- Trend of occupancy sensors is going towards more advanced technologies.

- Technology is changing with more converting to LEDs.

- Sensors are becoming more built in and network ready.

- Cost of lighting controls is decreasing (cost was prohibitive for quite some time).

- Businesses are far more aware of what is available about things they can do to save energy.

- Impact of the building code updates (the utilities are reducing rebates due to code).

All lighting vendors surveyed report noticing changes in customers' level of understanding of the benefits of lighting control technologies over the past three years. Half the vendors indicate customers are asking more about advanced technology controls - especially daylight dimming controls.

6.1.1 Current and Expected Future State of Lighting Controls Market

To better understand whether the recent trends found for Massachusetts Large C&I Retrofit Lighting Control measures are occurring in other jurisdictions or nationally, DNV GL conducted a literature review of existing lighting control market potential studies and evaluations performed outside Massachusetts. While there is a lack of quantitative information from other jurisdictions and at the national level regarding recent trends seen in retrofit lighting control programs that offer occupancy sensors, daylight dimming, and photo sensor controls, two major findings were uncovered in the literature review:

- Current market saturation for lighting controls is low but has more potential, and
- Substantial interest is growing in the market for wireless and integrated controls.

6.1.2 Recommendations for Program Expansion, Contraction and Future Marketing and Rebate Opportunities

6.1.2.1 High Potential Technologies

Interviews with program implementation staff, and lighting controls vendors highlighted some technologies in which the program may focus on in the future.

- **Advanced/Networked Lighting Controls –** Whole building, advanced/network lighting controls are becoming more prominent and cost effective as ESCOs are starting to implement these more frequently. This type of technology can be as sophisticated as lighting designers and programmers can make it. They can integrate the best of all lighting controls systems including, on/off scheduling, vacancy control, daylight dimming, and individual user controls. Though these types of systems are best suited for new construction types of projects, lighting vendors and designers should be encouraged, through program incentives, to look for opportunities to implement these complex systems in existing facilities where possible.

- **Wireless Controls** - Wireless controls are gaining in popularity as it allows the users to implement lighting controls without having to run the additional electrical wires necessary for traditional lighting controls. Wireless controls should be considered as a lower cost alternative to Advanced/Network controls in some retrofit applications.

- **LED Lighting and Controls –** Many PAs and vendors surveyed noted the savings potential combining LEDs and lighting controls. There are many possible controls strategies offered with newer LED technology, including dimming capabilities. New LEDs with integrated controls offer increased lighting systems savings when combined in a package, or connected to an advanced building automation or lighting control system.

- **Daylight Dimming** – Many vendors suggested that customers are asking about daylight dimming controls more frequently. Vendors theorize that customers are becoming more comfortable with lighting controls systems, and are eager to learn more about how to make daylight dimming work in their facilities. It should be noted that some PA respondents thought that this was a challenging technology to implement due to the difficulties that some vendors have in explaining the savings and benefits for potential daylight dimming projects to their customers.

6.1.2.2 High Potential Sectors

The following represent some of the sectors in which the program may benefit from focusing more in terms of lighting controls opportunities. In addition to the specific sectors listed, spaces that are overilluminated, could benefit from more flexibility in light levels, while spaces with highly variable occupancy, are good candidates for lighting controls.

- **Offices** – There appear to be significant opportunities for lighting controls installations in office facilities. In addition to traditional occupancy/vacancy controls and daylight dimming controls, large offices would be good candidates for the more sophisticated types of controls, since they tend to have dedicated energy managers, and existing energy management systems.

- **Small business (<300 kW) -** There are opportunities for integral controls like common areas in multi-family buildings and hotels/motels. In this sector, one of the biggest advances is the advent of the dimming feature of LEDs.

