Final Report: Baseline Characterization

Market Effects Study of Investor-Owned Utility Programs to Support LED Lighting in California

California Public Utilities Commission
Prepared by KEMA, Inc. and TRC Energy Services

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KEMA, Inc. / 155 Grand Ave., Suite 500 / Oakland, CA 94602 USA T +510-891-0446
www.dnvgl.com

Table of Contents

Table of Contents

List of Exhibits

Table of Contents

Table of Contents

Table of Contents

Table of Contents

Executive Summary

This is the final report of the Baseline Characterization of the markets for light-emitting diode (LED) lighting in California. The Baseline Characterization is the first phase of a planned two-part study to assess the effect of programs sponsored by California's Investor-Owned Utilities (IOUs) on the markets for LED lighting in the state. The objectives of this phase are to characterize the structure and current state of the market for LED lighting for residential and commercial applications in California and in comparable market areas, referred to collectively as the comparison area. In particular we are concerned to research and analyze the market elements that characterize its current condition and prospects for development. Relevant market elements include:

The Supply Chain

1. Knowledge and understanding of LED products and delivery methods among firms in the market.
2. Capacity to market and deliver LED lighting, including stocking, specification capabilities, installation capabilities.
3. Current practice in marketing, pricing, specifying, and installing LED lighting versus competing technologies
4. Fit of LED lighting with the business practices and competitive strategies of firms in the supply chain. Motivations and barriers regarding product design, marketing, and promotion.
5. Effect of building codes and product standards on sale and specification of LED products.

Customer Markets

1. Awareness of LED lamps and fixtures among customers in key market segments.
2. Knowledge and understanding of application, performance and price advantages/disadvantages versus competing technologies.
3. Motivations and barriers regarding adoption of LED lamps and fixtures.
4. Current levels of adoption for LED lamps and fixtures.
5. Recognition and use of California IOU programs to support adoption of these products.

A second phase of the study is planned for the 2015–2016 timeframe. That effort will collect information to develop indicators of the market characteristics listed above in both phases for California and the comparison area. At that time, evaluators will compare changes in those indicators over the period between the study phases to characterize the effects of the IOU programs on LED market development in California.

California IOU Programs

Residential Programs. During the 2010--2012 program period, the three investor-owned utilities (IOUs) that provide electric service in California—Pacific Gas & Electric (PG&E), Southern California Edison (SCE), and San Diego Gas & Electric (SDG&E)—offered limited incentives for ambient LED lamps through their Upstream Lighting Program (ULP). This was a period of small scale trials, and did not reflect the characteristics of a fully-implemented rebate program. Actual production program activity started in 2013.The ULP provided incentives for a small number of LED products during the 2010-2012 period, primarily for holiday light strings and night lights. The 2010-2012 ULP provided incentives for just under 110,000 LED replacement lamps—only reflectors—and primarily in wholesale club chains. For purposes of comparison, the 2010-2012 ULP provided incentives for more than 71 million compact fluorescent lamps (CFL) and fixtures, including more than 10 million CFL reflector lamps.

Non-Residential Programs. During the 2010–2012 program cycle, the California IOUs offered financial incentives for the purchase and installation of a variety of LED lighting products through a number of different program channels including prescriptive rebates, custom rebates, and discounted purchases from selected distributors. The programs provided incentives for 70,992 individual projects located at 32,332 commercial, industrial, and multifamily residential sites. This is roughly 2.3 percent of the IOU's full service commercial and industrial electric customers. *Ex ante* savings for these projects totaled 195.1 GWH per year, or 9 percent of total annual savings for all non-residential lighting projects supported by the IOUs in the 2010–2012 program cycle.

Study Methods

This study draws on a broad array of primary data collection and analysis of secondary sources. Figure E1 summarizes the principal research activities we conducted in support of the study. To economize on costs and respondent burden, we undertook joint data collection efforts with several other CPUC evaluation projects. For the most part, the joint work involved adding questions to surveys that targeted a population of end-use customers or supply-side market actors of interest in this study.

Figure E1
Summary of Data Collection and Analysis Activities

Data Collection Effort/**Key Topics/*(Sourced from Other CPUC Studies)***	Sample Sizes	
	California	**Comparison Area**
OVERARCHING MARKET ISSUES AND TRENDS		
Manufacturers: strategy, R&D activities, distribution chains, customer response	12 (11 firms)	
National Program Managers: strategy, manufacturer response, trends observed	4	
Analysis of Product Databases/Secondary Literature Review	x	
NON-RESIDENTIAL MARKET (COMMERCIAL & INDUSTRIAL)		
Distributors: market shares in key applications, pricing, customer response	20	18
Designers/Specifiers: Practices re: specifying LEDs, trends in customer response	19	20
Installation Contractors: market shares in key applications. *(WO 17,24, 29)*	94	64
End Use Customers: Awareness, Knowledge, and Adoption of LEDs *(WO 24)*	3,320	384
Analysis of Building Codes: Comparison of provisions that may affect LED use	x	x
Processing of CA IOU program databases	x	
RESIDENTIAL MARKET		
Retailer Survey: stocking & promotion of LEDs, commercial importance *(WO 28)*	352	150
Retail Shelf Survey: stocking, pricing, and promotion of LEDs & fixtures *(WO 28)*	200	150
Customer Survey: Awareness, Knowledge, and Adoption of LEDs *(WO 13, 28)*	800	1,000

Identification and Selection of Comparison Area. As discussed above, the study plans to use an assessment of the differences between California and the comparison area in the direction and pace of change in market indicators over time to characterize the market effects of the IOU programs that promote LED lighting. Given this study design, we established the following criteria for selecting the comparison area:

- Absence of large-scale utility programs promoting LED lighting;
- Resemblance to California in terms of residential customer population attributes known to affect promotion and/or adoption of efficient lighting products, including level of urbanization (related to the size and structure of the retail sector), income, and education.
- 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, and level of urbanization (related to size and structure of distributor and contractor networks).

This process resulted in the selection of Kansas, Nebraska, Georgia, and Arizona as the comparison area for this study. Over the period that our research was in the field, utilities Arizona, Georgia, and Nebraska implemented programs that provided incentives to commercial customers for purchase of LED lamps. The programs in Georgia and Nebraska have relatively

low levels of funding and participation. However, some customers and vendors in those states whom we interviewed in surveys reported being aware of, and in a few cases, participating in these programs.

Summary of Findings

Residential Sector Findings

Table E1 below summarizes the residential LED market development indicators proposed as part of this study. These include the retailer awareness rate; metrics for availability, lamp model diversity and pricing at retail; consumer awareness, purchase and installation rates; and consumer purchase quantities. The following paragraphs synthesize these and other findings from the report to provide a strategic view of the residential LED lighting market for reference by program sponsors and regulators.

The study found no significant differences between California and the comparison area with regard to key indicators of residential market development for LED lighting. As Table E1 shows, the values for key market indicators of consumer awareness and adoption of LED products on the one hand and retailer stocking and pricing of important product types were virtually the same in the California and the comparison area. This suggests that the residential market for LED lamps and fixtures has attained similar stages of development in both areas prior to full-scale program implementation in California. Detailed findings in support of this conclusion are as follows.

- **Consumers have access to a growing variety of LED lamps and fixtures at the retail level.** On average, retailers stocked 7 models of LED lamps in late 2012, versus 30 models of CFLs and 40 models of incandescent lamps. Home improvement stores in California stocked 30 LED models on average, versus 36 LED models in the comparison area.
- **Pricing trends for LED lamps varied by product type and retail channel.** As April 2014, prices for 60 watt equivalents have fallen below $10 per unit online and are roughly equivalent in large home improvement stores. This compares to prices for all types of LED lamps in the $15 range recorded in the shelf surveys conducted for this study in 2013. Comparison of the results of shelf surveys undertaken in California in 2012 and 2013, however indicate that these price decreases are not universal across product types (form factors) or channels. For example, the price of A-lamps sold in big box stores decreased by roughly two dollars between 2012 and 2013, while it increased by $1.50 at all other types of retailers. Similarly, the average price LED reflector lamps decreased by $6.50 per unit at big box stores while increasing by roughly one dollar at other retailers. Retailers continue to identify high first cost as the major barrier to LED sales to residential customers. On average, across major retail channels, prices for the various types of LED lamps were similar in the two study areas.

Table E1. Market Indicators for Residential LED Lighting

Market Indicator *(Source)*	2012 – 2013 Values	
	California	Comparison Area
RETAILER AWARENESS RATE (*Retail Store Manager Phone Survey*)		
Percent of retail store managers aware of LED lamps	96%	97%
AVAILABILITY (*Retail Store Shelf Survey*)		
Percent of retail stores stocking LED lamps	26%	32%
Percent of retail stores stocking LED fixtures	55%	44%
RETAILER PRODUCT DIVERSITY (*Retail Store Shelf Survey*)		
Average number of LED lamp models available per store	7.0	6.9
PRICE (*Retail Store Shelf Survey*)		
Average LED A-lamp price on Large Home Improvement store shelves	$18.26	$19.97
Average LED Reflector lamp price on Large Home Improvement store shelves	$32.26	$32.74
CONSUMER AWARENESS RATES (*Self-reports per Consumer Phone Survey*)		
Percent of consumers aware of LED lamps	83%	80%
CONSUMER PURCHASE RATES (*Self-reports per Consumer Phone Survey*)		
Percent of consumers who have purchased LED lamps since Jan 2010	19%	16%
Percent of LED-aware consumers who have purchased LED fixtures since Jan 2010	17%	19%
SATURATION		
Average number of LED lamps installed per household (*Self-reports per Consumer Phone Survey*)	1.62	1.49
Average number of LED lamps installed per household (*On-site Survey*)	0.5	n/a
CONSUMER PURCHASE QUANTITIES (*Self-reports per Consumer Phone Survey*)		
Average number of LED lamps purchased per household (population level) since Jan 2010	1.55	1.03
Average number of LED fixtures purchased per household (pop. level) since Jan 2010	0.51	0.56

- **Retailer support for LED lamps is strong.** The shelf surveys conducted for this study found that LED lamps are available from 26 percent of all retailers who carry lighting products of any kind in California and 32 percent of retailers in the comparison area. In both study areas, LED lamps are available in all wholesale clubs and hardware stores, 75 percent of home improvement stores, one-third of drug stores, and one quarter of grocery stores. Retailers reported strong business motivations for stocking LED lamps. In both study areas, retail store managers mentioned corporate policy and customer requests for LED lamps as the main motivations for stocking them.
- **Customer awareness of LED lighting products is high.** Eighty-three percent of sample customers in California reported that they were aware of LED lamps, as did 80 percent of sample customers in the comparison area. This was roughly equivalent to the

level of recognition for compact fluorescent lamps, which have been in the market for thirty years.

- **Customer adoption of LED lamps has reached measureable levels and is and increasing.** The strongest evidence for this finding comes from on-site lighting inventories conducted with large samples in California. The 2009 survey (n = 1,237) found fewer than 0.1 LED lamp installed per household; the 2012 survey (n = 1,987) found an average of 0.6 LED lamps installed. These findings are consistent with results of the consumer telephone survey (conducted in 2013), which found that 16 percent of customers reported purchasing at least one LED since January 2010, and an average number of lamps installed per household of 1.6. Self-reported purchase and saturation of LEDs was similar in the Comparison Area. Nineteen percent of CA customers reported that they had purchased at least one piece of LED equipment between 2010 and 2013, as did 16 percent of comparison area customers.
- **Customers are satisfied with the performance of the LED lamps they have installed.** Eighty-six percent of California residential customers who purchased LED lamps rated them from 8 to 10 on a 10 point satisfaction scale (where 1 means "not at all satisfied" and 10 means "very satisfied"), as did 74 percent of customers in the comparison area.

Commercial Sector Findings

Table E2 displays the proposed commercial LED lighting market development indicators. Summarized at a high level, we find that:

1. **The broadest indicators of market development – primarily measures of awareness and adoption of LED lighting products developed from population-based surveys of customers and contractors – suggest that the commercial markets in California and the comparison area had reached comparable levels of development as of early 2013.**

2. **However, the results of the distributor and designer[1] interviews, as well as some findings from the customer and contractor surveys, suggest that early adopter segments of the supply chain and customer population may be more advanced in their awareness and adoption of LED products in California than in the comparison areas.**

[1] As used in this report the term "Designers" refers to engineers and architects who specialize in the design and specification of lighting systems for commercial facilities. These firms and individuals are generally engaged only on relative large new construction and renovation projects.

Table E2. Market Indicators for Commercial LED Lighting

Market Indicator *(Source)*	2012 - 2013 Values	
	California	Comparison Area
LED AVAILABILITY (*Distributor Survey – Self Reports)*		
Average number of linear fixture models carried by sample distributors	10	9
Average number of high bay fixture models carried by sample distributors	8	11
Average number of downlight fixtures carried by sample distributors	23	17
PRICING (*Distributor Survey – Self Reports)*		
Median "price premium" for linear LED fixture (Troffer)	140%	100%
LED MARKET SHARE – DISTRIBUTOR-SUPPLIED PROJECTS *(Distributor Survey)*		
Interior Linear Fixtures	18%	7%
Downlights	39%	31%
High Bay Lighting	21%	3%
Outdoor Lighting	36%	39%
LED MARKET SHARE – GENERAL (*Contractor Survey – Self Reports))*		
Interior Linear Fixtures (as % of interior linear fixtures installed)	5%	4%
Linear Fixture Retrofit Kits (as % of interior linear fixtures installed)	6%	2%
High Bay Lighting	10%	4%
Outdoor Fixtures	17%	12%
Medium Screw-Based Lamp Fixtures (Downlights)	15%	7%
CUSTOMER AWARENESS & INTEREST		
% of contractors (installation weighted) reporting customers always or mostly ask about LEDs for relevant installations. (*Contractor Survey –Self Reports, Project-weighted)*	28%	7%
Percent of customers aware of LEDs without prompting (*Customer Survey – Self-Reports, size weighted)*	96%	94%
Percent of customers reporting they are "very familiar" with LEDs for business use (*Customer Survey – Self-Reports, size weighted)*	28%	27%
CUSTOMER KNOWLEDGE OF LED PRODUCT ATTRIBUTES V. ALTERNATIVES (*Customer Survey – Self-Reports, size weighted)*		
Percent of customers who report that LEDs offer more precise control	41%	38%
Percent of customers who report that LEDs last longer	76%	72%
Percent of customers who report that LEDs are more energy efficient	81%	80%
CUSTOMER ADOPTION OF LED TECHNOLOGIES(*Customer Survey – Self-Reports, size weighted)*		
Percent of customers who report having at least one type of LED lighting product installed in their facility	46%	42%
Percent of customers who report having LED linear fixtures installed	6%	6%
Percent of customers who report having LED linear replacement kits	6%	9%
Percent of customers who report having LED downlights installed	17%	10%
Percent of customers who report having screw-based LED bulbs installed	12%	13%

The following paragraphs provide details on the two major findings.

Similarity in Broad Indicators of Commercial LED Market Development

- **Awareness of LED products among commercial customers is high in both study areas.** Awareness of LED products is nearly universal among commercial customers. Twenty-eight percent of customers in CA and 27 percent in the comparison area report being "Very Familiar" with LED lighting products for business use.
- **Commercial customers in both study areas are knowledgeable about key attributes of LED lighting.** The large majority of customers in both study areas correctly characterized LED lamps as having longer useful lives, being more energy-efficient, and costing more than alternative technologies. Forty-four percent of sample customers in California and 41 percent in the comparison area also correctly characterized LEDs as providing for greater control over light levels than alternative technologies. They also knew that LEDs cost more than alternative products. The portions of customers with accurate knowledge of LED attributes were nearly identical in the two study areas.
- **Over 40 percent of the commercial market in both study areas (weighted by kWh or employees) has purchased and installed at least one type of LED lighting product.** The portion of sample customers who reported having at least one LED product installed at the time of the survey was 46 percent in California and 42 percent in the comparison area. Data on the number of fixtures purchased and installed suggest that customers are still in a trial phase with all products categories. Most reported installations of LED products of all types involved 30 or fewer units.
- **Contractors in California and the comparison area report installing roughly equal shares for LED linear fixtures and high bay lighting.** Contractors are directly involved in the full range of commercial lighting installation projects and are therefore in position to provide the most accurate view of technology shares in those projects. The fourth set of rows in Table E2 above summarizes the average share of installations accounted for by LED products for key applications reported by contractors in California and the comparison area. The LED share for linear fixtures, retrofit kits, and high bay lighting are quite low in both study areas, but somewhat higher in California.
- **Customers are satisfied with their LED installations.** Overall, customers are very much satisfied with the LED equipment they have installed. Over three-quarters of all LED purchasers in both study areas rated their satisfaction with their installations from 8 to 10 on a 10 point scale (where 1 means "not at all satisfied" and 10 means "very satisfied"). This finding contrasts sharply with early records of customer complaints concerning the performance and appearance of compact fluorescent lamps and early versions of electronic ballasts/T8 technology.

- **The number of available models for all major applications is increasing at all levels of the supply chain.** Generally, products introduced by manufacturers are finding their way quickly into the stream of equipment stocked, specified, and installed. Distributors reported stocking or having access to 20 to 30 models of product types that have been in the market for a number of years, such as downlights and outdoor fixtures. They reported stocking or having access to 10 to 15 models of more recently introduced product types, such as LED overhead panels and high bay lighting. Web sites for large warehouse distributors currently display similarly extensive lines of fixtures and lamps. Very few designers or contractors mentioned availability of appropriate products as a barrier to increased adoption of LED lighting.
- **Prices are decreasing for products in all categories, but remain the major barrier to adoption.** Virtually all respondents among distributors, contractors, and designers reported that prices were decreasing for major LED product categories. However, analysis of national data show that prices for commercial fixtures is decreasing more slowly than prices for LED lamps, largely because the solid state components of the fixtures are falling in price more rapidly than the other components such as sheet metal and other electronics. All groups of supply side actors as well as customers identified high prices as the major barrier to further adoption of LEDs.

Differences in Selected Indicators of Market Development

- **Contractors in California report that customers request LEDs in advance of their recommendations much more frequently than contractors in the comparison area.** Contractors representing 28 percent in the market in California reported that customers initiate requests for use of LEDs in all or most of their relevant installation projects, versus only 7 percent in the comparison area. Generally, differences in reported market experience and practice between sample contractors in California and the comparison areas were not statistically significant due to limited sample size and variability in the responses.
- **Contractors in California report installing higher shares of LEDs for downlights and outdoor lighting than contractors in the comparison areas.** In California, the reported LED market share for products that have been available in large numbers for a number of years, namely outdoor fixtures (17 percent) and downlights (15 percent) are beginning to suggest transition from the early adopter to early majority phases of market acceptance. Uptake for these products in the comparison area has not progressed as rapidly. Market share of other LED products is considerably lower in both study areas. The differences in LED share between the two study areas are not statistically significant, due primarily to limited sample size for the contractor study and the variability in the responses.
- **Distributors and manufacturer representatives in California report selling larger shares of selected LED products than their counterparts in the**

comparison area. The distributors and manufacturer representative firms interviewed for this study generally focus on supplying new construction and large remodeling projects. Roughly 60 percent of projects completed by the interviewed firms in California and 50 percent of those in the comparison area were in new construction and remodeling. Typically new construction and remodeling lighting projects constitute a small portion of the total market (less than 20 percent of total installations). Given the relatively high representation of larger projects in the distributors' portfolios, they can be understood as a leading indicator for the development of broader market. As the third set of rows in Table E2 shows, there was little difference between the study areas in the LED share of downlights and outdoor fixtures. However, the reported LED share of linear overhead and high bay lighting was much higher among California distributors than among those in the comparison area. These findings may indicate greater willingness among CA distributors to promote products that have only recently been introduced to the market, as well as greater interest among the distributors' direct customers.

- **The reported price premium for LED linear fixtures was higher in California than in the comparison area.** Distributors in California reported a median price premium for LED versus fluorescent linear fixtures of 140 percent, versus 100 percent in the comparison area. This finding could reflect a higher level of demand for LED linear fixtures, although caution should be used in generalizing from a relatively small sample.
- **Differences in applicable building codes.** The most recent revisions of California's Title 24 building energy codes favor the use of LEDs to a greater extent than the International Energy Conservation Code, 2009, which many states including those in the comparison area have adopted as the model for their state building codes. These provisions include more stringent lighting power alliances, requirements for continuous and/or multilevel dimming, and extension of code coverage to a large share of remodeling and retrofit projects. (University of California, Davis, 2014)
- **Influence of codes and standards.** While nearly all designers in both study areas reported that they used LEDs to meet energy codes, 16 of 17 California interviewees identified this as an important strategy for meeting code requirements versus only 10 of 15 comparison area respondents. Similarly, 15 of 20 distributors in CA identified code compliance as an important motivation for selecting LEDs v. 6 of 18 in comparison area.

Conclusions and Implications for Market Effects Assessment

From the findings summarized above, we conclude that development of the commercial market for LED lighting is well under way in both California and the comparison area. California's level of development as of the beginning of 2013 was slightly more advanced, particularly in regard to larger projects served by specifying distributors and manufacturers. The advancement of the

California market was also evidenced by contractor reports of higher LED shares for downlights and outdoor fixtures, as well as the frequency with which they reported customer initiation of requests for LEDs.

We do not believe that the differences observed between the two study areas in the development of commercial LED lighting market stem primarily from IOU programs to support LEDs. During the 2010 -2012 cycle, participation in LED incentive programs was relatively low. Less than two percent of commercial customers received incentives for LEDs versus the 46 percent who reported having LED products installed in their facilities. Some of the observed difference could be attributable to conditioning of the market through decades of programs to promote efficient commercial lighting in general.

We believe that at least some part of the observed difference in selected market development indicators can be attributed to differences between the California and comparison area markets for which we simply were not able to account in the development of the comparison area. At this point in time, it is impossible to identify a region that features the robust lighting supply chain found in California as well as the huge market to support it *and* that is not served by long-standing energy efficiency programs. The sheer size and complexity of the California market means, among other things, that the high end of the market is sufficiently large to drive a diffusion process. This hypothesis is consistent with the large differences in LED market reported by distributors and manufacturers representatives and by the differences in contractor-reported LED shares for product types that have been in the market the longest.

Some of the observed differences in uptake of LEDs in the commercial sector may also be due to recent changes in Title 24. These apply lighting power allowances and control requirements which are generally more strict than corresponding sections of the International Energy Conservation Code 2009 version, which many states use as the model for their building energy codes. Moreover, the 2013 Title 24 revisions extend the range of remodeling and retrofit projects to which code requirements apply. Prior to this revision, code requirements were invoked for all new construction plus all remodeling and retrofit projects in which 50 percent of luminaires in the affected areas are replaced. These limits have been reduced to 10 percent of luminaires or 40 total luminaires. The majority of designers in both study areas report using LEDs as part of their strategies to meet code requirements, although the percentage is somewhat higher in California. Similarly, a higher portion of CA distributors report that code compliance is an important motivation for specifying LEDs.

One of the main reasons the consultant team and its CPUC advisors selected the two-stage study approach was to provide a method for generating cross-sectional comparisons of the pace of market development in the event that the baseline study found that one or more elements in the development of the California LED market had already advanced beyond the comparison area. We recommend that the next phase develop measures of the pace of change in market indicators for California and the comparison area, and use those measures to assess met program effects.

We also recommend that special attention be given to changes in building codes in California and the comparison areas over the period between the studies and that elements of the research on designer, distributor, and contractor response to codes be strengthened.

Cross-Sector Findings

The market for lamps and fixtures of all types is international, and manufacturers hold the most powerful position among all market actors in terms of decisions regarding product design, pricing, distribution, and marketing. This study compiled extensive evidence of the intensity of competitive efforts by manufacturers to create a market for LED lighting products and to capture their share of that market. This competition shapes the availability and pricing of LED products in the local markets. Examples include:

- **The number and variety of quality LED lamps for residential use has increased rapidly in the past two years.** Between September 2012 and July 2013, the number of ENERGY STAR qualifying lamp models increased from 1,273 to 2,288. Reflector lamps for use in primarily in recessed and outdoor fixtures accounted for 71 percent of these models. However, the fastest-growing product type was omnidirectional screw-in A-lamps. Moreover manufacturers introduced multiple models with light output in the range of 60 to 100-watt incandescents.
- **The number of quality commercial grade fixtures available in the market has increased rapidly in the past two years**. Between January 2012 and January 2013, the number of commercial grade fixtures included in the DesignLights Consortium Qualified Products List more than doubled from 8,452 to 19,520, then increased by 71 percent to 33,329 by November 2013, before qualifying standards were changed.
- **Large numbers of companies have entered the market for LED lamps and fixtures**. In July 2013, over 170 companies had LED lamps approved for ENERGY STAR labeling. As in the incandescent and CFL markets, concentration in the LED lamp market is high, but there are a sufficient number of capable competitors to stimulate competition on price and product design. As of December 2013, 537 firms had products listed in the DLC Qualified Products List, versus 228 companies in December 2012. Also, more manufacturers have introduced significant model ranges of products in the past year.
- **Manufacturers have focused research and development and product development efforts on LED technology.** We interviewed ten commercial lamp and fixture manufacturers in support of this study. Four reported spending all of their R&D funds on LED products; 3 more reported that they spent 90 to 95 percent of their R&D budgets on LED products. None reported spending less than 50 percent of their R&D budgets on LEDs.

