A Guiding Light for Market Effects Research: Lessons Learned from LED Baseline Development across Multiple Regions

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ABSTRACT

Assessing the effects of energy efficiency programs on targeted markets, often requires, at a minimum, the comparison of market conditions over time, starting from a well-documented baseline. Assessment of a program's effects is further facilitated by comparing market conditions within the program area to market conditions outside the program area. However, using cross-regional and temporal comparisons adds complexity to the task of developing a baseline as the data used to estimate key market indicators, such as measure adoption, must be collected using methods that are replicable over time and, to the extent possible, in different regions... Thus, research to support market effects analyses requires that care is taken to ensure data collection and analysis methods are appropriate, replicable, and defensible.

In this paper, we present key results and methodological lessons learned from the baseline development of LED markets in multiple regions for two different market effects studies; the first completed in 2014 for the California Public Utilities Commission (DNV GL and TRC, 2014) and the second completed in 2015 for the Massachusetts Energy Efficiency Advisory Council (DNV GL, 2015a). While these studies aimed to develop various indicators of market status, we focus on measures of adoption in this paper. We discuss the methods used to develop these indicators, their meaning and relevance in market effects and analysis, and the applicability of various data sources that can be used to estimate adoption. We end with a presentation of key study results and an interpretation on what these results suggest about the state of the market and the use of the considered data sources.

Introduction

Evaluators face a number of difficult challenges when assessing the effect of local or regional energy efficiency programs on the adoption of efficient manufactured products by commercial and industrial customers. For studies of market effects, the most important of these challenges are to:

- Develop accurate estimates of one or more measures of adoption in the program area.
- Repeat those estimates over time.
- Develop data that can be used to estimate the portion of levels of adoption observed in the program area that are attributable to the effects of the program, versus other potential influences.

This paper summarizes two baseline studies on LED lighting that the authors recently completed for sponsors in California and Massachusetts, focusing on the methods used to address the challenges listed above and key results.

Studies Reviewed in this Paper

DNV GL recently developed comprehensive characterizations of baseline market conditions for LED lighting products in California and Massachusetts. These studies were designed to support the assessment of market effects generated by programs offered by Investor Owned Utilities (IOUs) in those

states to promote LED lighting.

The study plans called for the estimation of indicators of market development in California and Massachusetts on the one hand, and in a comparison area composed of regions not served by LED promotion programs funded by public benefits charges, on the other. We hypothesized that a comparison of the market indicator values between the two sets of regions would provide some insights into the effects of the Massachusetts and California programs for LEDs. While developing a national-level baseline would have been ideal, it was cost-prohibitive. Instead, we selected a comparison area of Arizona, Georgia, Nebraska, and Kansas as they met the following criteria:

- Absence of large-scale utility programs promoting LED lighting.
- Resemblance to California in terms of commercial customer attributes known to affect promotion and adoption of efficient lighting products: make-up of the population of commercial establishments by industry and size, size and structure of the population of business establishments, energy prices, level of urbanization (related to size and structure of distributor and contractor networks)[1].

Given the international scope and structure of the LED market, it was necessary to capture information from a wide range of actors to effectively characterize market conditions. Each study relied on a variety of primary data collection and analysis efforts across the entire lighting supply chain in each region. At the time the California and Massachusetts studies were conducted, multiple evaluations involving primary data collection targeting customers and vendor groups of interest were underway. To reduce respondent burden and study costs, each study was conducted in coordination with these other evaluation efforts. Similarly, many data collection instruments used in Massachusetts were based on questions previously asked in the comparison area as part of the California study. Table 1 summarizes the data collection and research efforts associated with the non-residential market.