6.1.2.3 Low Potential Technologies/Sectors

When asked if there were any technologies and/or sectors that the program shouldn't focus on as much, respondents generally stated that incentives should not be terminated or decreased for any technology or sector because there are still opportunities. However, some lighting vendors indicated that schools are difficult to implement effectively since some of them tend to have lower hours of use (i.e. less than 40 hours per week, and no summer operation)

6.1.2.4 Future Program Marketing and Rebate Opportunities

PAs and vendors were asked what they think the incentive programs could do to improve the number of retrofit lighting controls projects. In addition to vendors who unanimously suggested increasing incentives, the list below highlights some additional recommendations from PAs, vendors and DNV GL.

Many business are cautious about lighting system installations (i.e., how will it look, will it have the right lumen output and color rendering properties). They suggest being able to try lighting controls for free for 30 days and if business doesn't like the system, have the technology taken out;

- Every lighting application should include an investigation of lighting controls at the site level. This would put more focus on lighting controls, and would require that vendors are better educated on the different technologies.
- Additional opportunities can come from training workshops reinforcing technical standards and savings quantifications. By providing these forums, program staff could be in a better position to assist vendors and future program participants on calculating baseline savings or redirect vendors to other retrofit control technologies to capture similar savings.
- Generate an energy savings calculation and presentation approach to show customers positive implications of installing lighting controls measure(s).
- Should keep all current incentives in place and just figure out way to implement specific incentives for advanced lighting controls. Vendors also suggest increasing incentives for sites with 5,000 hours or more. However, this should be considered carefully as greater hours does not always result in higher savings.
- Need to provide greater financial and technical assistance for more complex efficiency projects.
- Need for more outside sales and account managers to contact and visit sites and bring in project expeditors to do implementation. In buildings that appear to be good candidates for advanced controls, PAs may consider teaming with a lighting controls expert, who specializes in implementing advanced controls systems. Some project expeditors are not comfortable specifying lighting controls because they don't know how well they work.

6.1.3 Recommendations for Impact Evaluation and Savings Estimation Approach

DNV GL looked to gather the best information and methods currently available for calculating prescriptive lighting controls savings. The findings of this section focus mostly on occupancy sensors, since this technology currently dominates the prescriptive lighting controls savings in MA.

6.1.3.1 Current Savings Estimation Approach from MA TRM.

The calculation for prescriptive lighting controls savings essentially operates as a custom calculation. It calculates kWh savings using values obtained from the application, using the following formula:

$$\Delta kWh = (Controlled\ kW)(Hours_{base} - Hours_{EE})$$

$$\Delta kW = Controlled\ kW$$

Where

Controlled kW	=	Controlled fixture wattage
$Hours_{base}$	=	Total annual hours that the connected Watts operated in the pre-retrofit case.
$Hours_{EE}$	=	Total annual hours that the connect Watts operate with the lighting controls implemented.

This equation calculates accurate savings estimates to the extent that the parameters entered into it are accurate. However, these parameters are drawn entirely from customer or vendor-reported information on the application, including *Hours* and *Controlled kW*. While *Controlled kW* is relatively easy to accurately estimate from product cut sheets of lamp and ballast configurations, *Hours (reduction)* is notoriously hard to estimate accurately. The program does not require the customer to perform any kind of M&V activities, so empirical data is not always collected. This issue may compromise the accuracy of tracking savings estimates for retrofit lighting controls.

6.1.3.2 Percent Savings

DNV GL recommends that the program make a change to its current calculation methodology. We recommend that the program adopt the parameter Percent Savings (%Sav) for use in its lighting controls calculation going forward. This parameter, used by most other programs and research institutions, allows for a more intuitive calculation of savings for all lighting controls measures, including those which do not turn off lights completely such as daylight dimming. Using Percent Savings results in the following formula:

$$\Delta kWh = Controlled\ kW * 〚Hours〛\_base * \%Sav$$

DNV GL compared occupancy sensor savings from each study, identified above in Section 5.1.2, by space type, as data were available. Percent reduction values were available from all studies but the National Grid study, and may be applicable to the Massachusetts TRM, which has default hours of operation estimates by building type in the appendix of the document, which can be multiplied by percent reduction to get to hours reduced by building type. However, since most MA PAs utilize site specific hours estimates in their savings calculations, an alternative approach would be to apply the percent reduction against estimated MA site specific pre-installation hours of use.