- **Manufacturers have focused their marketing efforts on supporting LED products**. All manufacturers interviewed for this study reported spending at least 75 percent of their marketing budgets to support LED offerings. Four reported spending 100 percent to support LED products.
- **Manufactures are cooperating with government testing and product certification programs**. Many identified the need to mitigate the risk that poor product performance will dissuade customers from trying, retaining, and recommending LED products.

Despite the level of product research and development discussed above, LED technology is forecasted to be nearly three times as expensive per unit of light output as linear fluorescents in 2025. Thus, over the next decade or so, LEDs will need to continue to compete on non-energy benefits such as longer useful life, reduced maintenance costs, improved control, fixture aesthetics, and greater control over light color.

Implications of Findings for Programs that Support LED Lighting

The characterization of the LED lighting markets summarized above suggests the following guidelines for state-level programs that support LED lighting.

Continue to support the development of product standards and management of product testing programs. Given the rapid influx of manufacturers and new products into the LED market, it will be important to ensure that new products meet basic performance standards in order to avoid negative customer reaction, similar to that which greeted the introduction of CFLs. The U. S. Environmental Protection Agency (EPA) has assumed this role for lamps through its ENERGY STAR program, and the DesignLights Consortium has taken up this function for commercial grade fixtures. In addition, the CEC has developed lamp standards for application in the California. The California IOUs currently support the EPA and DesignLights program, and have been deeply involved in related codes and standards proceedings before the California Energy Commission (CEC). It will be important to continue this work and to stay abreast of changes in product price and performance so that standards can be revised to reflect the best elements in available technology as products are introduced and improved.

Maintain incentives for LED fixtures and lamps. While early market response to LED lighting products has been strong, the level of acceptance for most product types and customer groups is still in the “early adopter” category. Moreover, first cost is the barrier to acceptance mentioned most often by customers and market actors in the supply chain. Incentives will not only assist customers in the “early majority” category to overcome cost barriers, they will also

call customer attention to other benefits offered by LED products, including extended life, low maintenance costs, low heat output, and enhanced controllability.

Increase energy savings in the short term by linking LED fixture incentives to improvements in controls. According to a recent national study of the non-residential lighting market, only 25 percent of total fixtures, accounting for 32 percent of total commercial sector lighting energy are under any kind of automated control.[2] A meta-analysis of 88 assessments of controls installations found a range of energy savings ranging from 24 to 38 percent of baseline consumption, depending on the control strategy employed.[3] Given the high level of control that LED light sources can support, structuring incentives to favor inclusion of controls in the installation could help increase the overall cost effectiveness of LED incentives during the next few years particularly given that the difference in efficacy between LEDs and fluorescent technology is forecasted to remain relatively small, at least in the near term.

[2] Navigant Consulting, 2012b.

[3] Williams et al., 2012.

1. Introduction

1.1 Study Objectives and Market Setting

This is the final report of the Baseline Characterization of the markets for light-emitting diode (LED) lighting in California. The Baseline Characterization is the first phase of a planned two-part study to assess the effect of programs sponsored by the California Investor-Owned Utilities (IOUs) on California's LED lighting markets.

LEDs are semiconductors that produce light when energized. LEDs first found commercial application in the early 1970s for indicator lights on electronic devices. At that stage the technology was very expensive and produced only low levels of light in a limited color spectrum. Advances in LED design, materials, and production technologies enabled lighting manufacturers to incorporate the technology into interior and exterior lighting products by the early 2000s. These products offered a number of advantages over established technologies, including:

- Significantly longer useful life and lower maintenance costs[4];
- Excellent control over light levels and dimming; and,
- Fine levels of control for color.

As is often the case with new technologies, the early general lighting products offset these promising features with attributes that discouraged wide adoption, including:

- Extremely high unit prices and costs per unit of light output compared to established technologies;
- Heavy weight and ungainly form factors, which limited application in existing fixtures and lighting layouts;
- Low maximum light output; and,
- Unsightly appearance.

Beginning around 2008, further advances in basic LED light source technology, fixture design, and production supported a rapid increase in the performance and availability consumer-friendly products. In that year alone, industry/government consortia in the United States, Europe, China, Korea, and other Asian countries committed over $600 million in funding for basic scientific research, product development, and demonstration of manufacturing

[4] The U. S. Department of Energy estimates the useful life (operating hours prior to 30% lumen degradation) of LED light sources at 35,000 to 50,000 versus 20,000 – 30,000 for linear fluorescent lamps and 8,000 – 10,000 for compact fluorescent lamps (U. S. DOE, 2009).

improvements.[5] According to interviews conducted for this study with manufacturers and government research and development program officials, this level of investment has persisted or increased over the past few years.

Since 2010, the number of LED lamps and fixtures available on the market for general interior and exterior applications has skyrocketed. The proliferation of models has been accompanied by a rapid decrease in prices for many types of LED products, as well as improvements in light output, control capability and other attributes that are important to end-users. Manufacturers have mounted robust marketing campaigns to support sales of these new products, and data collected for this study show that vendors at all levels of the supply chain—from distributors through retailers and installers—are vigorously promoting LED technology. For the most part, manufacturers have cooperated with government agencies and utility-sponsored efforts to establish performance criteria and testing regimes for LED products. These developments form an important backdrop to market effects analyses for utility programs to promote LED lighting.

The main objective of this phase of the LED Lighting Market Effects Study is to characterize the structure and current state of the market for LED lighting for residential and commercial applications in CA and in comparable market areas. In particular we are concerned with researching and analyzing those elements of the market that characterize its current condition and prospects for development. These elements are:

The Supply Chain

1. Knowledge and understanding of LED products and delivery methods among firms in the market.
2. Capacity to market and deliver LED lighting, including stocking, specification capabilities, installation capabilities.
3. Current practice in marketing, pricing, specifying, and installing LED lighting versus competing technologies
4. Fit of LED lighting with the business practices and competitive strategies of firms in the supply chain: motivations and barriers to promotion.
5. Private sector infrastructure to support further development of LED technology and promotion capabilities, including R&D, product testing and certification.
6. Effect of building codes and product standards on sale and specification of LED products.

[5] U. S. DOE, 2011.

Customer Markets

1. Awareness of LED lamps and fixtures among customers in key market segments.
2. Knowledge and understanding of application, performance and price advantages/disadvantages versus competing technologies.
3. Motivations and barriers to adoption of LED lamps and fixtures.
4. Current levels of adoption.
5. Recognition and use of California IOU programs to support LED product adoption.

We recommend that the second phase of the study be conducted in the 2015 – 2016 timeframe. In both phases of the study, information will be collected to develop indicators of the market characteristics listed above for California and the comparison areas. The analysis will compare changes in those indicators over time to characterize the effects of the IOU programs on the LED market development in California.

1.2 The California IOU Programs

1.2.1 Residential Programs

During the 2010--2012 program period, the three investor-owned utilities (IOUs) that provide electric service in California—Pacific Gas & Electric (PG&E), Southern California Edison (SCE), and San Diego Gas & Electric (SDG&E)—offered limited incentives for ambient LED lamps through their Upstream Lighting Program (ULP). This was a period of small scale trials, and did not reflect the characteristics of a fully-implemented rebate program. Actual production program activity started in 2013 during which the utilities were directed to transition to the new California product specifications discussed below. The ULP provided incentives to manufacturers (and in some cases, retailers) to reduce the sales price of energy-efficient lighting products in retail stores to test incentive and price levels.

As shown in Table 1 below, the ULP provided incentives for a small number of LED products during the 2010-2012 period, primarily for holiday light strings and night lights. The 2010-2012 ULP provided incentives for just under 110,000 LED replacement lamps—only reflectors—and primarily in wholesale club chains. For purposes of comparison, the 2010-2012 ULP provided incentives for more than 71 million compact fluorescent lamps (CFL) and fixtures, including more than 10 million CFL reflector lamps.

Table 1. Number of Program-Discounted LED Lamps Shipped by Retail Channel and Lamp Style, 2010-2012 ULP

Retail Channel	LED Product Type				Total
	Holiday Lights*	Night Lights	Fixtures	Reflector Lamps	
Discount	0	226,281	0	0	226,281
Drug	0	19,848	0	0	19,848
Grocery	1,974,000	493,620	0	270	2,467,890
Hardware	140,160	8,250	0	21,480	169,890
Home Improvement	1,530,000	163,978	119,740	16,239	1,829,957
Mass Merchandise	0	50,328	0	1	50,329
Wholesale Club	0	87,552	13,956	70,356	171,864
Other	27,300	896	144	1,404	29,744
Total	**3,671,460**	**1,050,753**	**133,840**	**109,750**	**4,965,803**

Source: 2010-2012 ULP tracking data.

* Note that counts of holiday lights reflect the number of individual LED lights for which the IOUs provided incentives and *not* the number of holiday light sets (or "strings").

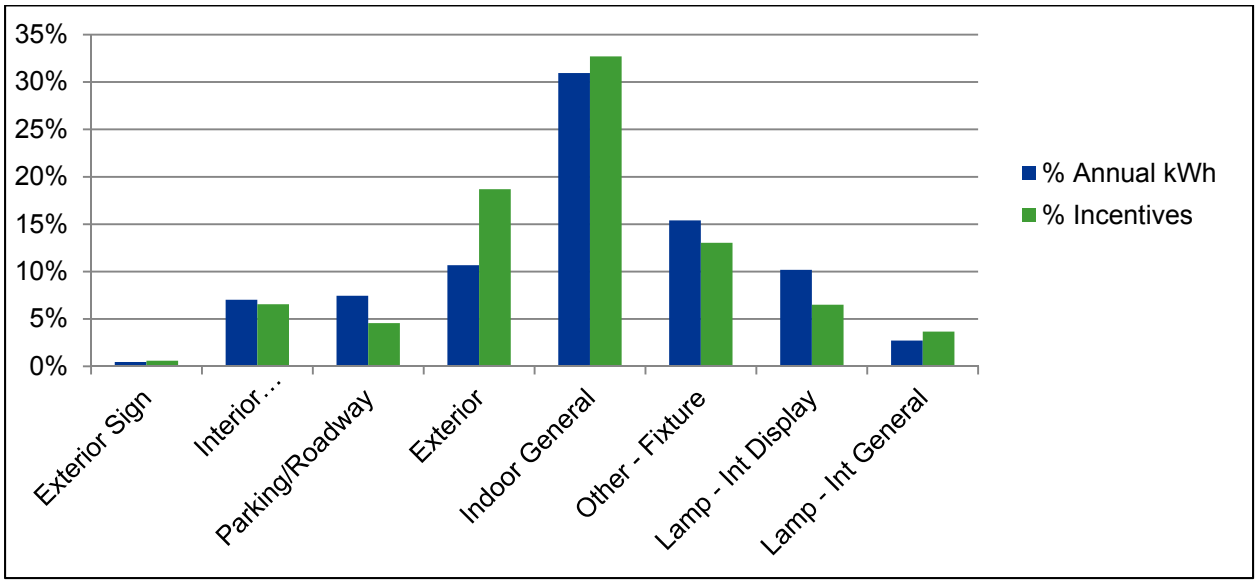
1.2.2 Non-Residential Programs

During the 2010–2012 program cycle, the IOUs offered financial incentives for the purchase and installation of a variety of LED lighting products through a number of different program channels, including:

- Prescriptive rebates for selected product and fixture types, including replacement lamps, interior general lighting, high bay fixtures, and exterior fixtures.
- LED lighting measures included in custom retrofit projects.
- "Discounted purchases from selected distributors.

The programs provided incentives for 70,992 individual installations located at 32,332 commercial, industrial, and multifamily residential sites. This is roughly 2.3 percent of all commercial and industrial customers who receive bundled service from the three IOUs. *Ex ante* savings for these projects totaled 195.1 GWH per year, or 9 percent of total annual savings for all non-residential lighting projects supported by the IOUs in the 2010–2012 program cycle. Figure 1 shows the distribution of incentives paid and annual *ex ante* savings by type of lighting application.

Figure 1. Distribution of Incentives and *Ex Ante* Savings by Lighting Application for Non-Residential IOU Projects with LED Lighting, 2010–2012



1.3 Methods

1.3.1 Overview

This study draws on a broad array of primary data collection and analyses of secondary sources. Figure 2 summarizes the principal research activities we carried out. We note that many of the data collection efforts were joint efforts with consultant teams conducting other evaluation and market research projects for the California Public Utilities Commission (CPUC) Energy Division. To economize on costs and respondent burden, we undertook joint data collection efforts with the following projects:

- CPUC Evaluation, Measurement, and Verification (EM&V) Work Order (WO) 13: Residential Lighting Program Process Evaluation and Market Characterization
- CPUC EM&V WO17: Measure Cost Study
- CPUC EM&V WO24: Commercial Market Share Tracking Study
- CPUC EM&V WO28: Residential, Advanced, and Upstream Lighting Impact Evaluation
- CPUC EM&V WO29: Non-Residential Downstream Lighting Impact Evaluation

For the most part, the joint work involved adding questions to surveys that targeted a population of end-use customers or supply-side market actors of interest in this study.

Figure 2. Summary of Data Collection and Analysis Activities

Data Collection Effort/Key Topics/*(Sourced from Other CPUC Studies)*	Sample Sizes	
	CA	Comparison Area
OVERARCHING MARKET ISSUES AND TRENDS		
Manufacturers: strategy, R&D activities, distribution chains, customer response	12 (11 firms)	
National Program Managers: strategy, manufacturer response, trends observed	4	
Analysis of Product Databases/Secondary Literature Review	x	
NON-RESIDENTIAL MARKET (COMMERCIAL & INDUSTRIAL)		
Distributors: market shares in key applications, pricing, customer response	20	18
Designers/Specifiers: Practices re: specifying LEDs, trends in customer response	19	20
Installation Contractors: market shares in key applications. *(WO 17,24, 29)*	94	64
End Use Customers: Awareness, Knowledge, and Adoption of LEDs *(WO 24)*	3,320	384
Analysis of Building Codes: Comparison of provisions that may affect LED use	x	x
Processing of CA IOU program databases	x	
RESIDENTIAL MARKET		
Retailer Survey: stocking & promotion of LEDs, commercial importance *(WO 28)*	352	150
Retail Shelf Survey: stocking, pricing, and promotion of LEDs & fixtures *(WO 28)*	200	150
Customer Survey: Awareness, Knowledge, and Adoption of LEDs *(WO 13, 28)*	800	1,000

1.3.2 Identification and Selection of Comparison Areas

The study plan uses an assessment of the differences between California and a specially-selected comparison area in the direction and pace of change in market indicators over time to characterize the market effects of the IOU programs that promote LED lighting. Given this study design, we established the following criteria for selecting comparison areas:

- Absence of large-scale utility programs promoting LED lighting.
- Resemblance to California in terms of residential customer population attributes known to affect promotion adoption of efficient lighting products: level of urbanization (related to the size and structure of the retail sector), income, education.
- 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, level of urbanization (related to size and structure of distributor and contractor networks).

The following paragraphs briefly describe how we implemented these criteria. Appendix B provides further detail on analyses performed in support of comparison area selection.

Absence of large-scale utility programs promoting LED lighting. At the time we developed the study design (May 2012), nearly all U.S. states had established regulatory requirements for utilities to conduct ratepayer-funded energy efficiency programs, and many

had begun to incorporate LEDs into their lists of eligible measures. To identify states or areas that were *not* served by such programs, we consulted a wide variety of sources including the American Council for An Energy Efficient Economy (ACEEE) Scorecard publications, state regulatory filings, and the U. S. Department of Energy (DOE) Database of State Incentives for Renewables & Efficiency (DSIRE).

After identifying states with relatively low levels of program activity, we visited the websites for their major utilities and contacted local program personnel to determine whether their programs supported LED lighting. We also examined earlier cross-sectional studies of energy efficiency measure adoption in states characterized by different levels of program effort.[6] These studies found that the length of time that programs had been in place was associated with higher levels of adoption. We therefore restricted selection to states which had historically ranked low on the ACEEE scorecard. Based on this research we identified nine states in which programs were not offered as of May 2012: Kansas, Nebraska, Georgia, Arizona, Nevada, Florida, Alabama, Mississippi, and South Carolina. Ultimately, we selected the first four of these states for inclusion in the comparison area on the basis of the analyses of their residential and commercial customer bases as described below.

Over the period that our research was in the field, utilities in Arizona, Georgia, and Nebraska implemented commercial incentive programs for LED lamps. The programs in Georgia and Nebraska have relatively low levels of funding and participation. However, a small number of customers and vendors in those states with whom we conducted interviews reported being aware of—and in a few cases, participating in—these programs.

Given trends of increasing state policy support for ratepayer-funded energy efficiency programs[7] and development of LED technology, we expected that some of the states initially selected for the comparison group would implement programs before the follow-up study. While this will complicate and perhaps preclude precise quantification of the market effects of California's IOU programs, we believe, on the basis of experience in conducting similar studies of other technologies, that the cross-state comparisons will provide useful insights into the general direction and magnitude of program effects. Given the scale and long history of the California IOUs' efforts to promote efficient commercial and residential lighting products, we anticipate differences between California and the comparison areas in the pace of change for LED lighting market indicators.

[6] See, for example, NMR Group, Inc. 2011; [The] Cadmus Group, Inc., 2009.

[7] ACEEE, 2013.

Residential and Commercial Market Analysis. As a first step in narrowing down the states to be included in the comparison area, we characterized all nine states identified as having no LED programs as of May 2012 according to the characteristics shown in Table 2.

Table 2. Residential and Commercial Market Characteristics Used in First Step of Assessing States to be Included in Comparison Area (Based on U.S. Census Data)

Residential Market Characteristics	Commercial Market Characteristics
▪ Percent of population over 25 years old with a bachelor's degree	▪ State Gross Domestic Product
▪ Median Income	▪ Size of labor force
▪ Percent of households with income > $100,000	▪ Average productivity per worker in the labor force
▪ Median home value (reported by occupant)	▪ Distribution of business establishments by major NAICS Code categories
▪ Percent of owner-occupied housing units	▪ Distribution of employment by NAICS Code
▪ Percent of homes with 4+ bedrooms	
▪ Percent of population in urban areas	

We then examined different combinations of states that would yield sufficiently large and diverse samples of business establishments to identify those that, in aggregate, would most closely resemble California in terms of the characteristics named above. The objective was to find a group of states which, as a composite, best resembled California among the various combinations available. This process resulted in the selection of Kansas, Nebraska, Georgia, and Arizona.

1.3.3 Primary Data Collection Activities: Residential Market

Retail Store Shelf Surveys. Lighting retail store shelf surveys involve visits to retail stores to collect information about the lamps and fixtures stocked in those stores. Field researchers gather detailed information regarding a variety of lamp types including packaging configurations, lamp style, manufacturer, wattage, price, and so on, to determine the availability, diversity, and pricing of each lamp type. For fixtures, field researchers recorded the presence or absence of a series of dedicated LED fixture types in each store. Field researchers conducted all shelf surveys during the late summer of 2012.

Table 3 shows the final distribution of stores in California and the comparison area by retail channel. In California, the stores selected for inclusion this study was based on sampling approaches used in previous shelf surveys conducted in California for other CPUC Work Orders. DNV GL staff utilized the IOU tracking databases and secondary research to create a sample

frame of stores across the seven selected retail channels.[8] In order to economize on cost and reduce elapsed time between surveys in California and the comparison area, we conducted shelf surveys only in two of the four comparison area states, Arizona and Georgia. We selected those states to include one representative each of areas with and without significant program activity in the years immediately prior to the study. Also, Arizona and Georgia had sufficiently large retail sectors to support the realization of the sample plan, which called for completion of interviews with significant numbers of stores in each of seven channels.

DNV GL analysts allocated the sample regionally to ensure representation of retail stores across each state and to ensure that both independent and chain stores were represented in the sample

Table 3. Final Sample Distribution by Retail Channel and Geography, 2012 Lighting Retail Store Shelf Surveys

Retail Channel	California		Comparison Area	
	# of Stores	% of Stores	# of Stores	% of Stores
Discount	28	14%	21	14%
Drug	27	14%	20	13%
Grocery	30	15%	22	15%
Hardware	28	14%	22	15%
Home Improvement	29	15%	21	14%
Mass Merchandise	29	15%	22	15%
Wholesale Club	29	15%	22	15%
Total	**200**	**100%**	**150**	**100%**

Telephone Survey of Retail Store Managers. The DNV GL team hired an experienced survey research firm to conduct 457 computer-aided telephone interviews with retail store managers (307 in California and 150 in the comparison area). In support of WO28, the DNV GL team implemented telephone surveys with retail store managers in the service territories of the three IOUs that provide electric service in California: PG&E, SCE, and SDG&E. The sample frame was drawn from the InfoUSA Salesgenie establishment database using an approach similar to that described above for the shelf surveys conducted in the comparison area (by mapping lighting retailer Standard Industrial Classification [SIC]and North American Industry Classification System [NAICS] codes to the seven relevant retail channels). DNV GL analysts used the same sample frame source for the retail store manager surveys conducted in the comparison area as in California. In the comparison area, analysts allocated the sample equally

[8] At the time of this research, there was no comprehensive listing available for California retail stores that sold residential replacement lamps. Under CPUC 2010-2012 EM&V WO13 – Lighting Programs Process Evaluation and Market Characterization, the DNV GL team subsequently developed an approach to build such a sample frame.

between the two states and set quotas by retail channel that were roughly proportional to the number of retail stores in each channel in the population.

Table 4 displays the number of retail store managers interviewed in California and the Comparison Areas by channel. DNV GL staff conducted the surveys between July and October, 2013. The final survey response rate was 8.5 percent.[9] We applied sample expansion weights such that the final sample represents the distribution of stores in the respective study areas that sell replacement lamps to consumers.

Table 4. Final Sample Distribution by Retail Channel
2013 Retail Store Manager Telephone Surveys

Retail Channel	California		Comparison Area	
	# of Stores	% of Stores	# of Stores	% of Stores
Discount	45	15%	12	8%
Drug	56	18%	22	15%
Grocery	56	18%	31	21%
Hardware	59	19%	32	21%
Home Improvement	32	10%	17	11%
Mass Merchandise	46	15%	28	19%
Wholesale Club	13	4%	8	5%
Total	**307**	**100%**	**150**	**100%**

Telephone Survey of Residential Consumers The DNV GL team fielded the California consumer surveys as part of CPUC EM&V WO28, while the market effects team fielded the comparison area surveys as part of CPUC EM&V WO54. All together, the two teams completed 1,800 surveys with consumers: 800 in California and 1,000 in the comparison area. The sample frame consisted of records from the IOUs' Customer Management Systems. DNV GL staff stratified the sample based on IOU service territory such that 40 percent of the completed surveys were in PG&E's electric service territory, 40 percent were in SCE's electric service territory, and 20 percent were in SDG&E's electric service territory.[10] The survey was conducted between March and June 2013. The final survey response rate was 6.7 percent. DNV GL analysts

[9] DNV GL staff calculated survey response rates using American Association for Public Opinion Research (AAPOR) formula RR3, which includes an estimate of the proportion of cases of unknown eligibility that are actually eligible (for additional detail, please refer to AAPOR, n.d.). Unless otherwise noted, this calculation approach is utilized throughout the report.

[10] Note that the WO28 consumer surveys also included a supplemental survey phase (after the initial 800 surveys were completed) that specifically targeted respondents who purchased specific lighting measures of interest to the impact evaluation report. This report focuses only on the "general population" component of the survey (the first 800 completes).

applied sample expansion weights such that the survey results represent the combined population of consumers in PG&E's, SCE's, and SDG&E's electric service territories.

In the comparison area, an experienced survey research firm collected the data during April and May, 2013 using a random-digit dial approach within the comparison area. Sample targets were split evenly between the two states (500 completes each) and the survey research firm ultimately achieved these targets for a total of 1,000 completed surveys. The response rate was 5.3 percent. DNV GL analysts applied sample expansion weights such that the survey results represent the combined population of comparison area states (Arizona and Georgia).

In-Depth Telephone Interviews of Lamp Supplier Representatives. As part of CPUC EM&V WO28, DNV GL interviewers conducted in-depth telephone interviews with representatives of lamp manufacturing organizations and buyers from large retail lighting chains during the third and fourth quarters of 2013. All of the respondents represented organizations that either manufactured or sold replacement lamps discounted by the California IOUs' 2010-2012 ULP (based on program tracking data). The complete 2013 sample frame included 30 manufacturing organizations and the 25 retail chains to which manufacturers shipped the largest shares of total 2010-2012 ULP lamps.

Table 5 shows the number of in-depth interviews completed by supplier type (manufacturer versus retail buyer). It also shows the percentage of total 2010-2012 ULP shipments represented by the 33 market actors with which DNV GL staff completed interviews. As shown, the manufacturing organizations that participated in the in-depth interviews represented a much larger percentage of total ULP shipments than the retail organizations (98% versus 13%). As such, the summaries presented in this report focus primarily on results from the interviews with participating manufacturers' representatives.