Table 1. Overarching and Non-Residential Data Collection Efforts across the Three Regions[2]

Data Collection Effort	Sample Sizes and Data Collection Timing		
Overarching Market Issues And Trends	California (2013)	Massachusetts (2013-2014)	Comparison Area (2013)
Local Program Managers	4	11	
National Program Managers	12		
Analysis of Product Databases/Secondary Literature Review	X	X	X
Analysis of Massachusetts Building Codes	X	X	X
Processing of PA program databases	X	X	X
Non-Residential Market			
Installation Contractors	94*	43	64
Designers/Specifiers	19	10	20
Distributors	20	10	18
Non-Residential End-Use Customers	3,320*	617*	384

The California and Massachusetts baseline characterizations were designed so that the primary research components could be replicated at a later date. Such a research strategy would enable the study sponsors to apply a cross-regional "difference of differences" approach to assessing the influence of the

[1] The comparison area was selected for the CPUC study, so state characteristics were compared to California. Before beginning the Massachusetts study, the research team compared demographics and firmographics from each region to ensure it was an acceptable comparison area for the Massachusetts study as well. More information on the selection process and comparisons between regions can be found in the baseline study reports.

[2] A "*" indicates a study that required coordination with other evaluation efforts.

program on key indicators of market development. This approach is described further below. As of this writing, the sponsors have not decided whether or when to proceed with such follow up studies.

Methodological Framework and Challenges

Researchers typically use a wide range of indicators to characterize conditions in markets for energy-efficient goods and services, as well as the effects of programs on those markets. On the customer side of the ledger, these include indicators of customer awareness and knowledge of product attributes, perceived motivations and barriers to adoption, and the extent of adoption itself. On the supply side, key indicators include measures of local availability, price, and vendors' perceived motivations and barriers to stocking, promotion, and sales. Vendors can also provide data to develop measures of adoption, such as point-of-purchase sales records, sales diaries, and shipment information. These kinds of quantitative indicators, as well as more qualitative assessments of technology development, industry structure, and competitor strategy in the supply chain provide program planners and managers with the rich understanding of technology and market developments needed to design and operate a successful energy efficiency program. However, in assessing program effects from a resource point of view, we are primarily interested in patterns and trends of measure adoption.

In and of themselves, indicators such as market share or saturation do not represent a program's effects on energy efficiency measure adoption. Such an indicator must incorporate the results of an analysis of the program's incremental influence on adoption, taking into account other influences such as improvements in product performance, reductions in price, product standards, and vendor promotional efforts. Analysis of customer and vendor self-reports of program influence on purchases and promotional efforts, respectively, is the best-known and most frequently used approach to quantifying program influence – usually in the form of free ridership and spillover factors in net-to-gross assessments. However, as discussed below, these methods are subject to high levels of uncertainty if used without reference to data on measure adoption among all customers in the program area, especially in fast-changing markets such as those for LED lighting.

In the paragraphs below, we briefly summarize the development of the C&I market for LED lighting, and the programs offered by regional sponsors and others to promote it. We then we discuss the range of methods available to assess the market effects of regional programs, their most appropriate applications, and limitations with specific reference to the commercial LED market. We next identify the range of measures of adoption that can be developed at the regional level, their applications in supporting market effects analysis, and their relative strengths. We conclude the methods section with a description of the particular challenges associated with assessing market effects for programs that promote LED lighting.

LED Market Conditions and Program Activity Prior to Baseline Studies

Market Development. The LED lighting market is dynamic, large, and developing quickly. Since 2008, government and industry have been investing basic science and manufacturing R&D into LED research at a rate of $600 million or more annually. Manufacturers interviewed for the baseline studies reported spending 70 to 100 percent of their product development budgets and 50 to 75 percent of their marketing budgets on LED products.

At the time we initiated the first of the two baseline studies, 2013, the market had already taken off and products were infiltrating supply chains across the country. The growth of the LED market is evident in the number of products that qualify for the ENERGY STAR label and Design Lights Consortium (DLC) Qualified Products List (QPL). The total number of lamp models that qualified for the ENERGY STAR label increased from 1,273 to 2,288 between 2012 to 2013. The number of models stabilized in 2014, but the number of qualified products for key replacement applications – A-lamps – increased from 6 to 19 percent of the total. Similarly, the number of LED products included on the DLC

QPL increased substantially since the testing program began in 2010 (Figure 1). By the middle of 2015, roughly 100,000 products, primarily fixtures for non-residential applications, were included on this list.