- DNV GL recommends using the weighted average values from the LBNL study, which is weighted by the total number of studies used for calculating percent reduction for each facility type. The percent savings value for occupancy sensors is 24%, and the percent savings value for daylight dimming is 28%. This recommendation should apply for all occupancy sensor and daylight dimming installations until a new large C&I lighting controls study is completed.

6.1.3.3 Coincidence Factors

Table 20 below shows the coincidence factor results from all occupancy sensor sources together. Coincidence factors are multiplied by the Controlled kW to estimate summer or winter peak kW reductions.

Table 20 – Occupancy Sensor CF Source Summary

Coincidence Factor	MA 2010 Prescriptive Lighting	National Grid Occupancy Sensor Large	National Grid Occupancy Sensor Small	SBDI Occupancy Sensor
Summer On-Peak	15.0%	30.4%	34.8%	17.0%
Winter On-Peak	13.3%	19.2%	28.0%	13.0%
Summer Seasonal Peak	14.3%	N/A	N/A	N/A
Winter Seasonal Peak	13.9%	N/A	N/A	N/A

The National Grid and SBDI studies are both less than ideal since the National Grid study was based on a small sample size, and the SBDI study is focused on small C&I, while this evaluation deals with large C&I.

- DNV GL recommends that the program continues to use the CF values from the recent 2010 prescriptive lighting impact evaluation for all occupancy sensor installations until a new large C&I lighting controls study is completed..

6.1.3.4 Future Impact Evaluation

DNV GL reviewed several studies, savings estimation methods, and had detailed conversations with program staff and lighting controls vendors in an effort to understand the lighting controls market in MA. The results of this study show that there is some uncertainty of the future of lighting controls as more new technologies infiltrate the market, and customers are becoming more comfortable with controls strategies. However, it is clear that lighting controls will continue to be offered as a program, and there will always be a need for accurate savings estimates. Recommendations for future impact evaluations include:

- DNV GL recommends that the PAs implement the above savings estimation methods and savings values until a new statewide lighting controls impact evaluation can be conducted. When it comes time for a new impact evaluation, DNV GL strongly suggests that the PAs consider a full pre/post metering approach. Pre/Post metering of lighting controls will be difficult to employ, but it offers the most rigorous approach for estimating the key savings parameters; percent savings and the coincidence factors.

A. Program Staff Interview Guide

Interview Guide for Program Administrator Lighting Implementers
Discussion of Declining Program Participation and Other Potential Program Improvements
Project MA-LCIEC-22 ~ Evaluation of Large C&I Retrofit Lighting Controls

Company: ____________________________Phone: ___________________________

Name: _______________________________Title: ___________________________

Call Log:

Date/Time	Notes
1 ____________	______________________________
2 ____________	______________________________
3 ____________	______________________________
4 ____________	______________________________
5 ____________	______________________________
6 ____________	______________________________

1. Introduction

My name is ____ of DNV KEMA, and as I mentioned in my email, I'm calling to talk with you about lighting controls in the Massachusetts large commercial and industrial retrofit programs. As you may know, I am part of the evaluation team assessing these programs. These interviews are part of the MA-LCIEC Lighting Controls Impact Evaluation.

I want to hear about your experiences with lighting controls, your thoughts on industry trends, and suggestions for improvement. Please be aware that the information you provide will be treated as confidential.

Is now a good time to talk or should we (re)schedule an appointment for another time?

[IF THEY ASK ABOUT INTERVIEW LENGTH, SAY: "THE INTERVIEW SHOULD TAKE ABOUT 20-30 MINUTES, DEPENDING UPON HOW MUCH DETAIL WE GO INTO."]