Table 5
Summary of 2013 In-Depth Telephone Interviews with Participating Lamp Supplier Representatives

Participating Supplier Type	Number of Completed Interviews	% of 2010-2012 ULP Lamp Shipments Represented by Interviewees
Lamp manufacturer	26	98%
Retail lighting buyer	7	13%
Total	**33**	

1.3.4 Primary Data Collection Activities: Commercial Market

Telephone Survey of Commercial Customers. To gather data on awareness, knowledge, and adoption of LED technologies in California, we worked with Itron, Inc. to add questions on those topics to their Commercial Market Share Tracking telephone survey as part of CPUC EM&V WO29. Itron, Inc. staff fielded the saturation survey between November 2011 and May 2013 and completed 7,890 interviews. The LED series was added to this survey while it was in the field, so these questions were asked of the final 3,320 respondents. Results weighted by respondents' energy consumption were used to represent the population of non-residential customers in California.

DNV GL developed the sample frame for the comparison area surveys using information obtained from the InfoUSA SalesGenie database. This database provided the analysis team with a list of non-residential establishments in our comparison states by NAICS code and employment size. We used these data to create a distribution of employment by major industrial groupings and developed a sample, stratified by industry type and employment, proportional to this distribution. Additional contact information to support this sample design was pulled from InfoUSA. The original sample target for this survey effort was 400 completes from non-residential customers in the three comparison states. A professional survey research firm fielded the survey during the summer and fall of 2013 and completed 427 surveys.

Table 6 shows the distribution of building types in the final sample for the non-residential customer survey efforts in California and Comparison Area. We note that the California sample included industrial customers while the sample in the comparison area did not.

Table 6. Final Sample Distribution by Business Type
2011-2013 Non-Residential Customer Telephone Surveys

Business Type	Percentage of Completed Surveys	
	California	Comparison Area
College	0.4%	4.7%
Food/Liquor	6.2%	6.6%
Health/Medical	8.7%	6.8%
Hotel	2.5%	4.2%
Miscellaneous	20.7%	17.8%
Office	16.7%	20.8%
Restaurant	7.5%	5.2%
Retail	12.9%	19.7%
School	6.1%	7.0%
Warehouse	9.4%	7.3%
Total n	**3,320**	**427**

Telephone Survey of Commercial Lighting Installation Contractors. The sample frame for this survey consisted of the InfoUSA database for California and the Comparison Area.

We limited selection to firms with primary SIC or NAICS code listings as electrical contractors and three or more employees. We segmented the sample into categories by number of employees and allocated the sample to those categories by the portion of total employees for the firms in population represented by each segment.

In order to encourage response and mitigate non-response bias in the Comparison Area, we offered contractors a $100 incentive for completion of the interview. We completed 94 interviews in the program area of California and 64 surveys in the Comparison Area. The survey elicited information on contractors' inclusion of various technologies, including LEDs, in their projects, their knowledge and understanding of the technology, promotional practices, and their views on the competitive advantages of installing LEDs.

To take account of large variation among the firms in the number of lighting installation projects they completed each year, we used their reported number of completed projects in a ratio estimation process to calculate the project volume-weighted market share of various technologies (T8, LED, etc.) and sales practices. This approach supports comparison of results from the contractor survey to the results of customer surveys, in which application of weights based on energy consumption or number of employees can be used to account for remaining size differences between establishments in the same sample stratum.

In-Depth Telephone Interviews of Lighting Distributors.

For this study we interviewed representatives of 20 California firms: 5 warehouse distributors and 15 manufacturer representatives. In the Comparison Areas we interviewed representatives of 18 firms: 8 warehouse distributors and 10 manufacturer representatives. Lighting industry analysts from TRC Energy Services, our subcontractor for this study, developed the distributor samples through professional and commercial directories and knowledgeable industry contacts in California and the Comparison Area. Sample selection was intentional, with the goal of identifying firms and individuals that would be likely to have close personal knowledge of the early stages of LED product introduction. Thus, the results of the interviews are more useful for characterizing developments and trends in the market than for estimating current levels of LED market share. The in-depth interviews were carried out by TRC Energy Services staff who have in-depth knowledge of lighting technology and markets. The interviews were carried out during the summer of 2013.

In-Depth Telephone Interviews with Lighting Designers. TRC Energy Services staff developed the sample and conducted the interviews of lighting designers. TRC staff developed the samples from membership lists of professional associations, commercial directories, and contacts in the architectural and design communities in California and the Comparison Area. As with the distributor interviews, selection of individuals into the sample was intentional, with the objective of including persons and firms with personal experience of the use of LED lighting in construction and remodeling projects. TRC staff completed interviews of 19 lighting designers in California and 20 lighting designers in the Comparison Area. In California, respondents were

equally divided among representatives of specialty lighting design firms and more general electrical engineering firms. In the Comparison Area, general engineering and architecture firms are more heavily represented, which reflects the difference in the population of firms between the two areas. TRC staff conducted the interviews during the summer of 2013.

In- Depth Telephone Interviews with LED Manufacturer Representatives. TRC Energy Services staff conducted interviews with 12 product and market managers representing 11 manufacturers of LED light sources and commercial fixtures. The sample was constructed to capture the diversity of firms producing LED lighting products, ranging from small fixture manufacturers who purchased LED light sources from other firms to major international companies that produce light sources, lamps, and fixtures. The interviews covered a broad range of topics, including the firm's history in developing and marketing LED products, trends in LED product sales, investment in R&D, promotional activities, and forecasts of trends in product development and prices. The interviews were conducted between January and April of 2013.

In-depth interviews with managers of LED R&D and market development programs. TRC Energy Services staff conducted interviews with managers of three large programs that support the development of the LED lighting market at the national and regional level. These are the U. S. Department of Energy's Solid State Lighting (SSL) Program[11], the Design Lights Consortium, which developed and operates an LED product testing program supported by utilities around the country, and the California Energy Commission's Public Interest Energy Research Program. The interviews focused on the interaction of national and regional programs with those operated by utilities, observations on the development of the LED markets, and the roles and influence of the various programs in that development.

Analysis of Building Codes. TRC Energy Services staff conducted a comparison of the lighting elements of California's Title 24 Building Standards Code to corresponding portions of ASHRAE 90.1 2009 currently in use by most states to identify elements that favor the use of LED lighting in the new construction and major remodeling projects that the code covers. This analysis was prompted by the hypothesis that Title 24 could exert an influence on LED lighting adoption that is stronger than building codes in other states.

1.4 Structure of the Report

The remainder of this report is structured as follows.

- **Section 2: The Residential Market for LED Lighting** presents an overview of the development of LED lighting product offerings for residential applications, the structure

[11] The Solid State Lighting (SSL) supports research and development activities for LED products and manufacturing processes, product testing and quality reporting, technical education for buyers, product competitions, and a wide range of other activities to advance LED lighting technologies.

of the supply chain, and findings from our primary research concerning the level of awareness, knowledge, and adoption of LED lighting among consumers and businesses in the supply chain. It concludes by presenting a set of market indicators that characterize the level of LED market development in California and the Comparison Area.

- **Section 3: The Commercial Market for LED Lighting** presents a view of the commercial market for LED lighting structured in parallel with the residential section.
- **Section4: Integrated Analysis and Conclusions** synthesizes the findings reported in the previous two sections to provide a view of the current development of the residential and commercial markets for LED lighting and draws the implications of that view for the structure of current program efforts. We also comment on the appropriateness of the research techniques deployed and the likely effectiveness of applying them in the second phase of the study.
- **Appendix A: References** provides complete citations for all sources cited in this report.
- **Appendix B: Selection of Comparison Areas** provides details of the analysis used to select the comparison areas.

2. The Residential Market for LED Lighting

2.1 Products and Applications

This section provides a high-level overview of typical LED lamp and fixture types as well as current forecasts for LED lamp pricing in the United States.

2.1.1 LED Lamps

Section 2.1.1 provides an overview of LED lamp shapes and compares 2012 and 2013 data on available LED lamps by shape from the U.S. EPA's ENERGY STAR program. The section closes with details regarding forecasted lamp pricing in the United States.

2.1.1.1 Overview

LED lamps are available in a wide variety of lamp shapes (form factors) that are similar to those available for CFLs and incandescent lamps (Figure 3). However, because LEDs are a directional technology—that is, because they do not emit light in all directions—some LED lamp manufacturers arrange the diodes to mimic omnidirectionality to support omnidirectional lamp styles (such as A-lamps or globe). This may result in somewhat different shapes for LED lamps as compared to other typical lamp technologies (such as the second image shown for A-lamp in Figure 3). This is often referred to as a "bulged" shape or form factor. Base types include traditional medium screw-base (MSB) lamps as well as candelabra- or small- screw-base (SSB). Lamps are also available with bi-pin and GU-base types.

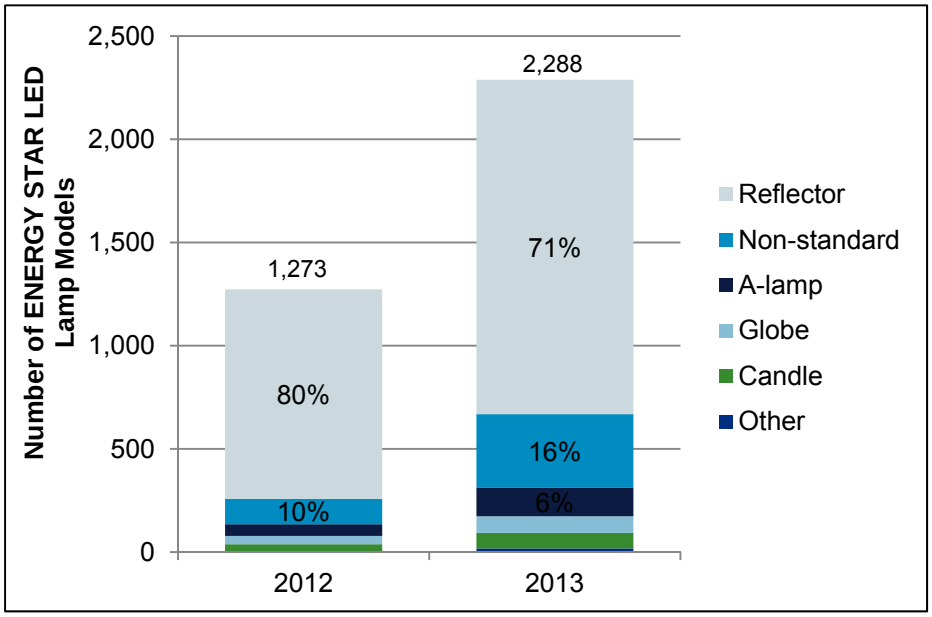
Figure 3
Typical LED Lamp Shapes

2.1.1.2 ENERGY STAR Qualified LED Lamps, 2012 and 2013

As of July 2013, there were approximately 2,288 LED lamp models on ENERGY STAR's list of qualifying products.[12] This list does not represent all LED replacement lamps available on the market, but provides details regarding the lamps that qualify for the ENERGY STAR label. As shown in Figure 4, nearly three-quarters of these were reflector lamp models (71% of all models): 57 percent PAR lamps, 9 percent MR lamps, 3 percent bulged reflector; and 2 percent other reflector styles. Other common lamp shapes include A-lamps, which comprised 6% of ENERGY STAR qualified LED lamp models listed in July 2013; globe (4%), and candle style LED lamps (2%).

The DNV GL team compared the July 2013 ENERGY STAR qualifying lamp models with comparable data from September, 2012. As shown in the figure, the total number of models increased by nearly 80 percent in that timeframe (from 1,273 models to 2,288). Results also show that the proportion of total lamp models comprised by reflectors shifted from 80 percent of all models in 2012 to 71 percent in 2013, with the majority of this shift absorbed by non-standard and "other" lamp shapes in 2013.

Figure 4
Summary of ENERGY STAR Qualified LED Lamp Models by Lamp Shape, 2012 and 2013



Source: U.S. EPA, 2012b and 2013b.

[12] U.S. EPA, 2013a.

2.1.1.3 Pricing Forecasts

The U.S. DOE tracks lamp pricing based on the retail cost of a light source measured by the cost per kilolumen in U.S. dollars ($/klm). According to a 2011 study, the cost for a traditional incandescent A-lamp in 2010 was approximately $0.50 per kilolumen (Table 7).[13] In 2008, DOE estimated the average cost of LED A-lamps (specifically the A19 size) to be $170 per kilolumen,[14] and in 2009, DOE's Solid-State Lighting Multi Year Program Report predicted that LED lamp prices would average $100 per kilolumen in 2010. In 2010, one year after the $100/klm projection was made, DOE documented LED A-lamp prices of $50 per kilolumen, far lower than originally predicted.[15] DOE suggests that the significant decrease in LED lamp prices is a result of a growing and rapidly changing market for LED lamps coupled with improvements in lamp manufacturing efficiency. Moving forward, projected costs for LED lamps in 2013 are $16.50 per kilolumen and in 2015, $11.30 per kilolumen.[16]

Table 7
Cost of Light Sources by Replacement Lamp Type in Dollars per Kilolumen, 2010

Replacement Lamp Type	Initial Cost
Incandescent Lamp (A19 60W high efficiency)	$0.50 per kilolumen
Compact Fluorescent Lamp (13W)	$2 per kilolumen
Compact Fluorescent Lamp (13W dimmable)	$10 per kilolumen
Fluorescent Lamp and Ballast System (F32T8)	$4 per kilolumen
LED Lamp (A19 60W dimmable)	$50 per kilolumen

Source: Bardsley Consulting *et al.* 2011.

Comparable price data for the specific products referenced in Table 7 was not available for subsequent years. However, in October, 2013, DOE updated its price forecast for a wide range of LED products based on historical data from the Commercially Available LED Product Evaluation and Reporting (CALiPER) program. LED A-lamps included in the analysis had a wide price variance in 2012, ranging from $20 to over $100 per kilolumen, with the average price around $60 per kilolumen.[17] Despite the high price observed in 2012, the forecast for A-

[13] Bardsley Consulting *et al.*, 2011, Page 38.
[14] Navigant Consulting, 2010. Page 69.
[15] Bardsley Consulting *et al.*, 2011, Page 38.
[16] Navigant Consulting, 2012, Page 64.
[17] PNNL, 2013.

lamp prices drops to an average price of just over $10 per kilolumen by 2017.[18] DOE predicts a similarly steep price decline for most LED lamp shapes studied.

In 2010, DOE found that the average retail price for 400 lumen (40 watt equivalent) warm white LED A-lamps was $20 per lamp and that 800 lumen (60 watt equivalent) A-lamps averaged approximately $40 per lamp.[19] In 2010, DOE also documented average prices for reflector lamps in the $20 to $30 range for a 6 to 7 watt MR-16 lamp (250-350 lumens) and between $40 and $60 for a 17 to 18 watt PAR 38 lamp (750-850 lumens).[20] Overall, DOE found retail prices for LED lamps were around $36 on average, roughly 30 times higher than the initial cost of incandescent lamps and 9 times higher than the initial cost of CFLs in 2010.[21]

To complement the 2010 initial cost data previously cited and DOE's LED cost per kilolumen price projections, we looked at a recent article published by Green Tech Media which documents significant cost reductions achieved by a major LED manufacturer. In March of 2014, an LED manufacturer with an estimated 10 percent North American lighting market share, brought a 1600 lumen, 100 watt incandescent equivalent LED A-lamp to market for just under $20.[22] To understand just how quickly prices are falling for LED lamps, another competing manufacturer priced their 100 watt equivalent LED at around $50 in November 2013.[23]

2.1.2 LED Fixtures

The U.S. EPA's ENERGY STAR program provides a list of energy-efficient residential fixture types on its website, including 13 indoor fixture types and 5 outdoor fixture types.[24] Not surprisingly, given the relatively recent emergence of LED technologies, LED fixtures were available in only a subset of these styles as of January, 2013 for residential or combined residential/commercial applications—7 indoor fixture types (including recessed downlights, downlight retrofit kits, accent lights, under cabinet, cove, surface-mount downlight, and portable desk task lights) and 3 outdoor fixture types (including porch, post-top, and security lights; see Table 8).[25]

Recessed downlights and downlight retrofit kits comprised nearly three-quarters of the fixture models listed at that time: 45 percent of listed fixture models were recessed downlights and 27

[18] *Ibid.*

[19] Bardsley Consulting *et al.*, 2011, Page 39.

[20] *Ibid.*

[21] *Ibid.*, Section 3.5.

[22] LaMonica, 2014.

[23] *Ibid.*

[24] See http://www.energystar.gov/index.cfm?c=ssl.pr_residential_apps for details.

[25] Note that the list also includes commercial fixtures, but DNV GL analysts excluded these from their analyses.

percent were downlight retrofit kits. Other common LED fixture styles included accent lights (13%) and under cabinet lights (11%). Other fixture styles comprised only 2 percent or less of all models that qualified for the ENERGY STAR label in January 2013.

Table 8
Summary of ENERGY STAR Qualified LED Fixture Models by Fixture Style, January 2013

Fixture Style	ENERGY STAR Qualified LED Fixture Models	
	n	%
Recessed downlight	518	45%
Downlight retrofit kit	308	27%
Accent Light	151	13%
Under cabinet	122	11%
Cove	23	2%
Porch	14	1%
Post-top	9	1%
Surface-mount downlight	6	1%
Security	3	0%
Portable Desk Task Light	1	0%
Other	5	0%
Total	**1,160**	**100%**

Source: U.S. EPA, 2013c.

2.2 Relevant Product Standards

This section of the report provides an overview of four key regulations and standards that currently affect California's market for residential replacement lamps: the Energy Independence and Security Act of 2007; California Assembly Bill 1109 (the California Lighting Efficiency and Toxics Reductions Act), also passed in 2007; the United States Environmental Protection Agency's ENERGY STAR program; and the California Energy Commission's "California Quality" LED Lamp Specification.[26]

[26] Note that this background information was written for the forthcoming "California Residential Replacement Lamp Market Characterization Study" from DNV GL and is reproduced here for context

2.2.1 Energy Independence and Security Act

The U.S. Congress passed the Energy Independence and Security Act (EISA) in 2007. EISA requires general purpose lamps[27] to meet new efficacy standards as detailed in Table 9. The standards do not ban incandescent lamps or lamps of a specific wattage, which are common misconceptions regarding EISA. Instead, it establishes minimum efficacy requirements that traditional incandescent lamps cannot meet, effectively pushing the most inefficient lamps out of the market. EISA's efficacy requirements target the most common general purpose lamps; thus, many lamp types are exempt from the standards (including three-way, high light output[28], shatter resistant, rough service, and vibration service lamps).[29]

Table 9
Summary of EISA Efficacy Requirements

EISA Effective Dates	Incandescent Lamp Wattage (W)	Typical Incandescent Light Output in Lumens (lm)	Typical Incandescent Efficacy (lm/W)	EISA Replacement Wattage (W)	EISA Light Output Ranges (lm)	EISA Minimum Efficacy Ranges (lm/W)
1/1/2012	100 W	1690 lm	17 lm/W	72 W	1490-2600 lm	21-36 lm/W
1/1/2013	75 W	1170 lm	16 lm/W	53 W	1050-1489 lm	20-28 lm/W
1/1/2014	60 W	840 lm	14 lm/W	43 W	750-1049 lm	17-24 lm/W
1/1/2014	40 W	490 lm	12 lm/W	29 W	310-749 lm	11-26 lm/W

Source: U.S. Environmental Protection Agency (EPA), 2011.

In addition to regulating manufacture and importation of general purpose incandescent lamps, EISA also includes efficacy standards for reflector lamps and fluorescent tube lamps (the latter of which were not included as part of this study). Additionally, EISA includes a second phase of regulations set to start in 2020, which will require at least 45 lumens per watt (lm/W) for all general purpose lamps.[30] However, in December 2011, the U.S. House of Representatives passed a last-minute rider (attached to the omnibus government spending bill) that prevents DOE from enforcing EISA.[31] This created the potential for phased-out incandescent lamps to continue to

[27] EISA defines a *general purpose lamp* as a standard incandescent or halogen type lamp that is intended for general service applications; has a medium screw base; falls within a lumen range of 310 to 2,600 lumens; and is capable of being operated at a voltage at least partially within 110 and 130 volts. We apply this definition of general purpose lamps throughout this report.

[28] High light output lamps are defined by lumen levels greater than 2,600 lumens and are typically represented by 150-300W traditional incandescent bulbs.

[29] According to the U.S. EPA (2011), the U.S. DOE will monitor sales of exempt lamp types going forward, and if sales increase substantially, DOE has the authority to apply efficacy standards to those lamp types.

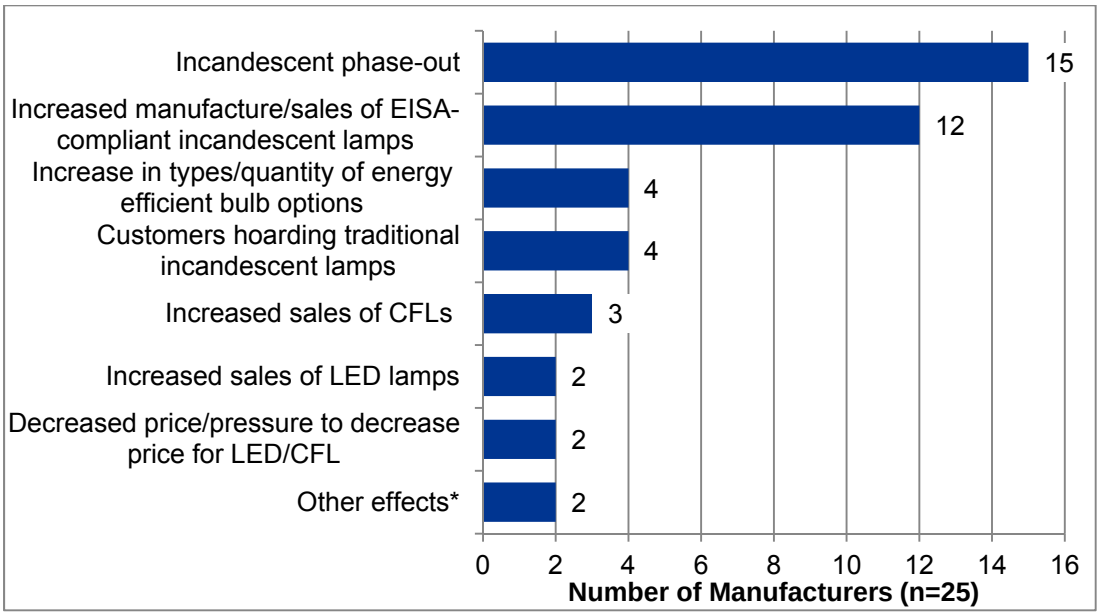
[30] *Ibid.*

[31] Cardwell, 2011.

enter the U.S. market, but according to the American Lighting Association, all major lamp manufacturers planned to proceed as if enforcement were imminent.[32]

The 2013 lamp supplier interviews asked manufacturers' representatives and retail buyers to describe "the most notable effects of [EISA] on the lighting market since it was first implemented in 2012."[33] Not surprisingly, among the 26 lighting manufacturers we interviewed, nearly two-thirds of them mentioned that EISA's most notable effect was the phase-out of traditional incandescent lamps as (15 representatives; see Figure 5). Nearly half of the manufacturers said they saw an increase in consumers selecting EISA-compliant (energy-efficient) incandescent lamps (including halogen products) to replace the phased-out incandescent lamps. Four of the 25 lighting manufacturers mentioned that the recent effects of EISA included consumer hoarding of traditional incandescent lamps. Two retail buyers also mentioned hoarding, with a perceived peak in hoarding behavior in early 2012 (coinciding with the national phase-out of traditional 100-watt incandescent lamps) and a subsequent decline in this behavior in late 2012 and 2013.

Figure 5
Participating Manufacturer Perceptions of EISA's Effects, 2013
(Supplier Telephone Interviews)



Note: Interview question allowed multiple responses.
* "Other effects" included: "increased need for consumer education" "and lack of consistency in product offerings."

[32] Enlightenment News, 2012.

[33] This remainder of this sub-section of the report is drawn largely from the forthcoming CPUC EM&V WO13 report titled "California Residential Replacement Lamp Market Characterization Report" from DNV GL. This information is reproduced here for added context.

Nearly all lighting manufacturers interviewed agreed that, for the most part, retailers will have sold through their stock of traditional incandescent lamps by 2014. The occasional exception, according to one manufacturer, is small independent discount stores—this representative suggested that these types of retailers will not sell through all of their traditional incandescent lamps by the end of 2014 because they will likely acquire other retailers' discarded stock of these lamps and continue to sell them.

2.2.2 California Assembly Bill 1109

California Assembly Bill 1109 (AB 1109), the California Lighting Efficiency and Toxics Reductions Act, was also passed in 2007 and required the California Energy Commission (CEC) to develop and implement a strategy that would reduce California's energy consumption related to general purpose indoor lighting by 50 percent by 2018.[34] California adopted the same efficacy standards as EISA, however, the effective dates for AB 1109 are one year earlier (Table 10).[35] AB 1109 also requires the state to set up a recycling program for lighting products and prohibits the sale of general purpose lamps that exceed certain levels of hazardous substances.[36]

Table 10
Timing Comparison: EISA (U.S.) and AB 1109 (California)

Affected Light Output Ranges (lm)	Effective Dates of Regulation	
	EISA (United States)	AB 1109 (California)
1490-2600 lm	1/1/2012	1/1/2011
1050-1489 lm	1/1/2013	1/1/2012
750-1049 lm	1/1/2014	1/1/2013
310-749 lm	1/1/2014	1/1/2013

2.2.3 ENERGY STAR

In 2010, DOE introduced the first ENERGY STAR specifications for light-emitting diode (LED) lamps and fixtures, focusing on quality and performance using the lessons learned from its years

[34] Huffman, 2007.