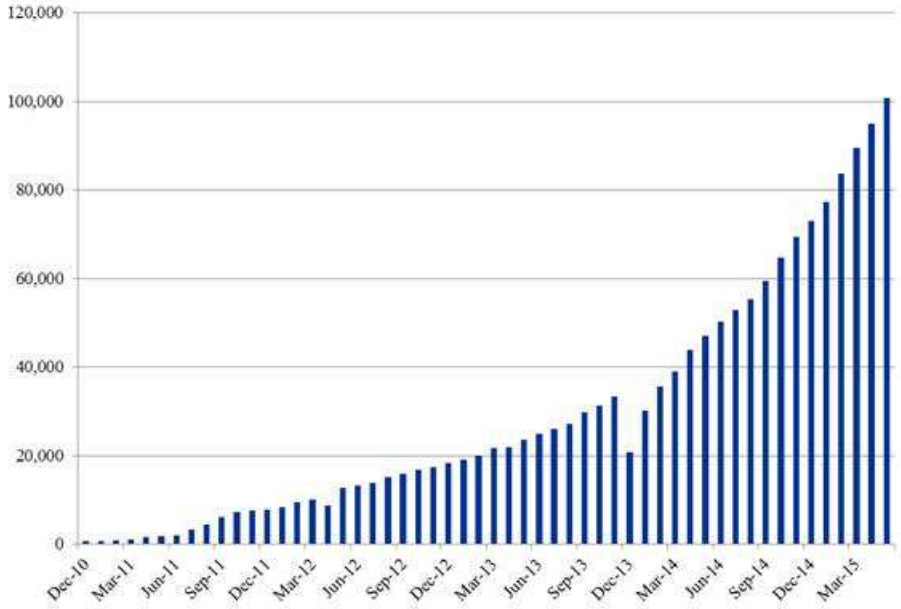

Figure 1. Design Lights Consortium Qualifying LED Products

Status of Programs to Promote LEDs at the Time of the Studies. Most evaluation methods guides define "baseline" as conditions or subject behavior that would have occurred in the absence of the program. (EPA 2007) In our experience, however, baseline studies are frequently commissioned after at least some relevant program activity is underway. This was the case for both studies reviewed in this paper.

At the national level, a number of organizations had launched efforts to promote the development of LED products and to test and certify their quality. The U. S. Department of Energy launched the Solid State Lighting (SSL) Program in 2006 to support technology and market development. SSL supports basic product and manufacturing research and development through competitive grants, conducts laboratory product testing and quality reporting, and provides market support through research and outreach. The U. S. Environmental Protection Agency initiated their product testing and qualification program for LED lamps in 2009. The Design Lights Consortium, a program of the Northeast Energy Efficiency Partnerships, established their testing and certification program for LED fixtures targeted to the commercial and industrial markets in 2010. These programs engaged manufacturers directly and provided a set of third-party qualified products for local program administrators to promote.

At the time we conducted our research, the support provided to the LED market in each region varied:

- *Strong Support: Massachusetts.* The Massachusetts Program Administrators (PAs) have provided strong support for energy efficient lighting for many years and began heavily supporting LEDs in 2012. The PAs incentivized almost 20,000 residential lamps and fixtures (less than 1% of program savings) in 2012 and over 1,000,000 in 2013 (14% of gross program savings). Similarly, the PA programs provided LEDs to 4,011 non-residential customers in 2012 and 4,694 customers in 2013. This equates to 37% and 48% of annual program lighting savings in 2012 and 2013, respectively.
- *Limited Support: California.* California's Investor-Owned Utilities (IOUs) have a long history of programs which support energy efficient lighting; these programs provided some support for LEDs in the 2010-2012 period. During this period, the IOUs incentivized roughly 110,000

residential reflectors and provided LEDs to roughly 32,000 non-residential customers (9% of non-residential lighting program savings).