To reduce the interview length and make the interview more conversational, we were planning to tape record the interview. Is that all right with you?

2. Individual's Role

IR1. First I'd like you tell me about your role at <UTILITY>, related to large C&I retrofit lighting controls?

[If this person appears not to be the most knowledgeable about how this program has changed over the years (at any point during the interview), terminate and ask for another contact at the utility with more knowledge of the lighting control program. Also feel free to gather contacts from the interviewee who may know more about specific issues and call them too.]

3. Program Background

First I'd like to ask you some questions related to the history and background of lighting controls within the Large C&I Lighting program.

a. When did <UTILITY>start offering rebates for large C&I lighting controls as part of retrofit projects?

b. What types of retrofit lighting control technologies are currently supported through < UTILITY's> lighting retrofit programs, specifically the [read each below]?

[Please ask the respondent to be specific: Product names & technology descriptions]

ba. Prescriptive program:

bb. Custom program:

c. Have the types of lighting controls supported by < UTILITY> changed over time? If so, how?

d. I'd like to ask about the individual technologies separately, including occupancy sensors, daylighting controls, advanced / networked controls, wireless controls, and [other, from above]. What large C&I sectors or business types are the largest consumers of these technologies' as program participants for retrofits?

da. Occupancy Sensors:

db. Daylight Dimming:

dc. Advanced / Network Ctl:

dd. Wireless Controls:

de. Other:

e. How would you describe the growth and decline curves for program-sponsored installations since the program began for [read each measure]?

Measure	2000	2006	2009	2012
B8. a. Occ. Sensors				
B8. b. Daylight Dimming				
B8. c. Advanced / Network Ctl.				
B8. d. Wireless Controls				
B8. e. Other				

PB5a. Have you observed in your projects installing fewer lighting controls than in the past?

f. What have been the reasons for the various increases and declines over the years?

[PROBE] Program funding changes, program equipment requirements / eligibility, marketing, code changes, program saturation, product problems, economy, technology shifts, etc…?

fa. Occupancy Sensors:

fb. Daylight Dimming:

fc. Advanced / Network Ctl:

fd. Wireless Controls:

fe. Other:

g. Have these changes occurred in both prescriptive and custom programs, large and small C&I, in the same way?

h. How would you describe the trend regarding the following technologies:

PB8a. High bay Occupancy Sensors:

PB8b. Office Occupancy Sensors:

PB8c. Daylight Dimming:

[PROBE] When did it take off? Would you say it has reached its peak, or is that yet to come? Do you feel that there is still a great deal of potential in this area, that it's been tapped out, or something in-between?

PB9. Are there other measures where trends were identified in PB5 that require some more explanation? If Yes – please elaborate.

4. Recent Changes

RC1. What would you say has changed over the last three years with regard to program activities, funding, and goals in regards lighting controls to the large C&I retrofit programs? Were these changes good for the program? Why or why not?

[PROBE] Program funding changes, program equipment requirements / eligibility, marketing, prescriptive vs. custom

RC2. What industry trends have you seen over the past three years that would affect lighting control installation with the large C&I retrofit programs?

[PROBE] Code changes, program saturation, product problems, economy, technology changes, etc…?

RC1a. Have you noticed any changes in customers' level of understanding of the benefits of lighting control technologies over the past three years? If yes, what were they?

RC2b Have you seen any changes in customer's acceptance of lighting controls for their facilities? If yes, what were they?

RC1d. Have you seen people becoming skeptical of certain types of retrofit lighting controls based on experience or for other reasons? If yes, what were the implications?

RC1e. Have you seen customers waiting for new products to come out, and holding off purchases until then? Or large numbers of them delaying projects for other reasons recently? If yes, why?

RC1f. [If RC2a to RC2b not answered] In your opinion, what are the barriers that discourage your target market actors from adopting more energy-efficient lighting control technologies? Why?