[35] For example, 100 Watt incandescent light-bulbs were banned in California starting January 1, 2011 with 75W bulbs banned starting January 1, 2012.

[36] California prohibited the same levels of hazardous substances as the European Union pursuant to the Restriction of Hazardous Substances (RoHS) Directive. RoHS took effect in 2006 and restricts the use of six hazardous materials in electronics; lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls, and polybrominated diphenyl ether.

of experience with the CFL market. To qualify for the ENERGY STAR label, LED lighting products must have:

- Brightness equal to or greater than existing lighting technologies (incandescent or fluorescent) and light is well distributed over the area lighted by the fixture;
- Light output that remains constant over time, only decreasing towards the end of the rated lifetime (at least 35,000 hours or 12 years based on use of 8 hours per day);
- Excellent color quality (i.e., the shade of white light appears clear and consistent over time);
- Efficiency as good as or better than fluorescent lighting;
- Light that comes on instantly when turned on;
- No flicker when dimmed; and
- No off-state power draw (i.e., the fixture does not use power when it is turned off[37]).[38]

According to a 2009 study, ENERGY STAR CFL sales accounted for nearly three-quarters of total CFL sales in the U.S. during 2007.[39] The California IOUs' energy-efficiency programs required that lamps must meet ENERGY STAR specifications to qualify for incentives beginning in the early years of lighting program activity.

2.2.4 "California Quality" LED Lamp Specification

In 2012, the CEC published a voluntary quality specification for LED lamps "to support policymakers and the lighting industry in their collective goal to move consumers away from the inefficient incandescent light of the past century to more efficient LED lighting technology."[40] In that document, the CEC acknowledges that meeting this goal will require not only efficient lamps but also lamps that meet consumer expectations with regard to lamp quality and performance.

In collaboration with representatives from industry, utilities, and academia, the CEC developed minimum quality specifications for LED lamps that they believe will meet or exceed consumer expectations for lighting. Because of the high concentration of incandescent lamps in the residential sector, the CEC focused on household applications in which LED lamps are suitable replacements for typical incandescent lamps. As such, the specification applies to screw-base and bi-pin A-lamp, flame-tip, globe, floodlight, and spotlight lamps.[41] It excludes

[37] Qualifications include an the exception regarding off-state power draw for external controls. With external controls, fixture power draw should not exceed 0.5 watts in the "off" state.

[38] U.S. EPA, n.d.(b).

[39] The Cadmus Group, Inc. et al., 2009.

[40] CEC, 2012.

[41] Base types included in the specification areE12, E17, E26, GU-10, GU-24, G8, G9, and GX5.3. Lamp shapes (form factors) include A-lamp (A); flame-tip (F); globe (B, BA, C, CA, G); reflector lamps

"colored LED lamps; LED light strips; linear LED pin-based lamps; LED rope lights; LED fully integrated luminaries; LED luminaire housings; or LED light engines not having American National Standards Institute (ANSI) standardized screw bases."[42]

The specifications are based on enhancements to the ENERGY STAR standard for LED lamps described above, with a particular focus on improvements to the color temperature, consistency, and color rendering (with requirements for Color Rendering Index [CRI] greater than or equal to 90); dimmability; length of life/warranty, and light distribution. For light distribution in particular, the specification includes different requirements for omnidirectional lamps, floodlights, and spotlights.[43]

The CPUC issued a decision in November, 2012, that required the California IOUs to provide incentives only for LED lamps that meet the "California Quality" specification within one year of the standard's adoption by the CEC.[44] The CEC adopted the standard in December 11, 2012. During the "transition period" of up to one year from that date, the CPUC allowed the IOUs to continue to provide incentives for LED lamps that met the ENERGY STAR standards. After December 11, 2013, compliance with the "California Quality" specification for LED lamps became mandatory for IOU incentive program eligibility.

During the 2013 supplier interviews, many lighting suppliers had reactions to this new requirement. Most of these reactions were negative, although a few manufacturers' representatives opined that the requirement represents a positive development.[45]

A number of manufacturers' representatives indicated that they would have introduced LED lamps into the ULP sooner if they had not been required to meet the CEC lamp specifications. One representative of a major lighting manufacturing organization expressed frustration with complying with these specifications because of the challenges associated with maintaining a California-specific product line that is different from the LED lamps they produce to sell in other states. For example, one commented that "it's really annoying," and stated that his company needs to "run separate SKUs [stock-keeping units] if we want to compete in or utilize the utility programs in California."

(bulged reflector BR20 BR30, and BR40; multifaceted reflector MR; parabolic reflector PAR16, PAR20, PAR30, and PAR38; and reflector R16, R20, R30, R40) and a handful of others.

42 CEC, 2012.

43 Note that the "California Quality" standard defines an additional lamp type not included in the ENERGY STAR specification ("floodlamp").

44 CPUC, 2012.

45 This remainder of this sub-section of the report is drawn largely from the forthcoming CPUC EM&V WO13 report titled "California Residential Replacement Lamp Market Characterization Report" from DNV GL. This information is reproduced here for added context.

A couple of manufacturers' representatives reported that when the ULP implemented the CEC standard's requirements for meeting a minimum CRI, they had to hold back some of their LED lamps from sale because the lamps did not meet the new standards. One representative mentioned that "the lion's share of the products that [they] offer is no longer available to the incentive programs, based upon their definition of what can be incentivized." Another representative mentioned that his firm was "kind of in a holding pattern" as far as ULP participation for these lamps because most of their LED lamps do not meet the CRI requirement in the CEC standard.

A few manufacturers argued that the ULP requirements that all LED lamps meet the CEC specifications were too draconian. They suggested that the ULP should allow sales of LED lamps intended for specific applications or below a certain price point even if these products do not meet the performance criteria of the LED specification. Some of their specific comments included:

- "There are ... a lot of things that don't make sense about [the ULP requirement that LED lamps meet the CEC specification. For example ... to present an LED bath bar to the California utilities, it has to meet all the CEC requirements and one of them is that it's dimmable. And, you know, there aren't a lot of people with dimmer switches in their bathrooms. And to make it dimmable, I have to increase the retail cost about $7, because I have to use a more expensive driver. And so to increase the retail by $7 to chase after a $10 rebate ... doesn't make a lot of sense."
- "The CEC's CRI spec is great if they had rebate for non-CEC spec that's lower. The wattage on that bulb is 13 watts. Some customers would take 80 or 85 CRI. Some people would still want that choice, e.g. they do not want 90 CRI and yet want to be efficient with LEDs. They should have a tiered incentive structure. For example, if you have a lamp as an accent, and you turn on at a distance, it doesn't matter if it's 90 or 85 CRI. I think the Commission should understand that."

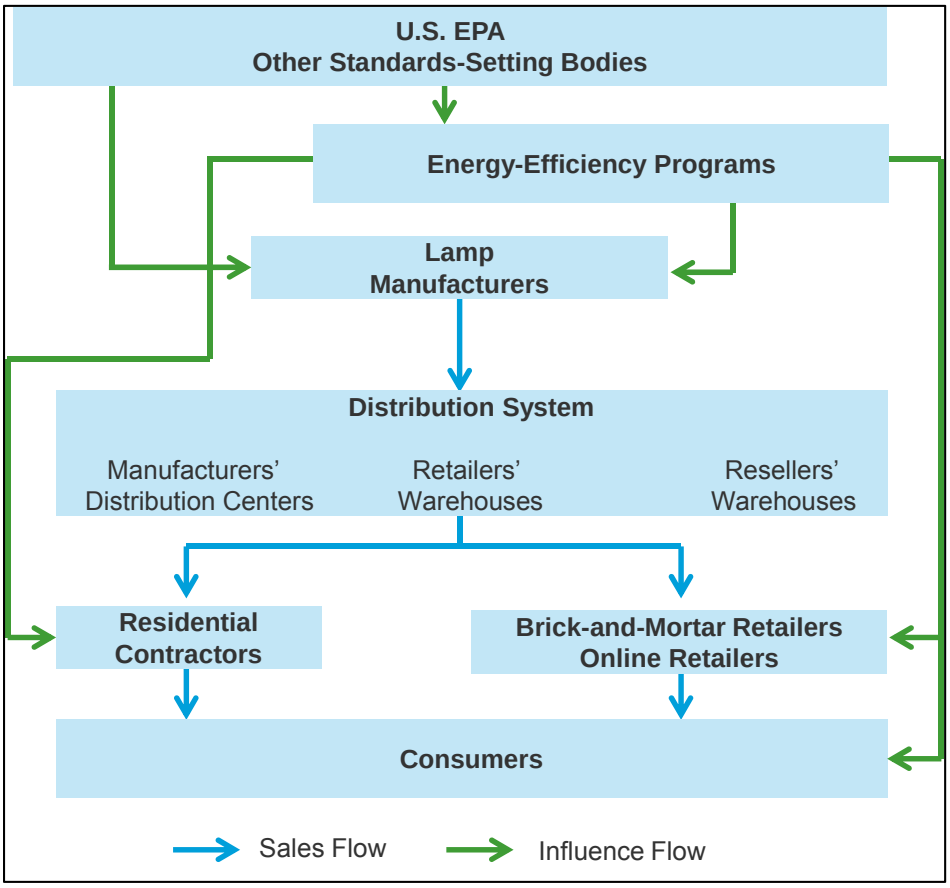
One of the retail buyers we interviewed reiterated the second point above, stating that "the CRI requirement is a bad idea" because "it's not relevant to a consumer." His impression was that consumers are not aware of the term "CRI" and that "no one needs to have a 90-plus CRI lamp in their house, because ... it's a commercial spec, essentially."

In stark contrast, a couple of the manufacturers' representatives thought there were some advantages to the CEC standards in terms of pushing technological advancement and improving lamp performance. "It is an encouragement for us to advance our technology ... when they ask for a higher standard than the current ENERGY STAR standard," said one representative. Another said, "I do agree in a way [with the CEC standards], because when people are paying so much money, and the utilities are giving so much [money in the form of incentives], why can't the product be top quality?" The latter mentioned that by focusing on high-quality LED lamps, he believed that the IOUs "are *not* making the same mistake as they did for CFLs."

2.3 Market Structure

This section of the report describes the structure of the residential market for LED products as well as the key market players. Figure 6 provides a high-level overview of the key market actors, which include the U.S. EPA and other standards-setting bodies (such as the CEC), energy-efficiency programs, lamp manufacturers and retailers, distributors (largely affiliated with manufacturers and retailers), contractors, retailers, and end-use customers. The green lines in the figure show the flow of influence within the market—for example, through the ENERGY STAR program, the U.S. EPA influences manufacturers (in terms of the products they produce) and energy-efficiency programs (in terms of eligible measures)—and the blue arrows indicate the direction of sales—for example, manufacturers sell LED lamps to retailers. Subsequent subsections provide more details regarding lamp manufacturers and retailers.

Figure 6
Residential LED Lamp Market Structure: Key Market Actor Groups



2.3.1.1 Manufacturers

Lamp manufacturers are a major influencer in determining lamps—that is, which technologies, models, packaging configurations, and so on—will appear in retail stores. Manufacturers typically have close relationships with their retail partners, and retailers typically have close relationships with one (or sometimes two) key manufacturers. The manufacturers exert their influence on where each lamp type appears in the retail store (positioning—e.g., on an end-cap, in the lighting aisle), how the lamp is priced, and special promotional or marketing efforts specific to an individual product or group of products. A 2012 report suggests that while manufacturers may meet with retailers once a year for "comprehensive product reviews" in which they review all of the distinguishing characteristics of each model, the manufacturer and retailer may also have less formal discussions throughout the year to address specific issues or special promotional opportunities as they arise.[46]

Several manufacturers are active in the market for LED lamps and fixtures. For LED lamps in particular, ENERGY STAR maintains lists of qualified lamps for sale in the United States. Based on data from July 17, 2013, there were approximately 175 organizations listed as "ENERGY STAR partners" at that time. The U.S. EPA defines an ENERGY STAR Partner as "an organization that signed a Partnership Agreement with EPA to manufacture or private label ENERGY STAR qualified products."[47] As such, it is likely that the count of partners somewhat over-represents the total number of LED lamp manufacturers (since some manufacturers may produce more than one brand). Nonetheless, these data provide an indication regarding the relative market presence of various LED Lamp manufacturing organizations.

As shown in Table 11, the top eleven partners accounted for more than 40 percent of all LED lamps listed by ENERGY STAR in July 2013 (42%), and the remaining 164 partners each account for less than 2 percent of total models available at that time. As shown, GE Lighting and Philips Lighting Company each accounted for approximately 8 percent of all the ENERGY STAR LED lamp models listed in mid-2013.

[46] D&R International, 2012.

[47] U.S. EPA, 2013a.

Table 11
Number of ENERGY STAR Qualified LED Lamp Models Available in the U.S by ENERGY STAR Partner, July 17, 2013

ENERGY STAR Partner	LED Lamp Models Listed	
	n	%
GE Lighting	191	8%
Philips Lighting Company	175	8%
OSRAM SYLVANIA	133	6%
Technical Consumer Products, Inc. (TCP)	110	5%
Lighting Science Group, Corp	85	4%
Toshiba International Corporation	67	3%
Solais Lighting, Inc.	45	2%
Green Creative	39	2%
Standard Products, Inc.	38	2%
Homelite Technology Co. Ltd	37	2%
Wooree Lighting Holdings Co. Ltd.	37	2%
All other partners (n=164; each accounts for <2% total models)	1,331	58%
Total	**2,288**	**100%**

Source: U.S. EPA, 2013a.

2.3.1.2 Retailers

In California, there are at least 7 retail channels that typically sell replacement lamps and/or fixtures to consumers:[48]

1. **Discount**. Discount stores typically sell products at prices lower than those of traditional retail outlets and may obtain these products through resellers and discount aggregators. Examples of discount chains in California include 99 Cents Only, Big Lots, and Dollar Tree.
2. **Drug**. Drug stores typically sell over-the-counter medications, first aid supplies, and prescription pharmaceuticals. Many drug stores also sell paper products, soft drinks and beverages, and a selection of grocery dry goods. Examples of drug store chains in California include CVS, Rite Aid, and Walgreen's.
3. **Grocery**. Grocery stores typically sell perishable and non-perishable food items and stock a small selection of household goods such as paper products and cleaning supplies.

[48] This sub-section of the report is drawn largely from the research conducted to support the forthcoming CPUC EM&V WO13 report titled "California Residential Replacement Lamp Market Characterization Report" from DNV GL. This information is reproduced here for added context.

This category includes produce markets and convenience stores. Examples of California grocery store chains include Albertson's, Food 4 Less, and Stater Brothers.

4. **Small Hardware.** Small hardware stores sell a variety of home repair, maintenance, and improvement products such as fasteners, tools, and plumbing and electrical supplies, and may stock cleaning products, paint, and lawn and garden products. Some may also stock goods that are regionally appropriate, such as hunting and fishing supplies or swimming pool chemicals. Small hardware stores are similar to home improvement stores except typically have far smaller square footage. Examples of small hardware chains in California include Ace Hardware, Hardester's Market and Hardware, and True Value Hardware.
5. **Large Home Improvement.** Large Home Improvement stores are a class of hardware stores that typically occupy warehouse-style spaces with large footprints over 30,000 square feet and often over 100,000 square feet (many with additional square footage dedicated to outdoor garden centers). Examples of large home improvement chains in California include The Home Depot, Lowe's, and Orchard Supply.
6. **Mass Merchandise.** Mass merchandisers typically stock a large assortment of goods (including clothing and housewares and sometimes food products and medications) at relatively low prices. Stores in this category include large mass merchandise chains as well as smaller "mom and pop" discount and variety stores. Examples of mass merchandise stores in California include chains such as K-Mart, Target, and Wal-Mart.
7. **Wholesale Club.** Wholesale clubs are typically warehouse-style stores that stock a wide variety of grocery and household items at lower prices than typically available in most other retail channels and typically require shoppers to carry membership cards. Examples of California wholesale club chains include Costco and Sam's Club.

There are other types of retailers that sell replacement lamps to California consumers – for example, lighting showrooms, electronics stores, and online retailers. Showrooms (such as Lamps Plus) typically stock light fixtures, ceiling fans, and a relatively broad selection of replacement lamps, while electronics retailers (such as Best Buy) typically sell home electronics and appliances and may sell a small selection of replacement lamps and/or fixtures. There are also countless online retailers that may sell replacement lamps to California consumers, including lighting-specific outlets (such as bulbs.com) and general merchandisers (such as Amazon). There is limited information available regarding these channels, however, and as such they are excluded from much of the discussion herein. Finally, stores that typically sell donated goods (such as Goodwill and Salvation Army outlets) occasionally stock small volumes of low-

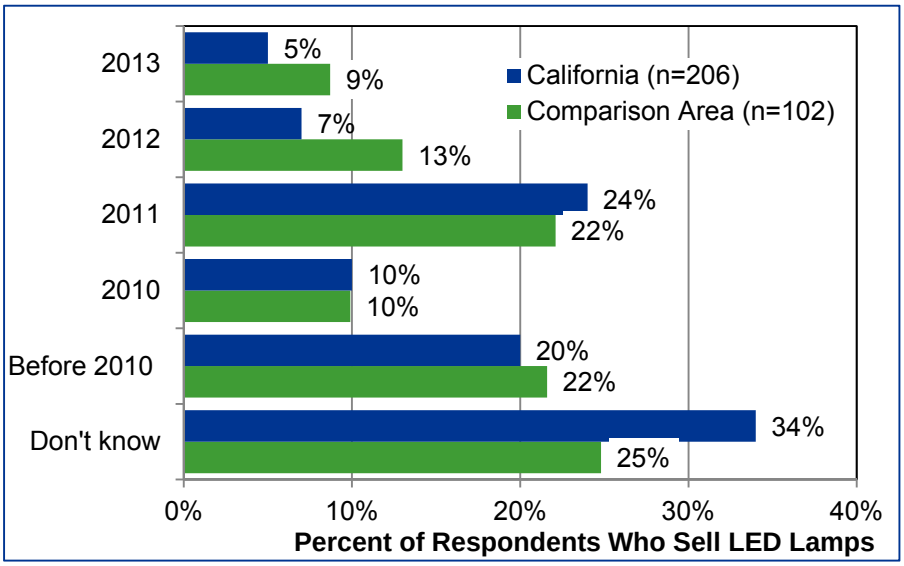
priced lamps, but these may be limited to products provided by manufacturers at little or no cost with sponsorship from utility energy-efficiency programs.[49]

Results of the retail store manager telephone surveys suggested similar level of self-reported awareness of LED lamps among retail store managers in both CA and comparison area in 2013 (96-97%). Shelf survey results suggest that roughly 30 percent of stores in both regions stocked LED lamps as of late 2012.

2.3.1.2.1 When Retailers Began Stocking LED Lamps

The retail store manager telephone interviews asked respondents in California and the comparison area who reported stocking LED lamps in 2013 to indicate when their stores began stocking LED lamps. As shown in Figure 7, roughly half of retailers in both regions began stocking LED lamps during or after 2010, and two in ten began stocking them before 2010. There are no statistically significant differences between California and the comparison area in terms of when retailers reported that they began stocking LED lamps.

Figure 7
Year in Which Retailers Began Stocking LED Lamps in California and the Comparison Area among Retailers That Stocked LED Lamps in 2013 (Retail Store Manager Telephone Surveys)



Note: Differences between California and the comparison area are not statistically significant at the 95 percent level of confidence.

[49] Based on 2010-2012 ULP tracking data.

2.3.2 Indicators of Market Development: Market Supply

The subsections below describe the availability, diversity, and pricing of LED lamps in retail stores as well as retailer promotional efforts, motivations for stocking LED products, and perceived market barriers. The majority of this information focuses on LED lamps, but information on fixtures is included where available. In reviewing these results, it is useful to keep the sampling and weighting scheme for the shelf survey in mind. We applied sample expansion weights to the CA and comparison area datasets such that the data represent the population of stores that carry residential replacement lamps in each geographic region. We did not apply weights that represent the share of total sales accounted for by each channel, primarily because we could not identify sources of such information that covered all important channels.

2.3.2.1 Availability

One measure of lamp availability is the percentage of stores that stock a particular product. Below we present availability results for LED lamps and LED fixtures.

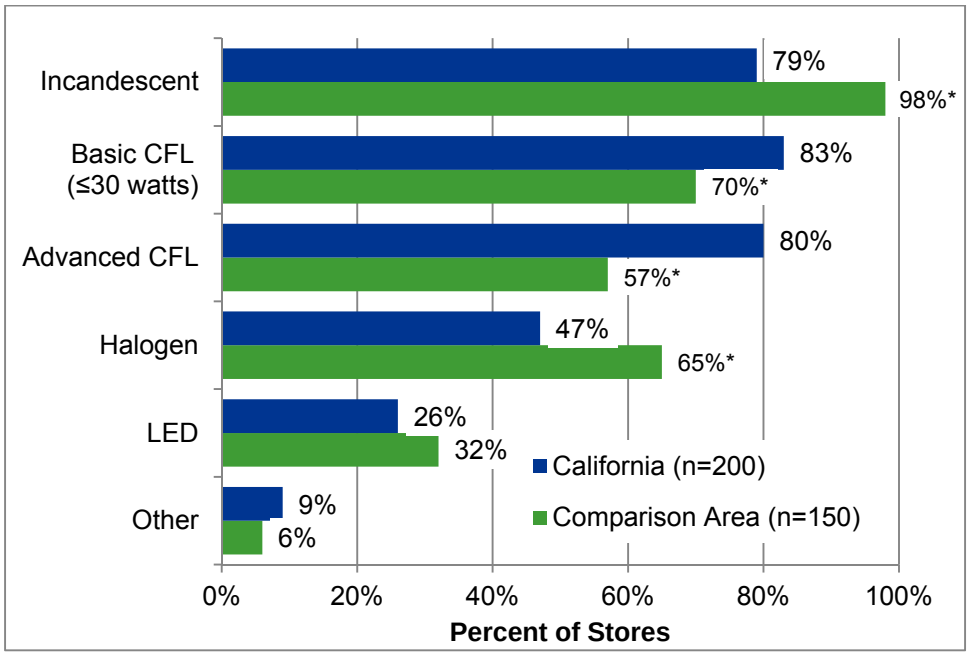
2.3.2.1.1 LED Lamps

Shelf survey results suggest that roughly one-quarter to one-third of stores stocked LED lamps in both CA and comparison area as of late 2012 (Figure 8). For nearly all other lamp technologies, shelf survey results demonstrate statistically significant differences in the percentage of stores stocking them by region in 2012: a significantly smaller percentage of stores stocked incandescent and halogen lamps in California than in the comparison area, and a significantly larger percentage of California stores stocked basic and advanced CFLs than comparison-area stores.[50]

There were no statistically significant differences in the percentages of stores stocking LED lamps between the regions at the retail channel level. In both regions, nearly all wholesale club and small hardware stores stocked LED lamps during the 2012 shelf survey visits. Roughly three-quarters of large home improvement stores stocked LEDs and roughly half of mass merchandise stores. Approximately one-third of drug stores in both regions stocked LED lamps, as did less than one-quarter of grocery stores. Field researchers found no LED lamps in any discount stores in either region during the 2012 shelf survey visits.

[50] In California, "basic CFLs" include medium screw-base, single-wattage, non-dimmable bare spiral lamps of less than or equal to 30 watts. All other lamp shapes (form factors), wattages, and base types are considered Advanced CFLs, as are all 3-way and dimmable CFLs. The CPUC made this distinction in its direction to the IOUs regarding the relative presence of basic versus specialty CFLs in their 2006-2008 energy-efficiency program portfolios.

Figure 8
Percent of Stores that Stock LED Lamps in California and the Comparison Area, 2012 (Retail Store Shelf Surveys)



* Difference from California results is statistically significant at the 95% level of confidence.