- *No Support: Comparison Area.* The four comparison area states have a limited history of supporting efficient lighting technologies. After the studies began, however, three of the comparison area states, Arizona, Georgia, and Nebraska, launched programs which provide limited support for LEDs.

Approaches to Quantifying Market Effects

The basic methodological strategies available to develop assessments of a program's market effects are largely the same as those for used to distinguish net from gross savings. In this case, we are interested primarily in the program's effect on measure adoption, as opposed to energy consumption. The principal methods used to assess program effects on measure adoption, net of other influences include the following:

Analysis of self-reports of program effects by targeted customers. This approach typically involves surveying samples of actual and/or potential program participants to elicit their assessment of the program's influence on their decisions to adopt energy efficiency measures or practices or, alternatively, to characterize what they would have done in the absence of the program. While customer-oriented self-report methods can yield useful information for program evaluations, their application in market effects studies is limited by the following factors.

- *Lack of information on purchases outside the program.* Recent market effects studies of programs to promote efficient high bay lighting (KEMA 2010, 2011) found high levels of adoption of efficient models among non-participating facilities. Most survey respondents in surveys of commercial facilities find it difficult to provide accurate information on the type, quantity, timing, and efficiency levels of lighting equipment purchased and installed. The quantity of eligible products purchased and installed by non-participants is a critical factor in estimating net program effects on adoption.
- *Low visibility of program influence for up-stream programs***.** Most of the LED promotion programs we identified target incentives to distributors. Some programs require that distributors inform customers of the discounts they provide on eligible products; others do not. A recent process evaluation of the Massachusetts program found that roughly 70 percent of participating customers were aware of discounts on equipment purchased with program support. The program is likely to be even less visible to non-participants who may nonetheless have been influenced by vendor promotions related to program efforts.

Quasi-experimental designs. This approach uses well-established quasi-experimental social research designs to assess and quantify net program effects. All of them produce estimates of the changes in the rate of adoption associated with the program. They then require estimation of measure adoption at the market level to quantify savings. Several, including cross-regional comparisons and structured expert judging also use market-level estimates of adoption directly in the analysis of market effects. Common strategies include:

- *Cross-regional Comparisons.* The rate of measure adoption in an area or market segment not targeted by the program is used as a baseline for comparison to rates of adoption in the program area. The difference between the two can be interpreted as the program's net effect. This type of analysis requires the development of uniform measures of adoption in the program and comparison areas. Deploying this method at different points of time provides an opportunity to apply a "difference of differences" approach in assessing program effects. Analysts who deploy this method must demonstrate that the program and comparison areas are comparable in terms of factors such as energy prices and customer demographics that likely influence the level of adoption independently of the program.

- *Vendor self-reports.* As more program attention is focused on firms in the supply chain for commercial products, distributors and contractors become important sources of data on both current market share, as well as the baseline level of adoption in the absence of the program.
- *Structured expert judging.* Structured expert judgment studies assemble panels of individuals with close working knowledge of the various causes for changes in the market, technology, infrastructure systems, markets, and political environments addressed by a given energy efficiency program to estimate baseline market share and, in some cases, forecast market share with and without the program in place.[3]

The remainder of this paper discusses the use of measures of adoption in cross-regional comparisons. However, the technical points apply to the development of these indicators for use in any analytical framework.

Measures of Adoption

The LED baseline studies discussed above developed primary data and/or used the results of other recent primary research to develop the following kinds of measures of adoption:

- *Rate of adoption***:** the percentage of customers (facilities in the targeted population) that report having purchased and installed at least one unit of the eligible product during the study period. It is much easier for commercial customers to report accurately whether they have purchased a certain product than to report the quantity. Moreover, for contractors who work on a project basis, it is more likely that they will be able to report the percent of projects in which a given technology is used versus the percent of all floorspace or fixtures installed that is accounted for by the technology in question.
- *Saturation:* the percentage of the total inventory of installed lighting equipment or lighted floorspace served by the technology in question. Generally speaking, accurate estimates of saturation in the commercial setting can only be obtained through on-site inspections by trained staff.
- *Market share:* the portion of total sales of a product type in a given period that is accounted for by the models that meet program specification. For example: the percentage of total reflector lamp sales accounted for by LEDs during a given program year. For estimating net program effects on adoption, this is the most direct and useful indicator. It is also the most difficult to develop from primary data.