RC1g. Would you say that the market is saturated for any of these measure or sectors? If yes, which measures, and why? For occupancy sensors in particular?If yes, why?

RC3. Of all the trends we've discussed, which do you see being the primary drivers for program-related installations?

In your opinion do you see a shift in a particular market segment towards high bay occupancy sensor retrofits?

RC4. Do these trends seem likely to continue based on your understanding of the program and the current market?

RC5. How well do you think the program is doing at addressing customer motivations and inhibitions for purchasing efficient lighting control technologies? Why do you feel this way?

RC6. How well do you think the program is doing at addressing distributor and contractor motivations and inhibitions for promoting efficient lighting control technologies? Why do you feel this way?

[If the issue of a drop-off in program activity hasn't come up yet, read the following paragraph and revisit the questions in the RC section. Otherwise skip.]

According to the program tracking data across Massachusetts we have seen a drop-off in installations of large C&I prescriptive retrofit lighting controls over the past two years, particularly with regard to occupancy sensor installations. We've been asked to try and get our heads around this issue and make recommendations with respect to evaluation and what level lighting controls might play going forward within the prescriptive lighting program given the recent downward trend in installations.

5. Future Actions

FA1. What do you think the program could do, if anything, to change the trend in lighting controls retrofit projects from negative to positive?

FA5a. What measures would you recommend adding or focusing on, which you think might have a future for saving energy in the retrofit lighting controls market?

FA5b. In what large C&I sectors do you see potential for increasing program-sponsored installations of retrofit lighting controls?

FA2. Do you think there are technologies or sectors that the program should stop focusing on, based on the market being saturated, economically tight, or limited for other reasons? [For each technology, probe for which of these reasons is driving their concern.]

FA3. Do you think there are technologies or sectors that the program should keep focusing on, which you are currently having success with? If yes, why?

FA4. Other Contacts

OC1. Can you tell me if there are others on your staff who might have additional insight into these questions?

[Record name and phone and/or email] ________________________________

OC2. Can you tell me if there are contractors or distributors who might have special insight into the reasons for program changes and ideas for increasing installation rates?

[Record name and phone and/or email] ________________________________

B. Interview Guide for Lighting Controls Implementation Vendors

Introduction

Hello. My name is _________________. I'm calling on behalf of the the Massachusetts utilities. We are conducting a study to better understand how lighting controls are being addressed by <the utilities > in major retrofitsof commercial and industrial buildings in Massachusetts. We would like to get your feedback about <UTILITY> programs and how the program incentives and/or information may have changed how you approach the lighting controls business.

Based on our records, we believe that:

Your company designs, implements, and/or commissions lighting controls projects in commercial and industrial buildings in Massachusetts.

I1. Can you speak about lighting controls installations in Massachusetts?

0 ❑ No *(Go to II2)*
1 ❑ Yes *(Go to II4)*

I2. Is there someone else in your company who might be a better person to speak to about this?

0 ❑ No *(Thank and terminate)*
1 ❑ Yes *(Go to* I3*)*

I3. Can you provide their name and contact information?_____
____
____

I4. Would you be willing to talk with me? All of the information you provide will be kept confidential.

0 ❑ No (*Thank and terminate)*
1 ❑ No, but will be interviewed later. *(Go to* I5*)*
2 ❑ Yes *(Go to II6)*

I5. Can you provide a good time to call and a telephone number?_____

____

____

I6. What is your position in your company?

____

I7. Do you provide lighting controls related services to clients?

0 ❑ No *(Skip to II9)*
1 ❑ Yes *(Go to I*I8*)*

I8. Within the past year, did you install lighting controls in retrofitted commercial and/or industrial buildings, in Massachusetts?

0 ❑ No *(Go to II9)*
1 ❑ Yes *(Go to B1)*

I9. Is there someone other than yourself within your company who does have this experience?