2.3.2.1.2 LED Fixtures

The percentage of stores that stock LED fixtures was the same in California and the comparison area when DNV GL field researchers conducted the 2012/2013 retail store inventories of LED fixtures. In both regions, roughly half of stores stocked LED fixtures at that time: 44 percent in California (n=78 stores) and 55 percent in the comparison area (n=137).[51]

2.3.2.2 Diversity

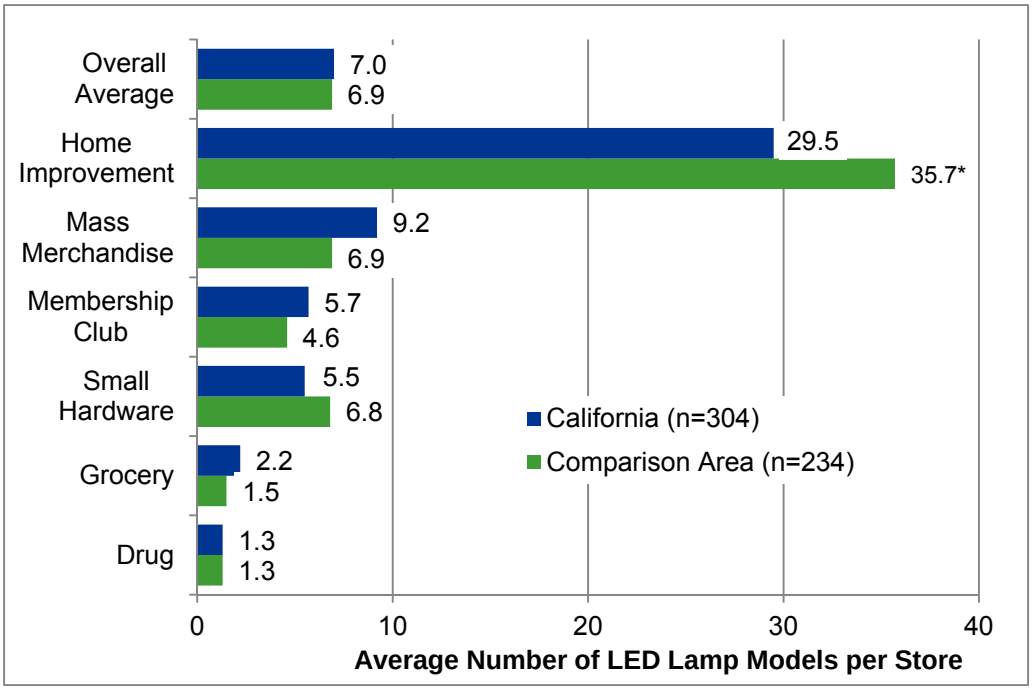
One measure of product diversity is the number of models available to consumers in retail stores. DNV GL field researchers collected details regarding the lamp models available in California and comparison-area retail stores during the 2012 shelf survey visits.[52]

Shelf survey results suggest that retail stores stocked roughly 7 LED lamp models per store, on average, across all store types in California and the comparison area as of late 2012. For comparison purposes, retail stores in both areas stocked an average of 40 incandescent lamp

[51] This difference it not statistically significant, possibly due to small sample sizes.
[52] Comparable information is not available for LED fixtures.

models and 30 CFL models at that time. When results are further examined by retail channel between the two areas, results are similar with the exception of home improvement stores (Figure 9). In the home improvement channel, California retailers stocked an average of approximately 30 LED lamp models per store compared to an average of nearly 36 LED lamp models per store in the comparison area. The reasons for this difference are unclear, but the overall average number of LED lamp models per store (across all channels) was the same in both areas (roughly 7 models).

Figure 9
Average Number of LED Lamp Models per Store in California and the Comparison Area by Retail Channel, 2012 (Retail Store Shelf Surveys)



Note that the figure excludes the "Discount" channel as field researchers found no LED lamps in discount channels in either California or the comparison area.
* Difference from California results is statistically significant at the 95% level of confidence.

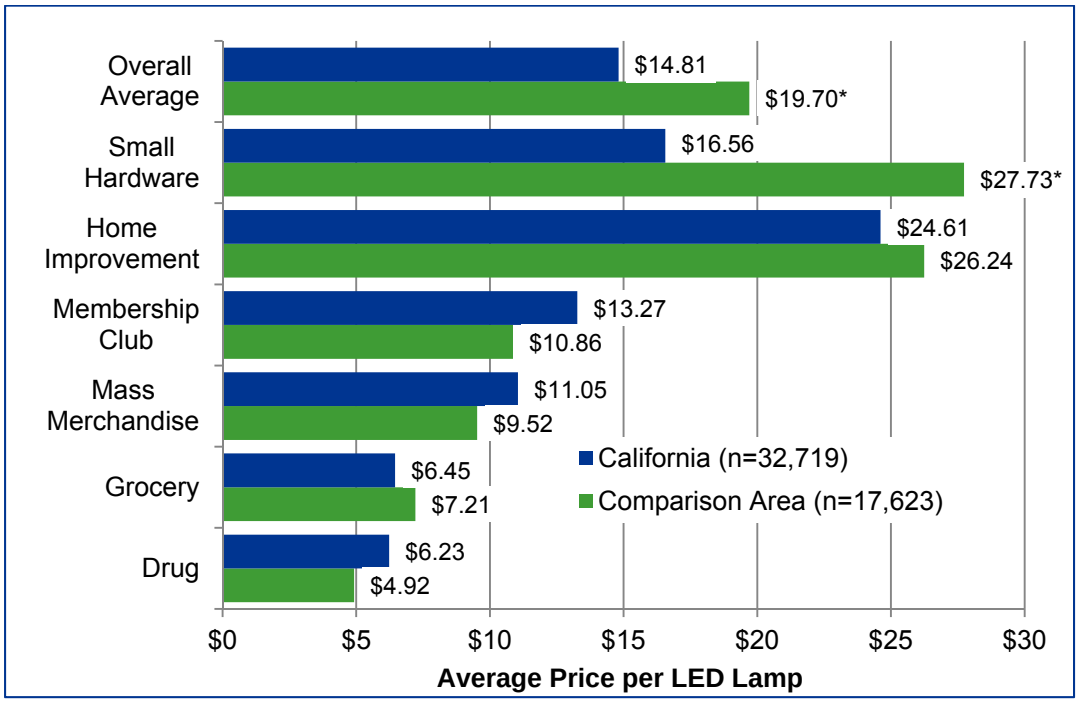
2.3.2.3 Pricing

During the 2012 shelf survey visits, field researchers recorded pricing information for each lamp model present in California and comparison area retail stores.[53] When results are examined across all retail channels, the average shelf price for LED lamps was approximately $5 lower in

[53] Comparable information is not available for LED fixtures.

California than in the comparison area across in late 2012 (roughly $15 in California versus roughly $20 comparison area; a statistically significant difference). When examined in further detail (by retail channel), results suggest that the overall difference in LED lamp prices is driven by a large price gap between the regions in the small hardware channel (Figure 10). Among other channels, differences in average prices ranged from roughly $1-3 per lamp between regions with no statistically significant differences between the regions in any channel other than small hardware.

Figure 10
Average Price per LED Lamp by Retail Channel for California and the Comparison Area, 2012 (Retail Store Shelf Surveys)



Note that the figure excludes the "Discount" channel as field researchers found no LED lamps in discount stores in either area.
* Difference from California results is statistically significant at the 95% level of confidence.

Shelf survey results suggest that the primary driver behind the difference in the overall average price for LED lamps in small hardware stores between California and the comparison area in 2012 was in the average price for A-lamps and (secondarily) the average price for reflector lamps (Table 12). The average price for LED A-lamps was nearly $32 higher in the comparison area than in California, and the average LED reflector lamp price was more than $13 higher in the comparison area than in California. In investigating the cause of these disparities, we found that the numbers of LED lamps and models carried in hardware stores was relatively small in both study areas, as was the average number of models (5 – 7). Given these conditions, a single high-

priced model could skew results in one direction or another. The results shown in Table 12 reflect the average price for the lamp type shown, weighted for the population of establishments in each retail channel.

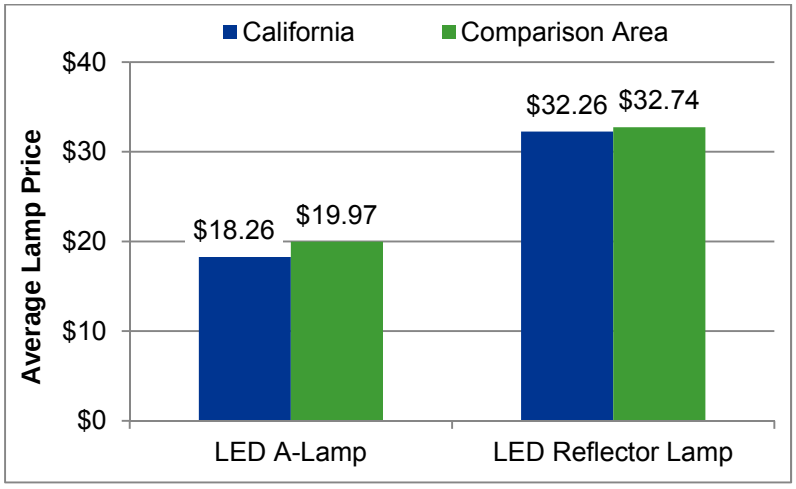
Table 12
Average Price per LED Lamp in Small Hardware Stores by Lamp Style in California and the Comparison Area, 2012 (Retail Store Shelf Surveys)

LED Lamp Shape	Average Price per LED Lamp		Number of LED Lamps	
	California	Comparison Area	California	Comparison Area
Reflector	$25.05	$38.72	121	85
Torpedo	$10.47	$13.58	114	37
A-lamp	$17.29	$40.28	72	48
Globe	$16.67	$15.83	72	27
Nightlight	$3.03	$4.69	32	30

The gaps in average pricing by lamp style and retail channel suggest that it may be more appropriate to track market progress at this level than across all styles and channels. Because of this, DNV GL analysts conducted further analyses to assess the average price per LED lamp in specific retail channels for LED A-lamps and reflector lamps (since these styles are present among the majority of retailers that stocked LED lamps when field staff conducted the 2012 shelf surveys). These analyses focused on the large home improvement channel because stores in this channel stocked a larger number of LED lamp models, on average, in 2012 than the other channels by a factor of 3 or more (see Figure 9 above). As such, the DNV GL team suggests that the average price for LED A-lamps and LED reflector lamps in large home improvement stores may be the most appropriate pricing metric to track for LED lamps.

Figure 11 shows the average LED A-lamp and reflector price in these retail channels for both California and the comparison area. There were no statistically significant differences in pricing between the two regions for LED A-lamps and reflector lamps in the home improvement channel. For LED A-lamps, prices averaged roughly $18-20 per lamp, and for LED reflector lamps, prices averaged roughly $22-23 per lamp in late 2012.

Figure 11
Average Price per LED A-Lamp and LED Reflector Lamp in Large Home Improvement Stores in California and the Comparison Area, 2012 (Retail Store Shelf Surveys)



Number of LED A-lamps: California n=1,950; Comparison area n=1,961.
Number of LED reflector lamps: California n=3,594; Comparison area n=3,877.
Number of large home improvement stores: California n=29; Comparison area n=21.

2.3.2.4 Promotion

The California retail store manager telephone surveys did not include questions regarding promotional efforts, but the comparison-area surveys did. Given that there were few statistically significant differences between California and the comparison area for the vast majority of results from the retail store manager surveys, it is likely that results from California would be similar to those from the comparison area. Key results from the 2013 retail store manager telephone surveys in the comparison area included the following.

- Ninety-seven percent of respondents in the comparison area were aware of LED Lamps.
- One-third of retail store managers in the comparison area reported that their stores had run one or more promotions or sales for LED lamps and/or fixtures since January 2010.
- Twenty-one percent of respondents in the comparison area who were aware of LED lamps reported that their stores had promoted LED lamps, 1 percent reported that their stores had promoted LED fixtures, and 10 percent reported that their stores had promoted both LED lamps and fixtures.
- The overwhelming majority of stores that ran LED lighting promotions reported that their stores sponsored the promotions (85 percent) and 13 percent reported that the product manufacturers sponsored the promotions.

2.3.2.5 Motivations for Stocking LED Lamps

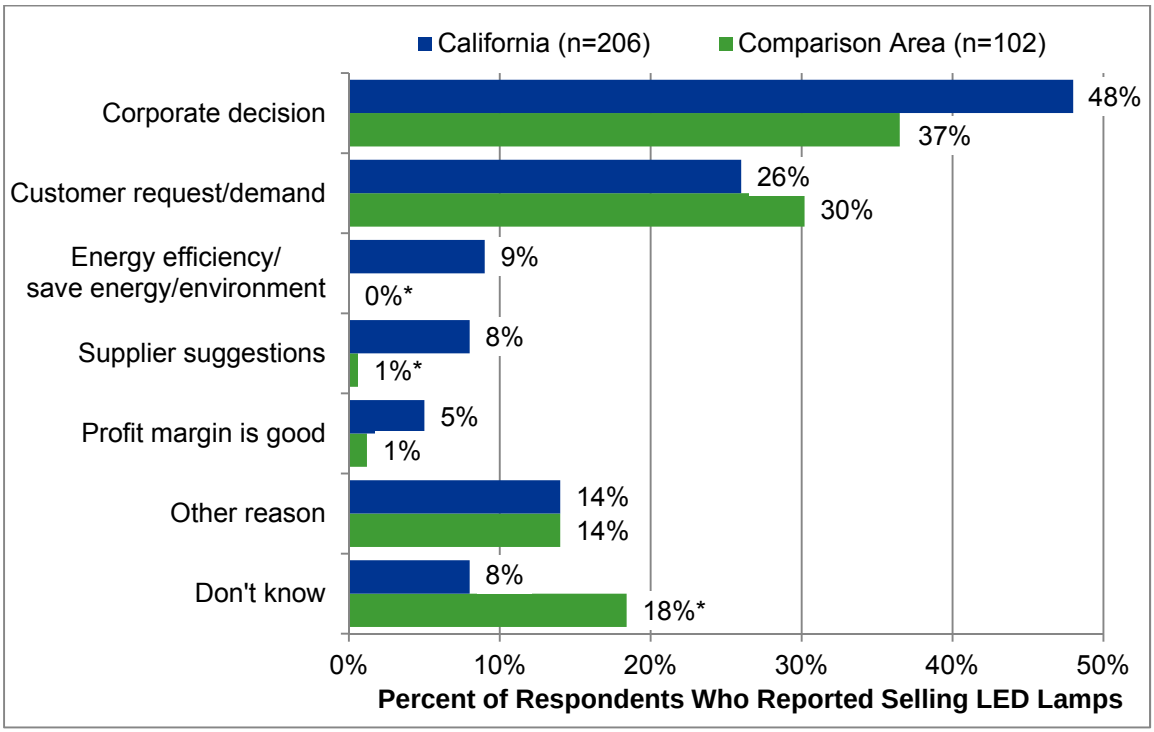
When asked why they decided to sell LED lamps, there was no statistically significant difference in the main reason cited by retail store managers between California and the comparison area:

roughly one-third to half of respondents cited corporate decisions (Figure 12). More than a quarter of respondents in each region cited that customer demand motivated them to sell LED lamps. These results are consistent with findings regarding manufacturer influence at high levels within the lamp supply chain. As shown in the figure, there were a few statistically significant differences between California and the comparison area in some of the responses cited less frequently:

- More retail store managers in California cited "LED bulbs save energy" (9%) or "supplier suggestions" (8%) as motivations than retail store managers in the comparison area (1% and 0%, respectively).

- More retail store managers in the comparison areas were unsure why their stores started stocking LED Lamps than store managers in California (18% versus 8%, respectively).

Figure 12
Motivations for Stocking LED Lamps among Retail Stores That Stock LED Lamps in California and Comparison Area, 2013
(Retail Store Manager Telephone Surveys)



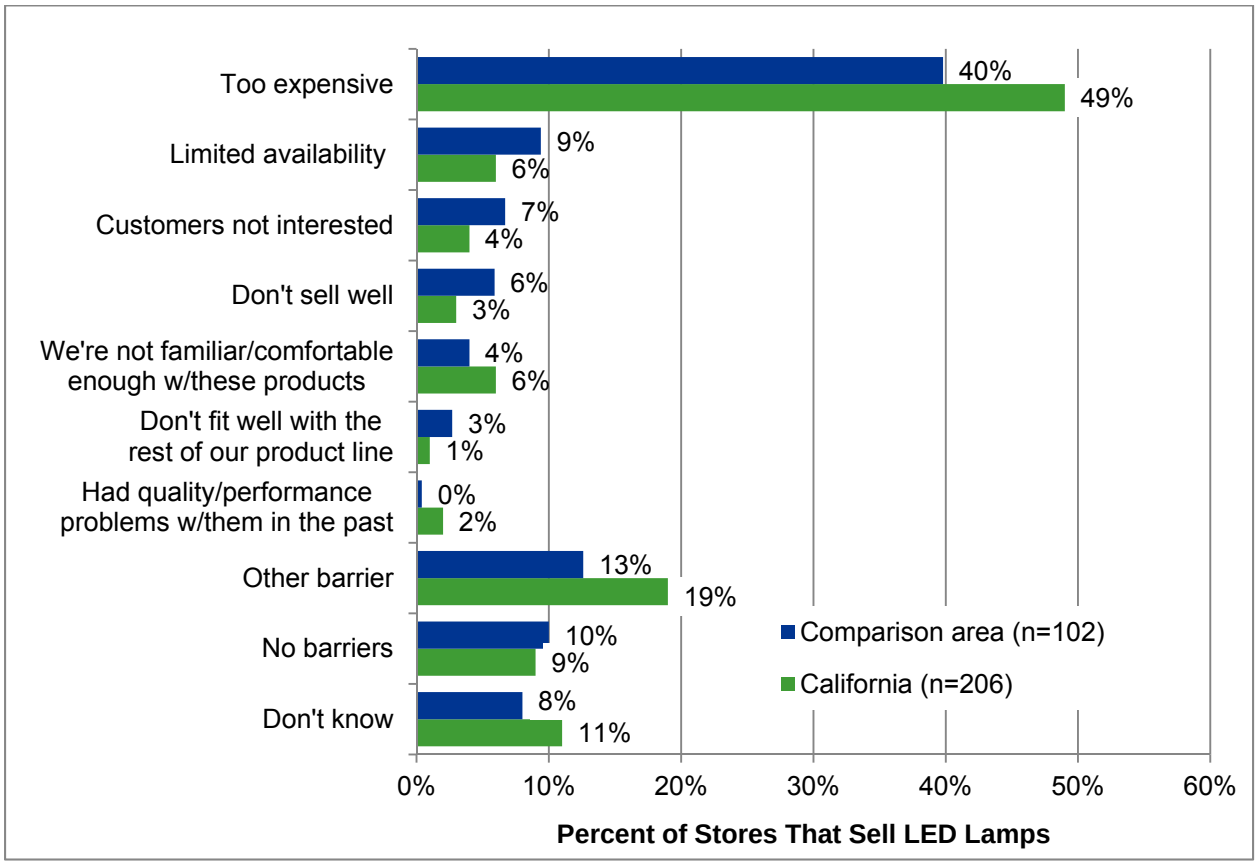
* Difference from California results is statistically significant at the 95% level of confidence.

2.3.2.6 Market Barriers

The retail store manager surveys asked respondents who reported that their stores sold LED lamps what was preventing them from selling more LED lamps to consumers.[54] Respondents in both areas cited lamp price more frequently than any other barrier (Figure 13). Respondents mentioned a scattered array of other barriers (such as limited LED lamp availability, or that LED lamps don't sell well), but there were no statistically significant differences between California and the comparison area in the percentage of respondents who cited each barrier. Roughly one in ten respondents in both regions stated that there were no barriers to selling more LED lamps to residential customers.

[54] Comparable information is not available for LED fixtures.

Figure 13
Barriers to Increased LED Lamp Sales among Retail Stores That Stock LED Lamps in California and Comparison Area, 2013
(Retail Store Manager Telephone Surveys)



Note: Differences between California and the comparison area are not statistically significant at the 95% level of confidence.

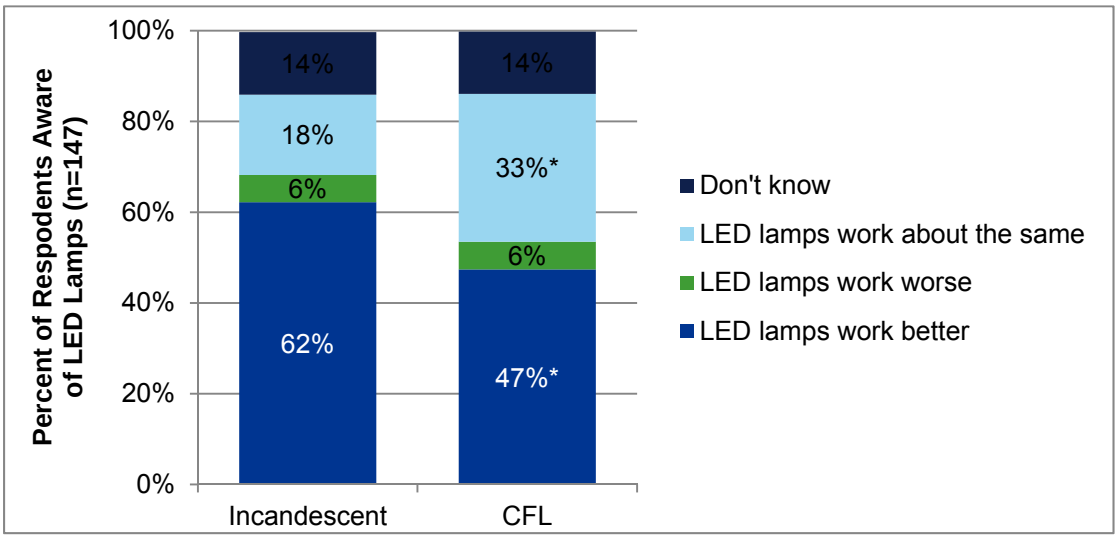
2.3.2.7 LED Product Performance

This subsection of the report describes retail store manager perspectives on LED product quality *in the comparison area only*.[55] The retail store manager interviews asked respondents in the comparison area who were aware of LED lamps to compare their perspectives on LED lamp performance with incandescent lamp and CFL performance.[56] Figure 14 shows the results, which suggest that nearly two-thirds of respondents believe that LED lamps work better than incandescent lamps and nearly half believe they work better than CFLs. The percentage of respondents who reported that LED lamps work better than incandescent lamps was

[55] The California retail store manager telephone surveys did not include questions regarding these topics.
[56]

significantly higher than the percentage who reported that they work better than CFLs. Conversely, the percentage of respondents who reported that CFLs work about the same as LED lamps was significantly higher than the percentage who reported that incandescent lamps work about the same as LED lamps. These results underscore the generally positive perspectives on LED lamp performance described above.

Figure 14
Retail Store Manager Perspectives on LED Lamp Performance Compared to CFLs and Incandescent Lamps Among Respondents Aware of LED Lamps in the Comparison Area, 2013 (Retail Store Manager Telephone Surveys)



* Difference from response provided for incandescent lamps is statistically significant at the 95% level of confidence.

2.4 Consumer Market

After providing some brief background information regarding housing stock in California and the comparison area, this section of the report reviews consumer familiarity with and use of LED lamps and fixtures.

2.4.1 Housing Stock

Table 13 provides an overview of the total number of housing units in California and the comparison area by housing type. As shown, California had roughly twice as many housing units in 2012 as in the comparison area (nearly 13.7 million compared to just over 6.9 million, respectively). In both regions, the vast majority of housing is comprised by single unit homes (approximately two-thirds in both areas), but California has a greater proportion of multi-unit homes (31% versus 21% in the comparison area) and the comparison area has a greater

proportion of mobile homes than California (10% versus 4%).

Table 13
Number of Housing Units by Housing Type in California and the Comparison Area, 2012

Housing Type	California		Comparison Area	
	n	%	n	%
Single unit*	8,909,117	65.2%	4,797,380	69.2%
Multi-unit	4,219,632	30.9%	1,422,753	20.5%
Mobile home	521,956	3.8%	694,185	10.0%
Other**	16,521	0.1%	13,345	0.2%
Total	**13,667,226**	**100.0%**	**6,927,663**	**100.0%**

Source: American Community Survey (ACS) 2008-2012 5 year estimate (http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=bkmk).
* Single unit homes include both detached and attached (i.e. townhomes).
** Other includes boats, RVs, vans, etc.

2.4.2 LED Lamps

Section 2.4.2 provides an overview of the saturation of various lamp technologies in household sockets; awareness and purchase of LED lamps and other lamp technologies in California and the comparison area, LED lamp installation and storage in both regions; and consumer satisfaction with LED lamps in both regions.

2.4.2.1 Socket Saturation

In the past five years, the CPUC Energy Division sponsored two phases of lighting data collection in California households. Most recently, in 2012, DNV GL field researchers gathered detailed socket inventory data in 1,987 households in PG&E's, SCE's, and SDG&E's electric service territories as part of the California Lighting an Appliance Saturation Study.[57] In 2009, DNV GL staff conducted similar inventories in 1,232 households in PG&E's, SCE's, and SDG&E's electric service territories as part of the residential lighting metering study conducted in support of the impact evaluation of the IOUs' 2006-2009 ULP.[58] These surveys found that the number of LED lamps installed per household was very small, but that the number increased from near

[57] DNV GL, 2014a. The 2009 results may change due to reweighting to match the newest set of weights developed for the California Lighting and Appliance Saturation Survey (CLASS). The results of this analysis will be available in July 2014.

[58] KEMA, Inc., 2010.

zero to 0.5 units out of roughly 47 to 48 light sockets per household between the 2009 and 2012 surveys.