Table 2 displays the potential sources of data to compute the measures of adoption discussed above and provides a high level view of the feasibility of those sources to create such indicators. Analysts interested in using these measures of adoption in market effects studies also need to take into account the following considerations:

- *Timeliness:* As discussed above, availability of LED lamps and fixtures has increased and prices have decreased quickly. Analysts must be able to deploy data collection and analysis efforts rapidly and, if possible, in repeated cycles.
- *Comparability over time or across regions:* A survey whose results will be compared over time or across regions should use the same sample frame (updated, of course), sampling approach, weighting and sample expansion methods, and questionnaire. Comparability over time can also be addressed by developing panels of respondents. Where quasi-experimental methods require the use of results from primary research conducted for other sponsors, we cannot control the

[3] Analysis of point of purchase data to assess the effect of price changes on purchase as well as conjoint analysis of stated and revealed preference have been used to assess net program effects. Their data requirements largely restrict their application to residential programs and products.

methods used. In such cases researchers must explore and understand the inevitable differences in methods between the two studies and make an open and transparent assessment of the effect of these differences on the observed results. We discuss a number of such instances below.

Table 2. Measures of Adoption and Data Sources: Applicability to Commercial Lighting Markets

	Market Share	Rate of Adoption	Saturation
Customer Phone Survey	**Not Applicable** Customers are generally unable to report accurately on quantity, timing, and efficiency level of lighting purchases	**Feasible** Customers generally can report accurately on whether they have purchased and installed a particular technology; frequently encounter uncertainty as to timing	**Limited** Some studies have developed useable information on percent of floor space served by subject technologies (KEMA, 2010)
Customer On-site Survey	**Limited** If technology has only been available at commercial levels for one – three years, saturation of installed technologies plus customer installation date can serve as proxy for market share	**Good** Identification of subject technologies by trained inspectors reduces uncertainties due to limited customer knowledge. Need customer verification of installation date	**Good** Given the nature of lighting technology applications, on-site inventories by trained inspectors is the only practical method to develop accurate data on saturation
Vendor Survey or Panel	**Good** Distributors and contractors have the best view of the flow of lighting products into commercial facilities. However, collection and interpretation of these data poses challenges of sampling, sample data expansion, and data validation	**Limited** Contractors directly observe the portion of projects that include the subject technologies. Applies mainly to fixtures as opposed to replacement bulbs. No direct method to expand sample findings to population.	**Limited** Vendors directly observe baseline inventories of lighting equipment in the course of their work. However they can provide only high level impressions. No direct method to expand sample findings to population of facilities.

Current State of the LED Market: Measures of Adoption

Rate of LED Adoption

Cross-regional comparisons for all LED product types. In conducting the California and Massachusetts LED baseline studies we encountered many of the complications associated with making such comparisons, including:

- *Studies conducted at different times.* The California customer data were collected as part of a Commercial Market Share Tracking (CMST) survey that captured information on a broad range of end uses. The version with the full battery of LED questions was in the field from November 2012 through May 2013. The comparison area survey was fielded in the second and third quarters of 2013; the Massachusetts survey in the last quarter of 2013 with a follow up in the first and second quarter of 2014. Given the rapid proliferation of LED lamps and fixtures and price reductions of popular product types, the differences in rate of adoption observed between the California and Massachusetts surveys – conducted one year apart – may just as likely be due to changes in the national market as to differences between local markets and programs.
- *Difference in sample frames and measures of size*. The California study used utility billing records for the sample frame and stratified on annual kWh consumption. In Massachusetts and the Comparison Area we needed to use a commercially-available establishment database as the sample frame, with number of employees being the most reliable measure of size for stratification and weighting. Billing data and commercial establishment databases differ in

significant ways with respect to definitions of the entities listed. It is not clear how these differences affect the results of the surveys.