0 ❑ No *(Thank and terminate the interview)*
1 ❑ Yes *(Go to Q*I10*)*

I10. Can you provide their name and contact information?*(Thank and terminate the interview)*___

____

____

Background

First, I have a few questions about your background. Specifically, I want to ask about your work in Massachusetts.

B1. About what percent of your business is associated with each of the following services?

0 ___Lighting Design
1 ___Lighting Installation
2 ___Lighting Maintenance
4 Lighting Commissioning
3 ___Lighting Finance
4 ___Other (*please specify*): ____

B2. What percentage of your work in Massachusetts involves replacing or remodeling indoor lighting systems in existing commercial or industrial buildings? ________ *Note:If respondent does not know, ask for an approximation using the following ranges. Read categories and check one answer*

0 ❑ 0%
1 ❑ 1-5%
2 ❑ 6-10%
3 ❑ 11-20%
4 ❑ 21-25%
5 ❑ 28-30%
6 ❑ 31-50%
7 ❑ 51-75%
8 ❑ 76-100%
9 ❑ DKNA

B3. Over the last year, about how many projects is that? __________
Note:If respondent does not know, ask for an approximation using the following ranges. Read categories and check one answer

1 ❑ 0
2 ❑ 1 to 25
3 ❑ 26 to 50
4 ❑ 51 to 75
5 ❑ 76 to 100

6 ❑ More than 100
8 ❑ DKNA

B4. In what types of buildings have you installed lighting in the last year?
(Read list and check all that apply)

1 ❑ Office	5 ❑ School	9 ❑ Hospital
2 ❑ Restaurant	6 ❑ College	10 ❑ Health Facility
3 ❑ Retail	7 ❑ Religious	11 ❑ Warehouse
4 ❑ Grocery	8 ❑ Hotel	12 ❑ Manufacturing

13 ❑ Other *please specify*____
14 ❑ DKNA

B5. Can you describe how you determine if a space/room is appropriate for controls?
*(If respondent does not know, probe with the following: Discussions with facility staff, short term logging, consider the space type, does it have a lot of day lighting, or some other method)*____

B6. Approximately how many total fixture units did you install with automated lighting controls, and also how many did you install with only manual switches in existing commercial/industrial buildings in Massachusetts in the last year?
___________ Automated Lighting Controls ____________ Manual Switches
(*If respondent does not know, ask for an approximation using the following ranges. Read categories and check one answer;)*

0 ❑ 0
1 ❑ 1-500
2 ❑ 501-1,000
3 ❑ 1,000 to 5,000
4 ❑ 5,001 to 10,000
5 ❑ 10.001 to 50,000
6 ❑ more than 50,000
9 ❑ DKNA

B7. In the last year, what percentage of the fixtures installed in commercial/industrial buildings in Massachusetts had the following control technologies?
(Read list and record all that apply)

1 ________ Occupancy sensors

2 ________ Daylighting controls (e.g. continuous dimming or bi-level switching)
3 ________ Manual Switching (e.g. single level or manual dual level switching)
4 ________ Manual Dimming
5 ________ Advanced/ Network Control
6 Wireless Controls
7 Other please specify:____________________

B8. How would you describe the growth and decline trends in the past several years (since 2006) for the following installations [read each measure]?

Measure	Trend (Growth/Decline/ Stay the same)	Reason for Trend [PROBE] Lack of support for lighting controls in <utility> operated energy efficiency Program, program equipment requirements / eligibility, marketing, code changes, market saturation, product problems, economy, technology shifts, etc…?
B9a. Occupancy Sensors Tracking data shows drop off after 2010		
B9b. Daylight Dimming		
B9c. Manual Switches		
B9d. Manual dimming		
B9e. Advanced Network Controls Can access from EMS/computer/remotely		
B9f. Wireless Controls		
B9g. Other		

B9. Have you observed more, less or the same amount of automated lighting controls installations than in the past?

B11. Have these changes occurred in large (facilities greater than 300 kW) and small (<300 kW) Commercial and industrial, in the same way?