Results from these socket inventories suggest that there were approximately 47 sockets per household in PG&E, SCE, and SDG&E's electric service territories in 2012, representing a decrease of approximately 2 percent compared to 2009, in which the average number of sockets per household in this area was approximately 48 sockets across all housing types.[59]

Table 14 provides more detail on the distribution of sockets in 2009 and 2012 by the lamp technology found in each socket (including empty sockets). As shown, the average number of sockets filled with incandescent lamps decreased by approximately 4 sockets per household (from roughly 27 to 24) between 2009 and 2012 while the average number of CFLs installed per household increased by the same margin (from roughly 10 to 14 sockets per household). In 2012, LED lamps were still installed in less than one socket per household, on average, in PG&E's, SCE's, and SDG&E's electric service territories.

Table 14
Average Number of Sockets per Household in PG&E, SCE, and SDG&E Electric Service Territories by Installed Lamp Technology, 2009 and 2012

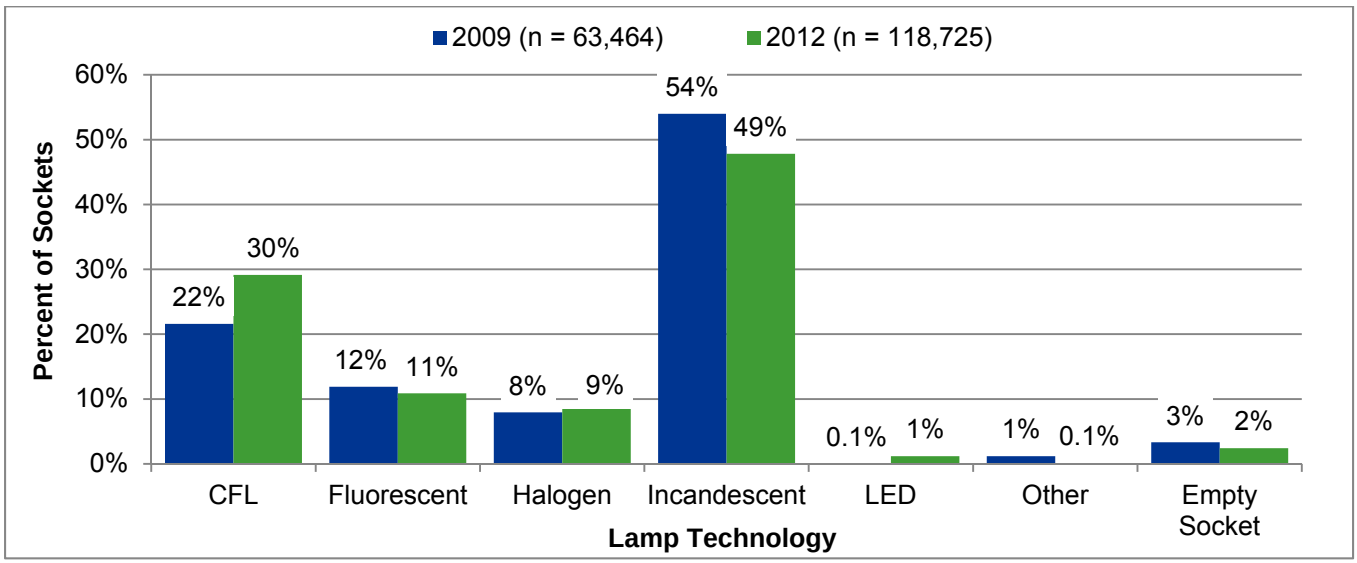
Lamp Technology	Average Number of Sockets per Household	
	2009 (n = 63,464)	2012 (n = 118,725)
Incandescent	25.8	22.3
CFL	10.3	13.6
Fluorescent	5.7	5.1
Halogen	3.8	4.0
LED	0.0	0.5
Other	0.6	0.1
Empty Socket	1.6	1.1
Total	**47.8**	**46.7**

As shown in Figure 15, the percentage of sockets in which incandescent lamps were installed in PG&E, SCE, and SDG&E territories decreased by just under 10 percent between 2009 and 2012 (from 54% to 49%, respectively), possibly as a result of AB 1109 in California. Concurrently, the

[59] KEMA, Inc., 2010.

percentage of sockets in which CFLs were installed increased by nearly 40 percent between 2009 and 2012 (from 22% to
30%, respectively). Also worthy of note is that the percentage of sockets filled with LED lamps is still very small, but increased from nearly zero percent of household sockets, on average, in 2009 (0.1%) to just over 1 percent of sockets in 2012, a ten-fold increase.

Figure 15
Percent of Household Sockets in PG&E, SCE, and SDG&E Electric Service Territories by Lamp Technology, 2009 and 2012



Annual results may not total 100% due to rounding.

Sources: DNV GL, 2014a and KEMA, Inc., 2010.

For purposes of comparison, nationally, the number of sockets per household grew from 43 in 2001 to 51 in 2010 across all housing types in the United States.[60] A 2011 assessment of housing stock in the Pacific Northwest (Idaho, Montana, Oregon and Washington) suggests that the average number of household sockets was approximately 63 in single-family homes, specifically.[61] Similar data are not available for the residential comparison area (Arizona/Georgia).

[60] Navigant Consulting, 2012.
[61] Ecotope, Inc., 2012.

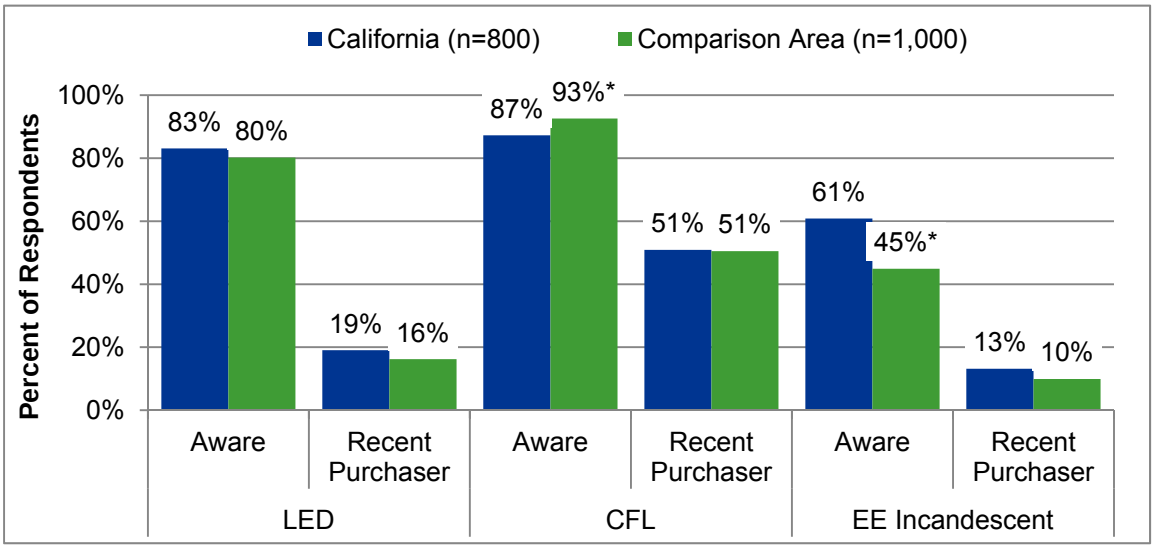
2.4.2.2 Awareness, Purchase, Installation and Storage

This subsection provides an overview of lamp awareness and recent purchases in California and the comparison area. It also provides additional detail regarding LED lamp purchase locations (retail channels) and the quantities of LED lamps purchased and installed in respondent households.

2.4.2.2.1 Awareness and Purchase (by Technology)

The consumer telephone surveys fielded in 2013 included questions regarding general awareness of various lamp technologies (LED lamps, CFLs, and energy-efficient incandescent lamps) and follow-up questions regarding whether the respondents who were aware of each lamp technology had purchased lamps since January 1, 2010. We refer to purchases since January 2010 herein as "recent purchases". Survey results suggest minimal differences in consumer awareness and recent purchases of LED lamps between California and the comparison area, but statistically significant differences in awareness of other energy-efficient incandescent lamp technologies between the regions (Figure 16). Among consumers aware of each lamp technology, there was no difference in purchase rates between the two geographic areas.

Figure 16
Lamp Awareness and Recent Purchase (since January 1, 2010) in California and Comparison Area by Lamp Technology, 2013 (Consumer Telephone Surveys)

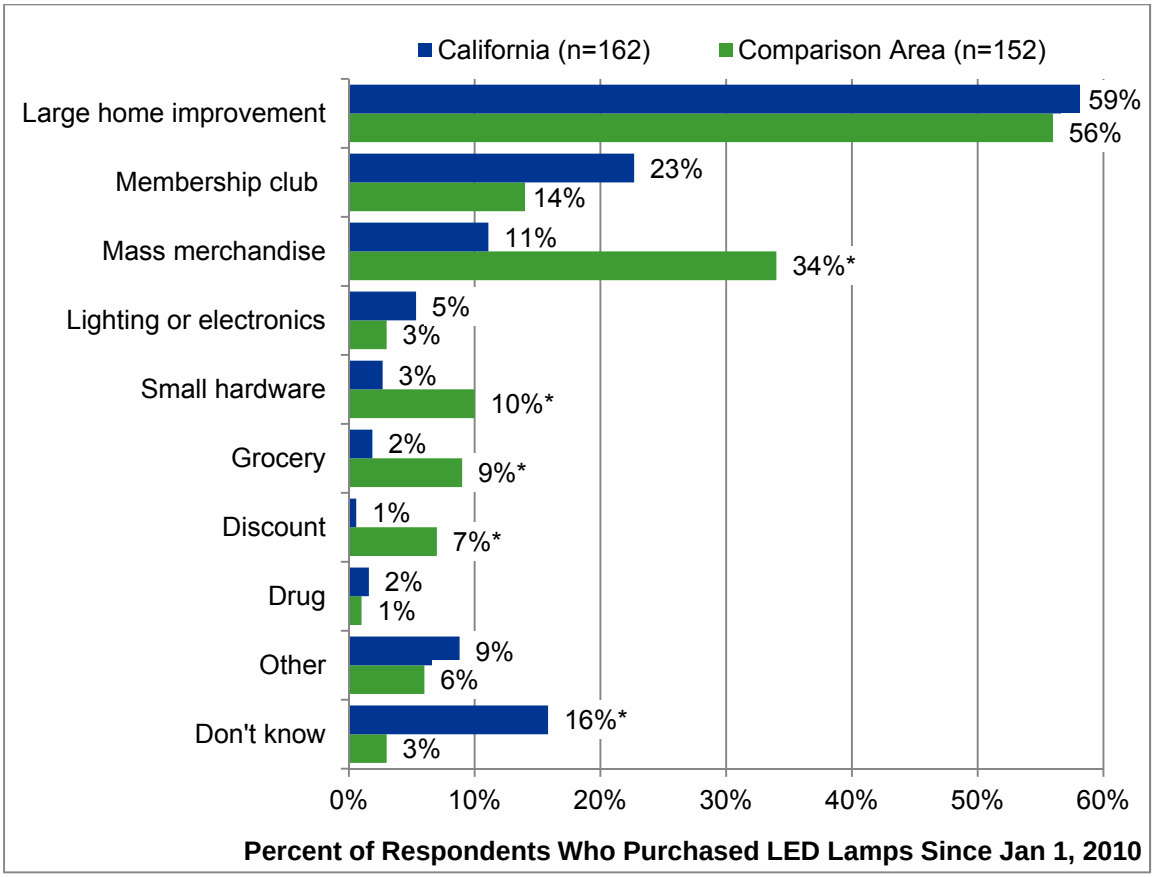


* Difference from California results is statistically significant at the 95% level of confidence.

2.4.2.2.2 LED Lamp Purchase Locations

Among consumers who reported purchasing LED lamps since January 1, 2010, the consumer surveys asked respondents to identify the types of stores in which they purchased those lamps. Respondents were allowed to provide multiple responses to the question. As shown in Figure 17, in both California and the comparison area, respondents mentioned large home improvement stores (such as Home Depot or Lowe's) more than any other retail channel (nearly 60% of respondents in both areas). A third of recent LED lamp purchasers in the comparison area purchased their lamps in mass merchandise stores (such as Wal-Mart or Target) compared to only 11 percent of respondents in California. Recent purchasers in the comparison area also mentioned small hardware stores, grocery stores, and discount stores significantly more than California shoppers. There were no other statistically significant differences between the regions in terms of the types of stores in which recent purchasers bought their LED lamps.

Figure 17
Store Types for Recent LED Lamp Purchases (since January 1, 2010) in California and Comparison Area, 2013 (Consumer Telephone Surveys)



* Difference from California results is statistically significant at the 95% level of confidence.

2.4.2.2.3 Quantity of LED Lamps Purchased and Installed

The consumer surveys asked additional questions regarding the quantity of LED lamps purchased and installed in California and the comparison area (Table 15). There were no differences in average consumer self-reported purchase and installation rates for LED lamps in California and the comparison area in 2013. In both areas, consumers reported recent purchases of roughly 1 to 1.5 LED lamps per household. Of all LED lamps ever purchased (either before or after January 2010), consumers reported that they had roughly 1.5 to 1.6 LED lamps installed per household.

These results suggest higher socket saturation (1.6 of 46.7sockets, or roughly 3% of sockets) than observed during the 2012 socket saturation study described above (0.5 of 46.7 sockets, or roughly 1%). We believe that the socket saturation data are more reliable as they are based on direct observation rather than consumer recall.

Table 15
Average Number of LED Lamps Purchased and Installed in California and Comparison Area since January 1, 2010 across All Respondents (Consumer Telephone Surveys)

Average Number of LED Lamps per Respondent	Average LEDs Purchase or Installed	
	California (n = 800)	Comparison Area (n = 1,000)
Purchased since Jan 1, 2010	1.55	1.03
Installed (of all LED lamps ever purchased)	1.62	1.49

2.4.2.2.4 LED Lamp Storage

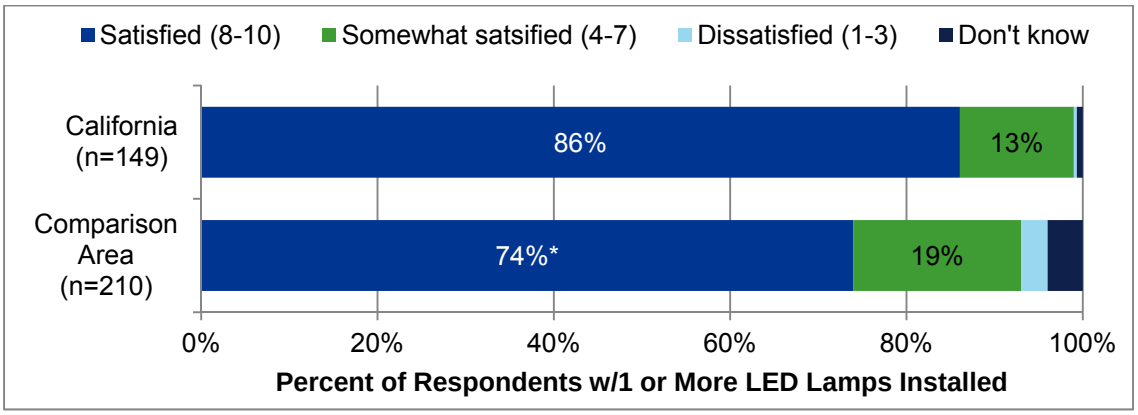
The surveys also asked respondents whether they were storing any LED lamps for future use. Roughly 80 percent of residential LED purchasers in both regions reported that they were storing one or more LED lamps in their homes. These high reported storage rates are somewhat surprising given the relatively high retail prices for LED lamps.

2.4.2.3 Satisfaction with LED Lamps

The 2013 consumer telephone surveys asked the following question of respondents who reported at least one LED lamp installed in their homes: “On a scale of 1 to 10 where 1 means ‘not at all satisfied’ and 10 means ‘very satisfied,’ how satisfied are you with the performance of the led bulbs installed in your home?” Results suggest that satisfaction with LED lamps among

LED lamp users is overwhelmingly high, with roughly three-quarters or more of respondents in each area rating their satisfaction in the top three ratings categories (8, 9 or 10). However, overall, satisfaction appears slightly higher in California than in the comparison area: 86 percent of California respondents provided top-3 ratings compared to only 74 percent of respondents in the comparison area (Figure 18).

Figure 18
Satisfaction with LED Lamps among Respondents Who Have One or More LED Lamps Installed, 2013 (Consumer Telephone Surveys)



* Difference from California results is statistically significant at the 95% level of confidence.

When asked why they purchased LED lamps, the majority of consumers who had one or more LED lamps installed reported that they purchased them because they "use less energy" or "last longer than the alternatives." There were no differences between regions in the reasons cited for purchasing LED lamps.

Of respondents who were aware of LED lamps but had not ever purchased them, the 2013 consumer telephone surveys asked why the respondents had not purchased LED lamps. Twenty-seven percent of respondents in both regions reported that they simply "do not need LED lamps." LED lamp non-purchasers cited this reason more than any other. Twelve to 14 percent reported that they have not purchased them because "LED lamps are too expensive." There were no statistically significant differences in the reasons given by consumer telephone survey respondents in either region for not having purchased LED lamps.

2.4.3 LED Fixtures

This section of the report reviews consumer purchases of LED fixtures, including fixture purchase locations. [62]

2.4.3.1 LED Fixture Purchases

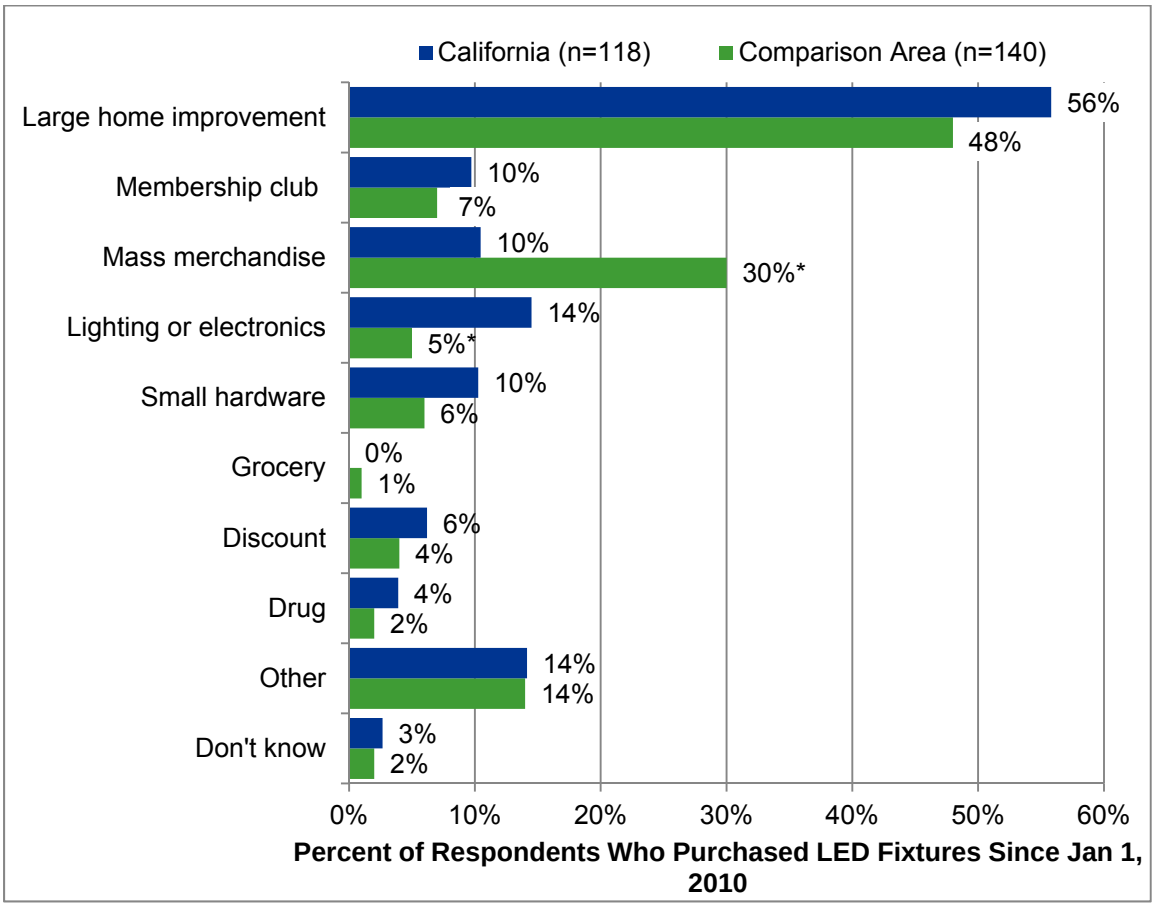
In both California and the comparison area, less than 1 in 5 consumers reported having purchased dedicated LED fixtures recently (since January 1, 2010;16-17%).In both geographic areas, LED fixture purchasers each reported having purchased an average of roughly 3.5 to 4.0 fixtures.

2.4.3.2 LED Fixture Purchase Locations

When asked where they purchased LED fixtures since January 1, 2010, respondents in both geographic areas mentioned large home improvement stores more than any other store type (56% of California respondents and 48% of respondents in the comparison area;). These results are similar to those presented above for recent LED lamp purchases (see Figure 17 above). There were few differences in where recent purchasers in California bought their fixtures versus purchasers in the comparison area, but a significantly smaller percentage of California purchasers bought their LED fixtures in mass merchandise stores compared to purchasers in the comparison area (10% versus 30%, respectively), again very similar to results for LED lamps. Approximately three times as many California purchasers of LED fixtures mentioned lighting and electronics stores as their purchase locations than purchasers in the comparison area (14% versus 5%, respectively).

[62] The surveys do not explicitly ask consumers about awareness of LED fixtures and instead assumes that consumers who are aware of LED lamp technologies are able to answer questions regarding fixture purchase and use.

Figure 19
Store Types for Recent LED Fixture Purchases (since January 1, 2010) in California and Comparison Area, 2013 (Consumer Telephone Surveys)



* Difference from California results is statistically significant at the 95% level of confidence.

2.4.4 Conclusions

The data on the residential markets for LED lamps and fixtures summarized above suggest that both the California and Comparison Areas have reached roughly the same level of development as of late 2013. Both present a portrait of a market that is in its earliest stages of development, but is progressing rapidly. Customer awareness for LED lighting products is high. Over 80 percent of customers surveyed in California and the comparison areas reported being aware of LED lamps. This is roughly the current level of recognition for CFLs, which have been in the market over 25 years. A significant share of customers in both California (20 percent) and the Comparison Area (16 percent) report that they purchased LED lamps and/or fixtures since in the three years since 2010. A 2012 saturation survey in California found slightly lower levels of LED installations – 0.5 units per household – than are consistent with that level of reported

purchases. However, we note that the prices of many kinds of LED lamps have decreased since 2012 and that retailers report increased levels of LED products since 2o12. Finally, we note that that very high portions of customers in both study areas who have tried LED lighting products are satisfied with their performance. This is in sharp contrast to initial customer comparisons to early compact fluorescent products.

3. The Commercial Market for LED Lighting

Section 3 reviews commercial LED products and applications, the commercial supply chain for LED products, and the commercial market.

3.1 Products and Applications

As of early 2014, LED products are widely available for virtually all major commercial applications. In addition to the range of replacement lamps described in Section 2.1, LED products are currently available for the following applications:

- **Outdoor signage and display lighting.** This was one of the earliest applications of LED lighting in the commercial sector.
- **Indoor and case display lighting.** Indoor case and display lighting was another early application in which the good color and heat management properties of LED lighting led to relatively high levels of adoption in an end-use that accounts for a relatively small portion of total lighting energy.
- **Outdoor pole fixtures and retrofit kits.** Over the past five years, LED technology has made rapid inroads into street and parking area lighting. Boston and Los Angeles, as well as many smaller cities and towns, have initiated replacement of their entire inventory of street lights using LED fixtures.
- **Exterior wall and architectural fixtures.** Use of LED outdoor wall and architectural fixtures has also grown rapidly over the past five years. Distributors interviewed for this project identified this as one of the early leading edge applications of LEDs.
- **High bay lighting.** As LED technology development has led to higher maximum light output, a number of manufacturers have begun producing LED-driven fixtures that can replace high intensity discharge and linear fluorescent technologies in high bay applications.
- **Linear general interior area lighting.** Around 2011, manufacturers began producing and marketing LED-driven products that could be substituted for the linear fluorescent fixtures that account for 80 percent of lighting energy in the commercial sector and 89 percent in the industrial sector. These include LED lighting panels and troffers that fit into fixture patterns typically established for linear technologies and replace or substitute for fluorescent fixtures. Manufacturers have also developed LED retrofit kits which can be inserted directly into rewired fluorescent fixtures.

3.1.1 Trends in Model Availability for Key Applications

Figure 20 displays the trend in the number of qualified commercial grade LED fixtures listed in the DesignLights Consortium® Qualified Products List. The DesignLights Consortium (DLC) is a program of the Northeast Energy Efficiency Partnerships, a regional non-profit founded in 1996 whose mission is to serve the Northeast and Mid-Atlantic to accelerate energy efficiency in the building sector through public policy, program strategies and education. The DLC promotes quality, performance and energy efficient commercial sector lighting solutions through collaboration among its federal, regional, state, utility, and energy efficiency program members; luminaire manufacturers; lighting designers and other industry stakeholders. The DLC initiated the Qualified Product List (QPL) for LEDs in 2010 to establish performance criteria and a testing regime for commercial grade LED luminaires (fixtures). Many utilities nationwide, including the California IOUs, require that fixtures receiving incentives be included in the QPL. As Figure 20 clearly shows, the total number of products listed has grown rapidly since the inception of the QPL program. As of January 2014, over 32,000 qualified products were listed, although this number declined later in the first quarter of 2014 as several thousand products for failing to meet revised performance criteria. Many of the fixtures removed were exterior pole and wall luminaires.