Table 3 presents the rates of LED adoption reported by commercial customers in California, Massachusetts, and the comparison area, applying both population and size weights. The former estimates the portion of *all* establishments with LEDs installed. The latter estimates the portion of total commercial consumption or employees in facilities with LEDs installed. While it is not identical to market share, the size-weighted measure does account for the large variation in the size of commercial customers. It is thus useful to facilitate comparisons of results between customer surveys and market share assessments based on contractor or distributor studies.

Table 3. Non-Residential Customer Rate of LED Adoption and Rebates. Customer Telephone Surveys: 2013

	California (n=1,770)	Massachusetts (n=617)	Comparison Area (n=384)
Businesses that have installed LEDs since 2009 [a] (Population-weighted)	32%	39%	33%
Businesses that have installed LEDs since 2009 [a, c] (Size Weighted by Consumption or Employment)	46%	63%	42%

a- Difference between California and Massachusetts results is statistically significant at the 90% level of confidence.
c- Difference between comparison area and Massachusetts results is statistically significant at the 90% level of confidence

The population-weighted rates of adoption were nearly identical for California and the comparison area – about one-third. In Massachusetts they were 6 percent higher. This may reflect the relatively high level of participation in Massachusetts programs – 10 percent of customers over two years. The difference between Massachusetts and the two other areas is more pronounced when size-weights are applied. This result is consistent with the findings of many evaluations that larger firms are more likely to adopt new technologies and to participate in energy efficiency programs. The results suggest that the customer market in California and the comparison areas were at roughly similar levels of development at the time of the baseline study and that pursuit of a "difference of differences" approach to assessing market effects will be feasible. However, the relatively high level of adoption found in Massachusetts suggests that the sponsors' programs have already begun to have a perceptible effect on the market.

Cross-regional comparisons for individual LED product types. We found that a larger portion of Massachusetts customers have installed screw-in bulbs than their counterparts in other regions (Table 4). These findings also indicate that overall, adoption of screw-in and downlight LEDs is higher than other types of lighting equipment. This result is consistent with the emphasis of the Massachusetts program on these technologies and the fact that adoption of LED bulbs does not require investment in fixture replacement.

Table 4. Percent of Non-Residential Customers Installing LED products, by type. Customer Telephone Surveys

Lamp or Fixture Type (Consumption or Employee-Weighted)	California (n=361)	Massachusetts (n=120)	Comparison Area (n=157)
Screw-in Bulbs[a,c]	12%	42%	13%
Spotlight/Downlight LEDs[c]	17%	14%	10%
Overhead Luminaire for General Lighting	6%	12%	6%
Outdoor Display[a]	5%	1%	7%
LED Light Sources that replace Linear Fluorescent[c]	6%	4%	9%

a- Difference between California and Massachusetts results is statistically significant at the 90% level of confidence.
c- Difference between comparison area and Massachusetts results is statistically significant at the 90% level of confidence

Comparison of Massachusetts customer-self reports to on-site results. Given the high rate of LED adoption found in the telephone surveys and its possible implications for program design, the Massachusetts program administrators (PAs) wished to corroborate these findings with on-site observations. Fortunately, the PAs had commissioned an on-site saturation survey of the population of commercial customers that was in the field at roughly the same time as the customer telephone survey discussed above. (DNV GL, 2015b). As shown in Table 5, the telephone survey resulted in a higher estimate of the rate of adoption than the on-site survey: 39 percent v. 32 percent. However, this difference was not statistically significant. At the time of these studies, only about 10 percent of Massachusetts business customers had participated in programs that promote LEDs. The apparently high level of LED adoption "outside the program" has prompted the Massachusetts PAs to target additional research to quantify spillover purchases among both participants and non-participants.