B12. How would you describe the sales trend regarding the following occupancy sensor technologies over the past several years:
[PROBE] When did it take off? Would you say it has reached its peak, or is that yet to come? Do you feel that there is still a great deal of potential in this area, that it's been tapped out, or something in-between?

B12a. High bay fixture mounted Occupancy Sensors:

B12b. High bay space occupancy sensors

B12c. Office Occupancy Sensors:

B13. Are there other measures where trends were identified in B8 that require some more explanation? If Yes – please elaborate.

Recent Changes

RC1. What industry trends have you seen over the past three years that would affect lighting control installation with the large C&I retrofit programs?
[PROBE] Code changes, market saturation, product problems, economy, technology changes, etc…?

RC1a. Have you noticed any changes in customers' level of understanding of the benefits of lighting control technologies over the past three years? If yes, what were they?

RC1b Have you seen any changes in customer's acceptance of automated lighting controls for their facilities? If yes, what were they?

RC1c. Have you seen people becoming skeptical of certain types of retrofit lighting controls based on experience or for other reasons? If yes, what were the common reasons?

RC1d1. Have you seen customers waiting for new products to come out, and holding off purchases until then? ____________

If yes, why? ______________

2. Have you seen large numbers of customers delaying projects for other reasons recently? ______________

   a. If yes, why? _____________

RC1e. [If RC1a to RC1d not answered] In your opinion, what are the barriers that discourage your target market actors from adopting more energy-efficient lighting control technologies? _______________________________

Why? ______________________________

RC1f. Would you say that the market is saturated for any of these measures or sectors? If yes, which measures, and why?

For occupancy sensors in particular? If yes, why?

Now I'd like to learn more about the <UTILITY> operated incentive programs and the trends.

RC2. Of all the trends we've discussed, which do you see being the primary drivers for installations of lighting controls that received program incentives?

RC3. In your opinion do you see a shift in a particular market segment towards advanced lighting controls?

RC4. Do these trends seem likely to continue based on your understanding of the current market?

RC5. How well do you think the incentive program is doing at addressing customer motivations for purchasing efficient lighting control technologies? Why do you feel this way?

RC6. How well do you think the incentive program is doing at addressing distributor and contractor motivations for promoting efficient lighting control technologies? Why do you feel this way?

RC7. How well do you think the incentive program is doing at addressing customer inhibitions for purchasing efficient lighting control technologies? Why do you feel this way?

RC8. How well do you think the incentive program is doing at addressing distributor and contractor inhibitions for promoting efficient lighting control technologies? Why do you feel this way?

Future Actions

FA5. What do you think the incentive program could do, if anything, to improve the number of completed installations of lighting controls retrofit projects?

FA5a. Which measures do you think would have the most potential to provide energy savings in context of the retrofit lighting controls market?

FA1b. How could the utility incentive programs support those measures?

FA5c. In what C&I sectors do you see potential for increasing incentive program-sponsored installations of retrofit lighting controls?

FA6. Do you think there are technologies or sectors that the incentive program should stop focusing on, based on the market being saturated, economically tight, or limited for other reasons? [For each technology, probe for which of these reasons is driving their concern.]

FA7. Is there anything the incentive program could do to improve the support of these technologies? If so, what?

FA8. Do you think there are technologies or sectors that the incentive program should keep focusing on, which you are currently having success with? If yes, why?

FA9. What do you think are the areas for improvement for <utility> operated incentive program?

Closing

I have just a few more questions before we end.

C1. Which of the following ranges describes the number of employees in your company or organization? *Read list and check only one.*

1 ❑ 1
2 ❑ 2 to 4
3 ❑ 5 to 9
4 ❑ 10 to 24
5 ❑ 25 to 49
6 ❑ 50 to 99
7 ❑ 100 or more
7 ❑ DKNA

C2. Which of the following ranges describes your company's annual revenue? *Read list and check only one*.