Figure 20
Trend in Total Products in the DLC Qualified Products List, 2010—2014

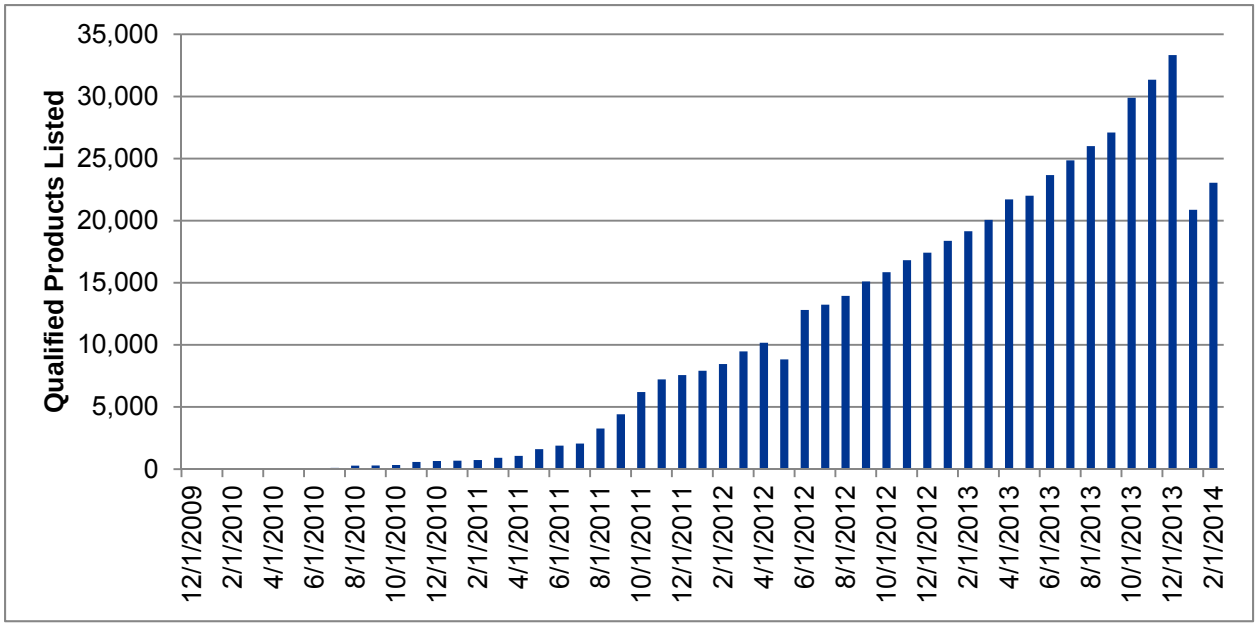
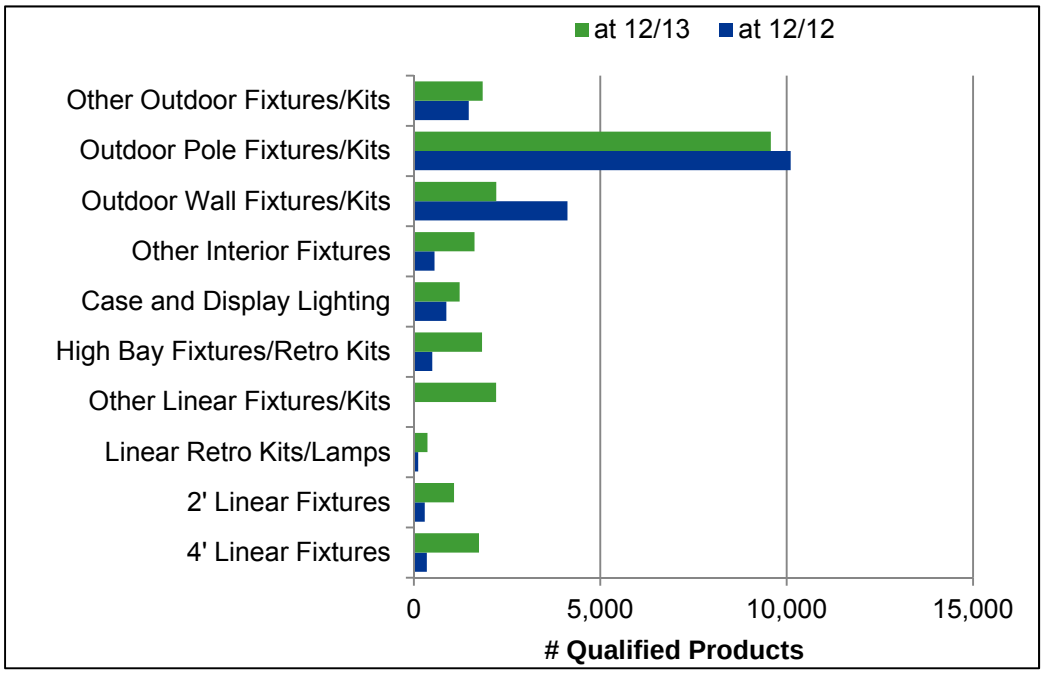


Figure 21 compares the distribution of DLC-qualified products by type at December 2013 versus December 2012. The most important trend visible in this chart is the rapid growth in the number of qualified products for interior area lighting, and for applications typically addressed by linear fixtures in particular. The 2013 QPL included 5,396 linear fixtures and retrofit kits compared to 752 in the 2012 QPL.

Figure 21
DLC Qualified Products by Type: 2013--2012



3.1.2 Trends in Pricing

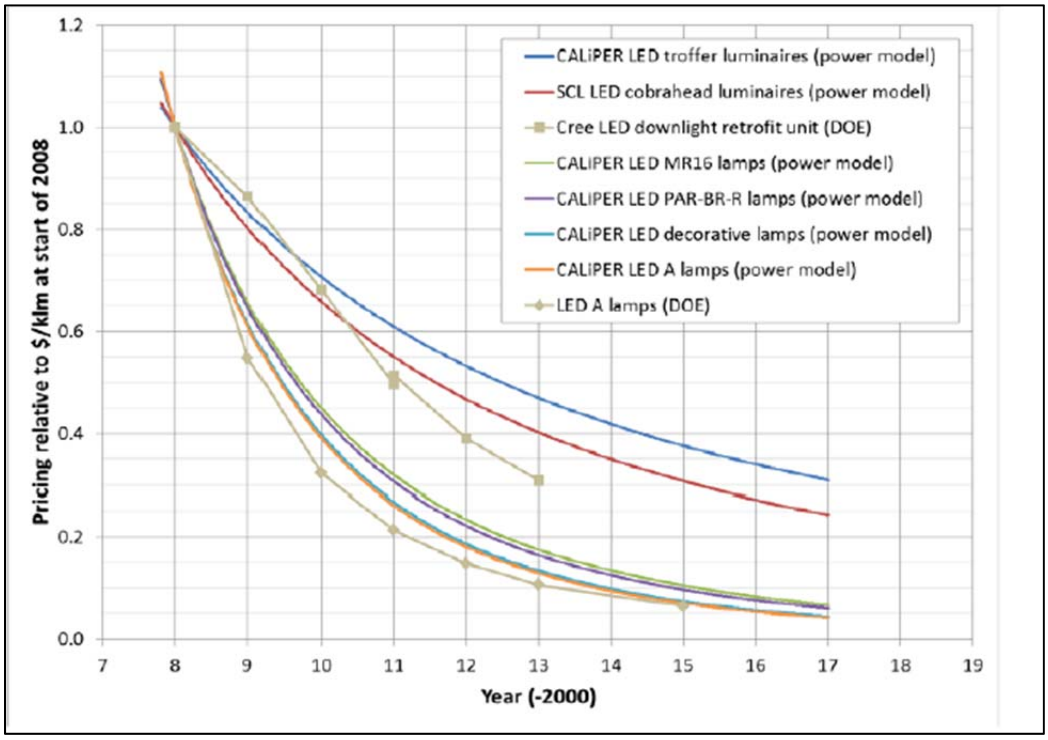
For purposes of analyzing technology and market development, pricing for lighting products is generally denominated in terms of dollar cost per kilolumen of output or $/klm. The Pacific Northwest National Laboratory has recently completed a study of trends in performance and pricing for LED lamps and fixtures.[63] This study analyzed three year trends in pricing for a range of LED products, based primarily on information from the U. S. DOE's CALiPER program.

Figure 22 shows trends and forecasts of prices in selected types of LED lamps and fixtures based on CALiPER data. Price points through 2012 are averages of actual purchase prices. The figure highlights a number of important facts in regard to LED products.

[63] Pacific Northwest National Laboratory (PNNL), 2013.

- Prices for all types of LED lighting products dropped significantly between 2008 and 2012. Prices for lamps decreased by 75 to 85 percent over the period, depending on type; fixtures by 45 to 55 percent.
- Prices are forecasted to continue falling through 2017, at which point lamp prices will be 7 to 10 percent of their 2008 level and fixtures 24 – 30 percent.
- The PNNL report identifies a number of reasons for the slower decrease in prices for fixtures versus lamps. Lamps face stiffer price competition from incumbent technologies than fixtures. Also, LEDs light sources are essentially semiconductors, and analysts anticipate that their prices will follow downward trajectories observed for similar devices. Light sources account for a greater portion of total product costs for lamps than for fixtures.

Figure 22
Trends and Forecasts of LED Product Prices Normalized to 2008 Levels

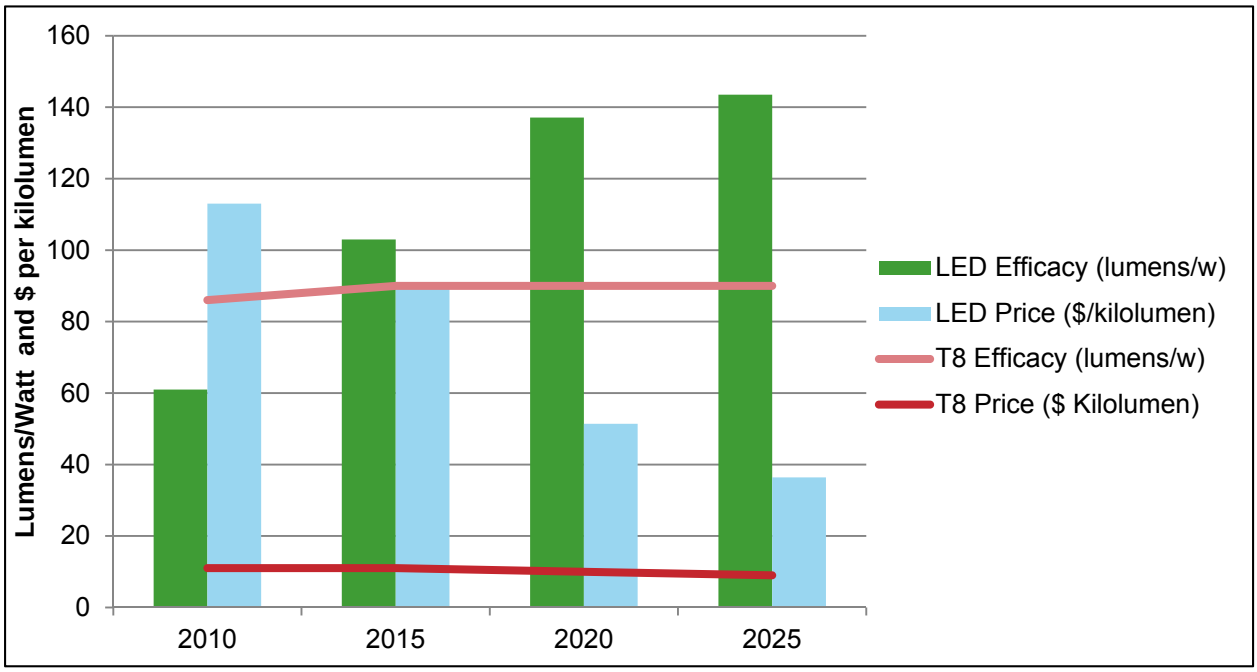


Source: PNNL, 2013.

The competitiveness of LED technologies will depend not only on trends in their absolute costs but in their relationship to the costs of competing technologies. Figure 23 summarizes the forecasts of prices and efficacy for LED troffers and their competing T8 fluorescent technology, drawing on two studies that analyze past trends and develop forecasts from industry expert

panels.[64] Efficacy is expressed as lumen output per watt, and cost is expressed as dollar price per kilolumen of output. By coincidence, those two indicators fall in roughly the same scale. The forecasts for LED technology are represented by bars; for T8 fluorescents by solid lines.

Figure 23
Forecasted Trends in Efficacy and Price: LED Troffers vs. T8 Linear Fluorescent



Sources: Navigant, 2012; PNNL, 2013.

The efficacy and price of T8 technology is forecasted to change only slightly over the period from 2010 to 2015. By contrast, experts expect that the efficacy of LED troffers will more than double from 62 lumens/w in 2010 to 143 lumens/w in 2015 and that prices will decrease from $115/klm to $37/klm over the same period. Even with these significant changes in efficacy and price, LED technology is forecasted to be nearly three times as expensive as linear fluorescents in 2025. Thus, over the next decade or so, LEDs will need to continue to compete on non-energy benefits such as longer useful life, reduced maintenance costs, improved control, fixture aesthetics, and greater control over light color.

[64] Navigant, 2012; PNNL, 2013.

3.1.3 Influence of Building Codes and Product Standards

TRC's review of the Title 24 2013 revision and comparison to ASHRAE 90.1 found that the 2013 standards will generally require lower installed wattages and require more controls. These changes present significant opportunities for the LED market. Downward pressure on wattage allowances provides an opportunity for high efficacy LED products to be specified to allow more flexibility in lighting designs. In addition, LED products, which are inherently dimmable, will become increasingly cost competitive compared to linear fluorescent products that require more expensive ballasts to accommodate the new multi-step control requirements.

In situations where an LED luminaire has higher efficacy than another light source technology, decreasing allowances make the more efficacious option more attractive. This has occurred with downlights and low wattage light sources like steplights. The requirement that light sources be controllable makes this a more cost effective proposition, and levels the cost comparison to equal capability products in most cases.

3.2 Commercial Market Supply Chain

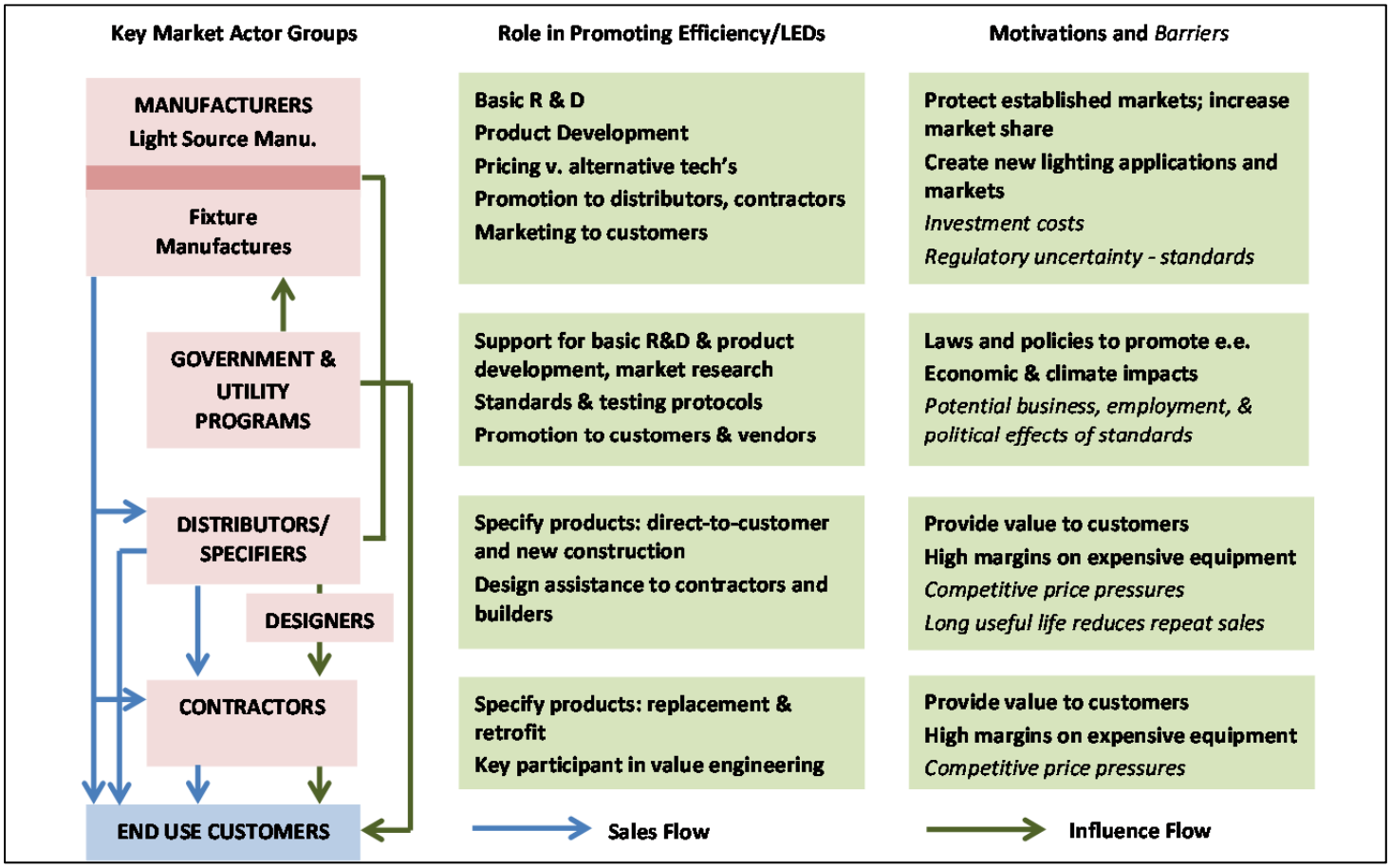
This section of the report describes the structure of the supply chain for commercial LED lighting products. For each important set of supply side market actors – manufacturers, distributors, designers, installation contractors, and national standards and research and development (R&D) programs – we describe:

- Their motivations to develop, promote, specify, and install LEDs in the course of their business activities.
- The barriers and disincentives they face for manufacturing and promoting LEDs.
- Current business strategies and practices in regard to production, promotion, and installation of LED lighting products.
- Market share of LEDs sold or specified for major applications.
- Trends observed in availability, performance, and price of LED products, as well as customer response to those products.
- Awareness and use of utility and national programs to support the sale of LEDs, and assessment of the influence of those programs on customers and supply-side market actors.
- Characterization of other influences on customer and specifier acceptance of LEDs, including building codes and product standards.

Figure 24 depicts the structure of the supply side of the LED market and summarizes the role and motivations of each major group in regard to delivering LEDs and promoting energy efficiency in general. The subsequent sections detail for each group of major supply side actors

the findings from the primary research conducted for this project on the topics and issues identified above.

Figure 24
Commercial LED Lamp Market Structure: Key Market Actor Groups



3.2.1 Manufacturers

Section 2.3.1 presents an overview of the number and concentration of LED lamp manufacturers. Most sell their products into the commercial as well as the residential markets. This is not the case for fixture manufacturers, however; most fixture manufacturers tend to focus almost exclusively on either the residential or commercial markets. In this section we thus focus on manufacturers of fixtures with primarily commercial applications.

Number of Manufacturers and Concentration by Product Offering. There are many more LED fixture manufacturers than LED lamp and light source manufacturers. Moreover, the number of fixture manufacturers with qualifying products has increased rapidly. As of December 2013, 537 fixture manufacturers had products listed in the DLC Qualified Products

List, versus 228 companies in December 2012. Also, more manufacturers have introduced significant model ranges of products in the past year. In December 2013, 210 manufacturers had 10 or more products in the Qualified Products List versus only 89 in December 2012.

The concentration of listed products among fixture manufacturers is greater than for lamps, but it is decreasing rapidly. In 2013, the top 10 manufacturers in terms of products listed accounted for 53 percent of all models in the database versus 78 percent in 2012. We also note the rapid pace of product introductions and withdrawals. For example, Cree, Inc.'s listed 2,227 DLC-qualified models in 2013 covering the full range of applications, up from 71 in 2012 concentrated primarily on interior area lighting fixtures. Clearly, the manufacturing sector is a very dynamic portion of the LED fixture supply chain.

R&D and product development strategy. Manufacturers interviewed for this study clearly identified innovation and advancement in LED technology as a major component in their competitive strategy. In particular, larger manufactures of whose lines include lamps and fixtures perceive a major potential threat from LEDs since there are many more companies who can produce LED circuits at scale than companies with the glass forming production technologies required for conventional lighting technologies.[65] The following observations from our research for this project are consistent with this strategy.

- Four of the ten manufacturers interviewed as part of this study reported spending all of their R&D funds on LED products; 3 more reported that they spend 90–95 percent of their R&D budget on LED products. None reported spending less than 50 percent on LEDs.
- At the May 2012 LightFair, the largest international lighting industry trade show, 92 percent of the 172 total products submitted for innovation awards in all categories of lighting applications used LED technologies.

Promotion and sales. All 12 manufacturers interviewed for this study reported spending at least 75 percent of their marketing budgets to support LED offerings. Four reported spending 100 percent to support LED products.

Distributor and Customer Acceptance. Eight of the twelve manufacturers interviewed for this study reported that the distributors whom they supplied were pleased with the product offerings. We followed up general questions on customer response by asking whether distributors were selling enough units to justify reorders. Of the eight interviewees who responded to that question, six reported that their customers were beginning to keep LED fixtures in stock (as opposed to sending in custom orders), but that reordering was a very recent phenomenon.

[65] McKinsey 2010.

When asked which elements of LED lighting would need to change to accelerate distributor and customer acceptance, the most frequently mentioned attribute was quality and color of light (5 mentions), followed by cost, broadening of applications, and increased reliability (all with 3 mentions).

Awareness and Assessment of National Programs. All of the manufacturers were aware of the U. S. DOE's SSL program, and all but one were aware of the ENERGY STAR program. All of the manufacturers also reported awareness of state or regional programs such as those operated by the New York State Energy Research and Development Authority (NYSERDA) and the CEC. In fact, five of the firms reported having received significant R&D funding from federal and state agencies. All but one of the manufacturers interviewed believed that the DOE SSL program, which provides support for technical and market research, has had a very positive effect on the market for LEDs. Typical comments included:

> *[The program is having] a large positive effect worldwide. Competitors from other countries are saying that they are basing their specs from the DOE lead.*
>
> *[I] strongly believe that the investment has accelerated the adoption of SSL, and helped stay focused on a complete comprehensive customer solution.*

Manufacturer response to the ENERGY STAR program was decidedly cooler, which may reflect the more testing-oriented mission in comparison to the DOE program. Most of the complaints about the program focused on the elapsed time required for testing.

Awareness and Assessment of Public Benefits Programs. Seven of the 12 interviewees reported that they were aware of programs to promote LEDs funded by public benefits charges at the state level. Of these seven, five reported that the programs had affected their product design and marketing decisions, primarily through the requirement that products needed to meet DLC performance criteria to become eligible for incentives.

At a broader level, we asked manufacturers whether they had observed differences in the pace of LED uptake between those regions that had been served by long-standing public benefits programs and those that had not. Ten of the twelve interviewees reported that they had observed these differences, some quite emphatically. In follow-up questions, most interviewees identified other factors as being key in affecting uptake in a given region, including utility rates and existing saturations of competing technologies. However, other things being equal, the interviewees attributed a decisive role to utility incentives.

Despite these views on the impact of state- or utility-level incentive programs on LED uptake, all of the manufacturers reported that they introduced new products at the same time in all regions, no matter what their program situation. Moreover, the manufacturers reported that they did not develop regional quotas for product shipments in advance of actual orders.

Summary of Manufacturer Findings. The information presented in Section 3.1 and the summary of manufacturer interviews strongly suggests that manufacturers will exercise the greatest influence – among all groups of supply side market actors – on the continued development of the LED market and level of energy savings that can be gained through that development. Manufacturers identified light quality, cost, reliability, and breadth of applications as the principal barriers to accelerated acceptance of LED lighting products. As described below, other market actors in the supply chain, as well as customers, identify those conditions as the inhibitors to growth in LED acceptance. Only manufacturers are positioned to mitigate those barriers through research, product development, and marketing activities that are under their direct control. Moreover, manufacturers have demonstrated that they are motivated to do so. The rapid entry of competitors into LED market, proliferation of products that meet national standards, and expansion of lighting applications served by LED technologies described above provides concrete evidence of the importance of LEDs in lighting manufacturers' competitive strategies. A related observation is that manufacturers have generally shown more willingness to cooperate with government agencies and utility initiatives such as the DLC in establishing and abiding by product standards and testing regimes than they did for other lighting products such as T8 fluorescents and CFLs. This difference in approach suggests that manufacturers acknowledge the value of independent standard setting and testing to promote consumer confidence in their new products.