Table 5. Massachusetts LED Rate of Adoption, all Interior LED Technologies. Phone Survey (2013), On-Site Surveys (2014)[4]

	Massachusetts Phone Survey (n=617)	Massachusetts On-site (n=344)
Portion of facilities with LED lamps or fixtures reported or observed installed. (Population-Weighted)[5]	39%	32%

A comparison of the rates of adoption by technology type from each survey effort also corroborated the finding of high rates of adoption for products heavily promoted by program administrator (PA) programs and low levels of adoption for LEDs used in linear applications[6].

Table 6. Massachusetts LED Rate of Adoption, by type. On-Site Surveys (2014), Phone Survey (2013)

LED Lamp and Fixture Types	Massachusetts Phone Survey (n=120)	Massachusetts On-site (n=344)
Screw-in lamps, Spotlights, and Downlights		
LED Screw-in Lamps and LED Spotlight Fixtures	26.1%	22.7%
LED Lamps that Replace Screw-in Bulbs*	25.1%	2.7%
Spotlight LEDs	5.0%	22.3%
Overhead Interior Lighting		
General Overhead and Linear Retrofit Kits	5.2%	0.5%
Overhead General Lighting	5.0%	0.5%
LED Light Sources that Replace Linear Fluorescent	3.1%	NA
Other LED Technologies		
LED Globe Lights	3.2%	2.2%

*Statistically significant with 90% confidence

[4] Phone survey results include facilities with LED Exit Signs; on-site results do not.
[5] For comparison purposes, the site-weighted overall rate of adoption is 32% in California and 33% in the comparison area
[6] We expect that customers' level of product knowledge influenced the differences observed in the rate of adoption for LED lamps that replace screw-in bulbs and spotlight LEDs.

LED Saturation

Saturation information from recently completed on-site assessments in Massachusetts (DNV GL, 2015b) and California (Itron, 2014)[7] are shown in Table 7 and Table 8. The proportion of LEDs in socket-based applications in Massachusetts is similar to the phone-survey rate of adoption shown in Table 6. However, since the majority of commercial lighting is comprised of linear fixtures, which have low levels of LED saturation, these results suggest the overall rate of adoption is not a good predictor of saturation but is an acceptable proxy for technology-specific saturation.

Table 7. Massachusetts and California Linear Lighting Saturation. Massachusetts On-Site Surveys (2014), California On-Site Surveys (2012-2013)

Linear Lamp Type (Site-Weighted)	Massachusetts-All buildings (n=323)	California-Office (n=237)	California-Miscellaneous (n=228)	California-Retail (n=219)	California-Restaurant (n=170)
T12	4%	9%	14%	8%	30%
T8	90%	90%	84%	85%	70%
T5	3%	1%	3%	8%	1%
LED	0.1%	<0.1%	0.1%	0.1%	0.0%
Other	2%	<0.1%	<0.1%	0.0%	0.0%

Table 8. Massachusetts and California Lamp Saturation. Massachusetts On-Site Surveys (2014), California On-Site Surveys (2012-2013)

Lamp Type (Site-Weighted)	Massachusetts-All Buildings (n=302)	California-Office (n=206)	California-Miscellaneous (n=217)	California-Retail (n=195)	California-Restaurant (n=163)
CFL	44%	67%	64%	37%	52%
Halogen	10%	9%	12%	32%	9%
Incandescent	24%	22%	22%	17%	29%
LED	23%	2%	2%	13%	5%

Market Share of LED Fixtures

Contractor-Reported Market Share Results. As a group, contractors are in the best position among all market actors to provide data on technology shares for fixtures, as opposed to lamps, since most state building codes require that licensed electricians install fixtures in commercial facilities. Moreover, contractors generally have sufficient knowledge of currently available equipment to be able to report accurately on the share of different technologies they install. Researchers have used the results of contractor interviews, analyzed using ratio estimation methods, to account for differences in project volume among sample firms, to develop plausible market share estimates for many types of commercial lighting equipment. (KEMA 2010, KEMA 2011, DNV GL 2014).