1 ❑ under $200,000
2 ❑ $200,000 to $499,999
3 ❑ $500,000 to $999,999
4 ❑ $1 million to $2.4 million
5 ❑ $2.5 million to $4.9 million
6 ❑ $5 million to $9.9 million
7 ❑ $10 million to $24.9 million
8 ❑ $25 million to $49.9 million
9 ❑ $50 million or more
98 ❑ Don't know
98 ❑ Refused

C3. Is there anything else you would like to say concerning <UTILITY> commercial and industrial programs?

____

____

Thank you for completing the survey. Your responses will help <UTILITY> to do a better job of serving the commercial, industrial and professional design and construction communities.

C. LBNL Study Sources

Publication Venue	Number of Papers	References
IESNA	9	Grandersonetal., 2010; RubinsteinandEnscoe, 2010; Galasiuetal., 2007; Jenningsetal., 2001; Boyceetal., 2000; Jenningsetal., 2000; VonNeidaetal., 2000; Manicciaetal., 1999; Rubinsteinetal., 1998
ACEEE	8	KoyleandPapamichael, 2010; Mukherjeeetal., 2010; PageandSiminovitch, 2004; Figuerioetal., 2002; Reinhart, 2002; Floydetal., 1996; Piggetal., 1996; Schrumetal., 1996
Energy and Buildings	5	Roisinetal., 2008; Bourgeoisetal., 2006; LeeandSelkowitz, 2005; AtifandGalasiu, 2003; BodartandDeHerde, 2002
Lighting Research and Technology	4	Newshametal., 2008; Leslieetal., 2005; Mooreetal., 2003; Mooreetal., 2002
Solar Energy	3	Kapsisetal., 2010; YangandNam, 2010; Galasiuetal., 2004
Other journals	5	Lietal., 2010; Lietal., 2006; ChungandBurnett, 2001; NilssonandAronsson, 1993; CarriereandRea, 1984
Other conference proceedings	8	BirtandNewsham, 2009; GalasiuandNewsham, 2009; Doulosetal., 2007; Deruetal., 2006; FloydandParker, 2005; Rubinsteinetal., 2003; Parkeretal., 1996; RubinsteinandKarayel, 1982
Consultant and government reports	30	LRC(2008, 2004a, 2004b, 2004c, 2003a, 1997a, 1997b, 1995); HerschongMahone Group(2005, 2003a, 2003b); CLTC(date unknown; CLTCetal., 2010); California Utilities Statewide Codes and Standards Team(2011a, 2011b); Pacific Northwest National Laboratory (Jones and Richman, 2005; Richmanetal., 1994); PIER (2008a, 2008b); ADM Associates Inc.(2002); Clanton & Associates(date unknown); Emerging Technology Associates Inc. (2010); Energy Solutions (2009); Energy Studies in Buildings Laboratory — University of Oregon(2006); Florida Solar Energy Center (Floydetal., 1995); International Facility Management Associationand Lawrence Berkeley National Laboratory(2005); Lawrence Berkeley National Laboratory (Rubinstein and Verderber, 1990); Sacramento Municipal Utility District (Bisbee, 2010); Southern California Edison (2009); Washington State University Extension Energy Program(2011)
Industry case studies	16	WattStopper(2010, 2008, 2007, dateunknowna–h); SensorSwitch(dateunknownaandb); Lutron(dateunknownaandb); Encelium(dateunknown)

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† ASHRAE 90.1, the national model building code, is updated every three years and includes several controls requirements in ASHRAE 90.1–2010 including automatic shutoff controls and photocells in certain space types. However, states have until 2013 just to update their codes to meet ASHRAE 90.1–2007, and some states still meet only ASHRAE 90.1–2001 (U.S. Department of Energy 2011a).
*References marked with an asterisk were used as background only; as they are not primary sources of energy savings estimates, they were not included in the meta-analysis.