As shown in
Table 9, California and Massachusetts contractors report installing a larger share of LEDs in the majority of the assessed applications than contractors in the comparison area. However, similar to the rate of adoption and saturation findings, in all regions, LEDs have only captured a small portion of the linear lighting market. The results of the contractor phone surveys also suggest that the market share of LEDs in non-linear fixtures is higher in Massachusetts than California or the comparison area. Again, these

[7] California results were published at the business type level. We report on the four largest business types here.

findings are consistent with our expectations given the relatively high level of program effort in Massachusetts to support LED lamps and down lighting fixtures.

Table 9: Share of LED Technologies Installed in Linear Applications . Contractor Telephone Surveys[8]: 2013 (California/Comparison Area), 2014 (Massachusetts)

Fixture Type	California (n=94)	Massachusetts (n=43)	Comparison Area (n=64)
Interior Linear Fixtures			
T12	2%	1%	3%
T8	59%	82%	76%
T5	26%	10%	11%
LED	11%	7%	6%
Other	2%	0%	4%
Other Fixture Types			
Medium Screw-Based Lamps	15%	20%	7%
Outdoor Fixtures	17%	39%	12%
High Bay Fixtures	10%	15%	4%

Distributor-Reported Market Share Results. Distributors often have a wide view of the market as they supply lighting products for various new construction and retrofit projects. Moreover, upstream programs provide financial incentives and marketing support to lighting distributors to promote efficient lighting technologies to customers. Note in Table 10 that the market shares derived from the distributor interviews are higher than the shares developed from the contractor surveys for nearly all of the product categories. One potential reason for this discrepancy is that new construction and large renovation projects account for a greater portion of projects in which distributors are directly involved than is the case for contractors. (DNV GL 2014) Table 10 also shows that the level of adoption of LED technologies is higher in Massachusetts than it is in California or the comparison area. This is consistent with our expectations, given the relatively high level of program effort and participation in Massachusetts.

Table 10: Percentage of Distributor LED Sales by Fixture Type. Distributor Telephone Surveys: 2013 (California/Comparison Area), 2014 (Massachusetts)

Fixture Type	California (n=20)	Massachusetts (n=10)	Comparison Area (n=18)
Interior Linear Applications	18%	34%	7%
Downlights	39%	80%	31%
High Bay	21%	34%	3%
Outdoor Area Lighting	36%	64%	39%

Interpretation of Measure of Adoption Findings

Cross-regional studies of adoption of efficient lighting products have been used to develop plausible estimates of program net effects without heavy reliance on market actor self-reports of program influence (KEMA 2010, 2011). However, we must be clear that this approach is subject to

[8] The survey results were analyzed using a ratio-estimation process that weights responses based on contractors' self-reported number of completed lighting projects. These results represent the market share of lighting technologies and sales practices and can be compared to market share information from other market actors and customers.

many methodological challenges. As system benefit charge-funded programs have spread to most states, it has become difficult to find comparison areas without program activity. There are no straightforward statistical methods to control for the effects differences between regions in have on measure adoption, given the relatively few regions for which adoption data are available at a given time. Finally, there are no precise criteria for determining whether a comparison area can really serve as a baseline for a program area. Researchers build comprehensive profiles of the two areas, and it is up to the evaluation sponsors and stakeholders to assess whether a comparison is valid.

Notwithstanding these concerns, we believe that developing and tracking information on measure adoption at the regional market level yields a great deal of value for program planning, management, and evaluation. Employing a multi-faceted data collection approach for these studies enabled us to gather information needed to better understand the current conditions in the California and Massachusetts commercial LED lighting markets. The similarities in conditions between California and the comparison areas suggests that the relatively high levels of adoption in both regions were driven by factors such as competition among manufacturers to develop and market LED products and customer perceptions of value. California's long history of programs to promote other types of efficient lighting apparently did not significantly affect the rate of uptake for LEDs. In Massachusetts, high rates of adoption for the specific technologies supported by the program suggested strong program effects, including potentially high rates of spillover.

The strength of such conclusions depends, of course, on the confidence that researchers and program sponsors can place in the findings on which they are based. The experience summarized above suggests that, with sufficient care and transparency as to methods, cross-regional comparisons of measures of adoption can be a valuable resource for program evaluation and planning.

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