3.2.2 Distributors

For this study we interviewed representatives of twenty California distribution firms: five warehouse distributors and fifteen manufacturer representatives. In the comparison area we interviewed representatives of eighteen firms: eight warehouse distributors and ten manufacturer representatives. TRC staff identified distributors and manufacturer representatives to be interviewed through contacts in the local markets and their own experience in the commercial lighting industry. They specifically selected firms and individuals within those who were likely to provide informed views on the progress of LED technologies in their market areas.

These firms focus on supplying new construction and large remodeling projects. Roughly sixty percent of projects completed by the interviewed firms in California were for new construction and remodeling projects. Similarly, fifty percent of projects in the comparison area were for new construction as well. Typically new construction and remodeling lighting projects constitute a small portion of the total market (less than 20 percent of total installations). Thus, market share numbers provided by these firms characterize their particular clientele, which is oriented towards new construction and larger remodeling projects to a greater extent than the market as a whole. Nonetheless, the results of these interviews are useful for characterizing developments and trends in the market, as well as differences between California and the comparison area.

Stocking of LED Products. The survey asked how many LED product models interviewees sold for a variety of different product types in 2013. Table 16 shows the average number of LED products that respondents from the two study areas sold at that time. As shown, respondents sold roughly the same number of models for the applications that represent high portions of lighting energy consumption such as downlights and general overhead lights. Overall, California interviewees reported higher numbers of available products in all but two categories: outdoor area lighting and high bay fixtures.

Table 16
Average Number of LED Product Models Carried Among LED Distributors by Fixture Type, 2013 (Lighting Distributor Telephone Interviews)

Product Type	California (n = 20)	Comparison Area (n = 18)
Downlights	23	19
General overhead lights	10	9
Functional pendant lights	20	15
Task lights	20	10
High-bay lights	8	11
Pedestrian and low-level outdoor lights	34	15
Outdoor area lights (above 14')	24	30
Landscape lights	24	19

Current Price Premium. Interviewers asked respondents to discuss their views on LED costs compared to other currently-available lighting technologies. Knowledgeable distributors reported a wide range of price premiums for LED linear fixtures versus comparable T8s. As shown in Table 17, on average, respondents in the comparison area felt there was a lower price premium than distributors in California. The responses from California distributors clustered much more tightly around the median than did those from the comparison area, where a quarter of the respondents reported price premiums for LED linear fixtures of 24 percent or less, which is very much at odds with prices available on line and from studies cited earlier in this report. This difference in the distribution of price comparisons suggests that a higher portion of California distributors were sufficiently familiar with LED linear fixtures to provide informed responses to this question. The somewhat higher median price in California may also provide evidence of stronger consumer demand for LED linear fixtures. However, we note that the samples for these interviews were not drawn at random and that the sample sizes are small. We can more confidently conclude from these results that customers who purchase LED linear fixtures are willing to pay a substantial price premium in comparison to linear fluorescent technology, which currently offers roughly equivalent levels of efficacy.

Table 17
Price Comparison between an LED Troffer and T8 Fixture with Similar Light Output among LED Distributors, 2013
(Lighting Distributor Telephone Interviews)

LED Price Premium	CA (n = 17)	Comparison Area(n = 15)
First Quartile	114%	24%
Median Price Premium	**140%**	**100%**
Third Quartile	150%	125%

Market Share of LED Products for Key Applications. The survey asked the interviewees to indicate the share of LED products sold for various types of applications in the past year. Table 18 summarizes the results for the two study areas. The reported market shares for LED downlights and outdoor area were similar in the two study areas, ranging between 31 and 39 for both types of equipment. The study areas differed more substantially in regard to LED shares for linear fixtures and high bay lighting. Distributors in California reported an 18 percent LED share for linear interior fixtures and 21 percent for high bay fixtures versus 7 percent and 3 percent respectively for distributors in the comparison areas. We note that of LED downlights and outdoor fixtures have been available in large numbers in the market somewhat longer than linear and high bay fixtures. The interview results summarized in Table 18 may reflect greater willingness on the part of California distributors to promote "leading edge" products. They may also indicate greater customer interest in those products, at least among the generally "higher end" projects served by distributors and manufacturer representatives in the sample.[66]

[66] Reported LED shares for distributors are much higher than those reported by contractors in Section 3.2.4. These differences are due primarily to the wider range of projects served by contractors. We also note that the questions on LED shares in the distributor interview guide focused on the year prior to the interview, which was conducted during the summer of 2013. We then used questions about changes in market share to relate findings from those questions to the program period. The corresponding questions in the contractor questionnaire referred to the years 2011-2012.

Table 18
Self-Reported Share of Distributor Fixture Sales Accounted for by LED Equipment, 2013
(Lighting Distributor Telephone Interviews)

Fixture Type	LED Share of Fixtures Sold	
	California (n = 20)	Comparison Area (n = 18)
Linear General Interior Application	18%	7%
Downlights	39%	31%
High Bay	21%	3%
Outdoor Area Lighting	36%	39%

Interviewers also asked distributor representatives how their sales of LED products changed between 2011 and 2012 and what percent of sales were from various LED products. The majority of respondents reported that their LED sales in 2012 increased compared to 2011 (19 of 20 in California, and 16 of 18 in the comparison area). Distributors in California reported particularly rapid growth in lamp sales: 45 percent from 2011 to 2012 versus 20 percent in the comparison area. Decreasing costs of LEDs, increased customer awareness, and increased manufacturer interest in LEDs were some of the more common reasons respondents gave for why they believe their sales increased. Almost all respondents expected this trend to continue, though some felt the market would eventually plateau.

Customer Awareness of and Interest in LED Products. In each area, fifteen distributors reported that the facility managers with whom they work have requested LED products before the distributors recommended them. Table 19 describes the frequency of facility owner requests for LED products for use in general overhead lighting applications. As the table shows, the frequency of requests from facility owners was similar in both interview areas.

Table 19
Frequency of Facility Owner Requests for LED Products from LED Distributors, 2013 (Lighting Distributor Telephone Interviews)

Frequency with which Facility Owners Request LED Lighting (without distributor recommendation)	Number of Mentions Among Interview Participants	
	California (n = 15)	Comparison Area (n = 15)
All cases [where LED application is appropriate]	1	0
Most cases	4	5
Some cases	3	3
Few cases	4	4
Very few cases	3	3

Customer Motivations and Barriers to LED Adoption. When interviewers asked LED distributors what they thought were their customers' primary motivations for specifying LED products, responses were similar between the two study areas. Energy and maintenance benefits were most commonly cited by both the California and comparison area interviewees. Code limits, particularly the upcoming impact of California's Title 24 in 2014, was the third most commonly cited motivation in the California interview group, but was only cited by a few of the comparison area interviewees.

When asked about their customers' hesitations towards LEDs, respondents cited cost as the most common concern in both California and the comparison area, though many did note that concerns are dissipating as costs decline. Several respondents in both groups also mentioned that a general lack of familiarity with LED products was a cause of some customer hesitation.

Program Awareness and Assessment of Influence. The survey also asked respondents about their awareness of utility and national-level programs that encourage the use of LED products and energy efficient lighting in general. The survey first asked respondents about awareness of programs that promote energy efficient lighting in general. Those who reported being aware were then asked about awareness and participation in a number of national and state-level programs. Table 20 summarizes the responses to these questions. More comparison area respondents were aware of the U.S. DOE's SSL program, and more California respondents were aware of the DLC's Qualified Product List. The majority of respondents in both groups were aware of ENERGY STAR for LED products.

Table 20
Program Awareness and Participation of LED Distributors, 2013 (Lighting Distributor Telephone Interviews)

Program Name or Type	Number of Aware Respondents	
	California (n = 20)	Comparison Area (n = 18)
Aware of programs offered over the past ten years by utilities and other local or regional organizations to promote the adoption of energy efficient commercial lighting products in general, not specifically LED products?	19	16
Supplied lighting products to projects supported by incentive programs	9	9
Solid State Lighting program operated by the U.S. DOE	9	15
DesignLights Consortium Qualified Products List	19	14
ENERGY STAR standards for LED lighting	18	17

Respondents who were aware of the national programs were asked what effect they thought these programs had on the development of LED technologies and markets in their areas. Distributors in California generally had more positive views of the influence of the SSL program than respondents in the comparison area, who reported the market in their area was still undergoing education and this program was more geared towards manufacturers. Respondents in both areas suggested the DesignLights Consortium list is a useful resource as it provides a credible list of qualified products to make consumers comfortable with their purchases. Similarly, respondents in both areas opined that the ENERGY STAR specification for LED products also provided some quality assurance to customers, but many felt the specifications lagged the current state of technology development and were less useful for non-residential customers than residential customers.

Summary of findings from distributors. The interview results summarized above demonstrate that distributors in both California and the comparison area are very much aware and highly knowledgeable about developments in the LED lighting market, including the workings of programs to support that development at the national and state levels. Even though local program activity to support energy efficient lighting started later in the comparison area than in California, equal portions of distributors in both areas report being aware of and participating in those programs. While California distributors report somewhat higher levels of LED product stocking and customer interest in LEDs, the difference between California and the comparison area on these indicators is small. There was little difference between the study areas in the LED share of downlights and outdoor fixtures. However, the reported LED share of linear overhead and high bay lighting was much higher among California distributors than among those in the comparison area. These findings may indicate greater willingness among CA

distributors to promote products that have only recently been introduced to the market, as well as greater interest among the distributors' direct customers.

3.2.3 Designers

For this study TRC Energy Services staff interviewed representatives of nineteen California firms: three identified as lighting design firms, five as architecture firms, eighteen as engineering firms. One respondent also indicated that his firm consulted as well. In the comparison area we interviewed representatives of twenty firms: eleven identified themselves as lighting design firms, one as an architecture firm, and twelve as engineering firms.

The majority of commercial projects these firms provided lighting designs and specifications for new construction projects or additions. (roughly 60% in both areas). Nearly all of their remaining projects consisted of major remodeling efforts.

Experience Working with LEDs. The survey asked interviewees when they first started specifying LED products. Among the California designers, responses ranged from 2001 to 2012, and averaged around 2007. Responses among the comparison area designers were somewhat later, ranging from 2007 to 2012 and averaged around 2009 (slightly later than among California respondents).

The survey asked the interviewees to identify the barriers they faced with their early LED specifications. The most commonly cited barrier in both groups was cost. Only a few respondents cited any of the other barriers in the comparison area interview group, while the California interviewees also frequently cited issues like color quality or reliability. These responses may reflect the fact that California respondents adopted LED technology earlier than their comparison area counterparts on average. As a result, California interviewees may have experienced more of the growing pains of LED technology, whereas the comparison area interviewees started adopting LED technology after product quality had stabilized.

Availability of LED Products. The survey asked respondents to indicate how many different LED product models they could successfully specify for a variety of different fixture types. Table 21 shows the average number of LED product models reported by respondents in the two study areas. As the table shows, the number of viable products in each category is similar for most fixture types, but California respondents reported higher numbers of viable products in all but one category (outdoor area lighting).

Improved technology and product availability and increased manufacturer interest and R&D funding for LEDs were some of the more common reasons respondents gave for why the number of viable models has increased over time. All respondents in California reported that they expect that the number of LED fixture models available will continue to increase. Most respondents in the comparison area expressed similar opinions, although some suggested the

market was already oversaturated with too many products and manufacturers, making it difficult to have confidence in all of the available products.

Table 21:
Average Number of LED Product Models Available for Specification per Design Firm by Product Type, 2013 (Lighting Designer Telephone Interviews)

Product Type	Average Number of Models per Firm	
	California (n = 19)	Comparison Area (n = 20)
Downlights	11	8
General Overhead Lighting (2x4s, etc.)	7	6
Functional Pendants (i.e., direct-indirect)	8	4
Decorative, Accent or Feature	17	13
Task Lighting	7	4
High Bay Fixtures	3	3
Pedestrian and low-level outdoor lighting	12	10
Outdoor Area Lighting (greater than 14' height)	8	10
Landscape Lighting	12	8

Market Share of LED Products Specified for Common Applications. Interviewers asked lighting designers how their sales of LED products changed between 2011 and 2012 and what percent of specifications were comprised by various LED products. Although responses regarding market share from these firms do not reflect the whole market (due to their disproportionate number of projects in new construction and remodeling), we can draw comparisons between the two areas to assess whether locational trends exist.

The majority of respondents reported that their LED sales in 2012 were higher than in 2011 (18 of 19 in California and 16 of 20 in the comparison area). A few others reported that the share of projects in which LED products were specified had stayed the same over the past two year. None of the respondents reported a decrease.

The survey also asked the interviewees to indicate how often they specified LED products for various applications in the past year.

Table 22 summarizes the results for the two study areas. California respondents use LED fixtures for downlights and task lighting more often than those in the comparison area. By contrast, respondents in the comparison area use LEDs in decorative and accent lighting more often than those in California. Specifications for outdoor LED use are relatively similar for both

groups. Interviewees also indicated a variety of other fixture types where they use LEDs at some of the time, including theatrical and underwater or hazardous location applications. Six interviewees in the comparison area also noted using LEDs in parking garage applications.

Table 22
Percent of Total Projects with LED Specifications Among Lighting Designers by Application, 2013 (Lighting Designer Telephone Interviews)

Application or Product Type	Percent of Projects	
	California (n = 19)	Comparison Area (n = 20)
Downlights	44%	35%
General Overhead Lighting (2x4s, etc.)	14%	11%
Functional Pendants (i.e., direct-indirect)	10%	10%
Decorative, Accent or Feature	23%	35%
Task Lighting	56%	27%
High Bay Fixtures	5%	14%
Pedestrian and low-level outdoor lighting	39%	43%
Outdoor Area Lighting (greater than 14' height)	44%	43%
Landscape Lighting	47%	49%

Motivations for specifying LEDs. The designers interviewed for this study reported that customer interest in LED technology was a major motivation for specification. Fourteen designers in California and 16 in the comparison area reported working directly with customers. Of those, eleven in California and twelve in the comparison area reported that facility owners had requested LED products before the interviewees had made their own recommendations.

Responses from designers regarding additional motivations for specifying LEDs were similar in both areas. Energy and maintenance benefits were most commonly cited by both the California and comparison area interviewees. Code limits was the third most common response for California interviewees, but was cited only slightly more often than in the comparison area. Respondents in California cited LEDs ability to dim as a benefit to addressing current codes. In the comparison area, many respondents who mentioned codes did so with regards to specific lighting applications like high bay or task lighting. They also mentioned that requirements in the International Energy Conservation Code (IECC) 2012 could be addressed with good T8 design as well. By contrast, superior controllability was the third most common advantage cited by the comparison area interviewees, at more than twice the number of California interviewees.

When asked to identify factors inhibiting the specification of LEDs, designers in both areas mentioned cost most. However, 17 of the 20 designers in the comparison area identified cost as

a barrier versus only 8 of 19 in California. In interpreting these results, it should be noted that lighting designers are generally engaged only for relatively "high end" new construction and renovation projects, which constitute a relatively small portion of total lighting sales and installation.

Influence of Code on LED Specification. The survey also specifically asked interviewees about the use of LED technology to meet energy codes. As Table 23 shows, the vast majority of respondents in both interview groups have used LEDs to meet energy code requirements.[67] By contrast, when asked if the use of LED fixtures is important to meeting energy codes, 16 of 17 California interviewees said yes compared to only 10 of 15 comparison area respondents. Similar to what distributors in California indicated about code impacts on LED specification, designers in California indicated that because lighting requirements under Title 24 have become stricter, LEDs are playing an important part of the strategy they use to meet the energy code. In the comparison area, some respondents indicated that they are using LEDs to address IECC 2012, but others noted that there is little code enforcement in their areas, so they only use LEDs when necessary. Distributors in California also highlighted the importance of building codes in LED equipment selection. Fifteen of 20 interviewed identified code compliance as an important motivation for specifying LEDs, versus only 6 of 18 distributors in the comparison area.

Table 23
Using LEDs to Meet Energy Code, 2013 (Lighting Designer Telephone Interviews)

Use/Beliefs	California (n = 19)	Comparison Area (n = 19)
Use LEDs to meet energy codes	17	15
Believe use of LEDs is an important strategy for meeting code requirements	16	10

Program Awareness and Assessment of Program Influence. As Table 24 shows, most lighting designers who participated in the 2013 interviews were aware of lighting efficiency programs in some form. Next, the survey asked if their clients or customers had participated in programs that specifically promote LED products; about half of the respondents in California reported that they had clients who had participated in LED-specific programs, while only two of the Comparison Area respondents did. California respondents were more aware of the national program efforts than their comparison area counterparts. ENERGY STAR was the most well-known program for both groups.

[67] Note that only 19 interviews in the comparison area provided an answer because one of the interviews does not actively specify lighting products.

Designers in both areas had varying responses regarding the influence of the Solid State Lighting Program, but overall many reported that it has had some effect. Respondents in both areas indicated the Design Lights Consortium list is a useful resource if they need a list of qualified products, but is generally unknown to many customers. Conversely, respondents in both areas expressed the ENERGY STAR specification for LED products was well known within the industry, but is not providing a large impact to the market and is not properly addressing color rendering standards. Although nearly all of the sample designers in both study areas were aware of utility programs that supported efficient commercial lighting, half of the California designers reported participating in programs that support the use of LED lighting versus only 2 out of 20 interviewees in the comparison area.

Table 24
Program Awareness and Participation among Lighting Designers, 2013
(Lighting Designer Telephone Interviews)

Awareness/Participation	California n = 19	Comparison Area n = 20
Aware of utility programs that promote energy-efficient commercial lighting	19	18
Have participated in programs that support use of LED lighting	10	2
Aware of the US DOE Solid State Lighting program	14	6
Aware of the DesignLights Consortium Qualified Products List	14	8
Aware of ENERGY STAR standards for LED lighting	16	13

3.2.4 Contractors

Analysis Approach. Building and safety codes in most jurisdictions require that licensed electrical contractors be engaged for replacement and installation of all new commercial-grade lighting fixtures. Thus, as a group, contractors are in the best position among all market actors to provide data on technology shares for the full range of lighting installation projects: replacement on burn-out, retrofit, and new construction/remodeling. Moreover, contractors generally have sufficient knowledge of currently available equipment to be able to report accurately on the share of different technologies they install, as well as their adoption of design and installation practices. Finally, they have direct contact with customers and can provide first-hand information on customer response to products and installations.

Generally, when analyzing data from contractors on technology shares of installed equipment and prevalence of installation practices, it is useful to express the results in terms that are directly comparable to other kinds of market share data, such as sales data from manufacturers and distributors, or reported purchases from customers. The challenge in doing so lies in the

enormous range in the scale of contracting businesses. Table 25 shows the distribution of total electrical contracting establishments and their employees by size of firm. The sample did not include firms of 1 or 2 employees. As the table shows, the size of firms in the industry ranges from 3 to well over 1,000. Clearly the size of the firm must be taken into account in estimating market shares from observations of individual contractors. Moreover, there is a great deal of variation in the fraction of a contractor's activities accounted for by lighting installation. For some it is a main line of work. For others engaged primarily in heavy electrical construction or wiring of new construction that is leased unfinished, it is a sideline.

Table 25
Distribution of Electrical Contracting Establishments and their Employees by Employment Size Category: California, 2013

Employment Size Category	Percent of Total Electrical Contracting Establishments	Percent of Total Employees in Electrical Contracting Establishments
3 to 4	44.3%	18.8%
5 to 9	17.1%	13.2%
10 to 19	8.2%	12.2%
20 to 49	4.6%	16.1%
50 to 99	1.7%	12.4%
100 to 249	0.6%	9.4%
250 to 499	0.1%	5.3%
500 to 999	0.0%	0.5%
1,000 to 4,999	0.1%	8.2%
Total	11,431	92,115

To capture these differences among contractors, DNV GL has developed and deployed a ratio estimation method in which each sample contractor's survey responses are weighted to reflect the number of commercial lighting projects that they report having completed in the period prior to the survey as well as by the population weight of the size stratum from which the firm was drawn. Where the questionnaire seeks responses in the form of a number or percentage—say, the percent of linear fixtures installed with LED technologies—survey responses are summarized using the combined ratio estimator:

$$\hat{R}_c = \frac{\sum_h \frac{N_h}{n_h} \sum_i B_{h_i} x_i}{\sum_h \frac{N_h}{n_h} \sum_i x_i},$$

where

i = sample contractor,

N_h = number of contractors in the *population* in sample stratum h,

n_h = number of contractors in the *sample* in stratum h,

B_{h_i} = contractor i's response (expressed as a number or percentage), and

x_i = number of projects that contractor i reported installed in the study period.

If the question elicits a categorical response (e.g., yes/no), a B_{h_i} will be created for each possible response. For the selected response, $B_{h_i} = 1$. For the response/s not selected, $B_{h_i} = 0$.

This procedure essentially weights responses by the reported number of projects completed by each sample firm, thus providing an explicit representation of market share. The use of the combined ratio estimator supports the estimate of a standard deviation and standard error for each variable. "Project-weighted" averages or proportions are specifically designed to describe the average share of a technology installed or the prevalence of certain installation or design practices. For summarizing the distribution of characteristics of firms in the sample, for example, their average number of employees or projects completed, it is more appropriate to use simple population-weighted means and proportions. In our discussion of the results of the contractor survey, we will call out which types of summary statistics we use for each topic.

Characteristics of Sample Contractors. Table 26 displays selected characteristics of the contractors that responded to the survey. In developing the sample design, we were concerned primarily with allocating quotas to most efficiently capture the range of the population of electric and lighting installation contractors active in the respective study areas. As Table 26 shows, the characteristics of the sample firms in both areas are similar with regard to number of employees, geographic scope of operation, and percent of revenues from large and small commercial and industrial projects. The difference in average number of jobs completed is due to the inclusion in the sample of one California firm that claimed a very large number of completed projects – over 7,500 in two years. The next largest number was 1,500. This firm was large in terms of number of employees, and it is plausible that it could have completed that number of projects over two years. If this firm were eliminated from the sample, the average number of jobs completed by the sample contractors in California and the comparison area would have been equal.

The other apparent difference between the two groups lies in the percent of total commercial projects in new construction. The average percent of revenue from new construction projects and additions was 27 percent for contractors in California, versus 54 percent in the comparison area. This difference may reflect the some self-selection of firms in the comparison area sample.

Generally, electrical work in new construction is fairly concentrated among a region's larger firms. There are many large firms in California and, consequently, each of those larger firms captures a relatively small part of the new construction market. With a smaller number of firms in the comparison area population, the sample may have captured a larger share of firms with significant business in new construction.

Table 26
Summary of Sample Contractor Characteristics, 2013
(Commercial Lighting Contractor Telephone Survey)

Establishment Characteristic	Percentage of Completed Surveys	
	California (n = 94)	Comparison Area (n = 64)
Average Number of Employees[1]	35	32
Percent with Multiple Locations[1]	18%	17%
Average Number of Employees in State[1]	57	44
Average Number of Projects Completed per year in Commercial Facilities from Sampled Location[1]	116	73
Average Percent of Revenue from Projects in Large Commercial Facilities	47%	50%
Average Percent of Revenue from Projects in Small Commercial Facilities	35%	33%
Average Percent of Commercial Project Revenue from New Construction and Additions	27%	54%

[1] Calculated using population weights only. Not weighted for reported number of commercial lighting projects completed.

Installation of Selected Types of LEDs. Table 27 displays the project-weighted percentage of contractors who installed LED lamps and fixtures of various types in at least one commercial project during the period 2011 - 2012. The project-weighted share of contractors who reported installing LED overhead panels, medium screw-base lamps, and high bay lighting fixtures was nearly identical in both study areas. A larger share of California contractors reported installing linear retrofit kits and exterior lighting, but a larger share in the Comparison Area reported installing "other" types of LED lighting products. Due primarily to the relatively small size of the contractor samples, the apparent differences in Table 27 are not statistically significant.

Table 27
Project-Weighted Percent of Contractors
that Installed Selected Types of LED Technology, 2011 - 2012

LED Product Type	Project-Weighted Percent of Total Installations Represented by Firms that Installed Product in 2011 – 2012	
	CA (n = 94)	Comparison Area (n = 64)
LED Overhead Panels	72%	79%
LED Linear Retrofit Kits	47%	25%
Medium Screw-Base Lamps	45%	43%
Exterior	86%	59%
High Bay Lighting	39%	42%
Other	9%	30%
None	5%	9%

Share of LED Products in Linear Applications.

Table 28 displays the project-weighted average share of total linear general interior lighting installations accounted for by different technologies for the sample contractors during the period 2011 - 2012. We observe that contractors in California reported noticeably higher shares for T5 fixtures and lower shares for reduced wattage T8s than their counterparts in the comparison area. These observed differences are statistically significant. The share of LED equipment in linear installations was 11 percent in California versus 6 percent in the comparison area, with the share of LED retrofit kits accounting for most of the difference. The observed differences are not statistically significant, due primarily to the relatively small size of the samples and the high degree of variability in reported installation practices among the firms in both study areas.

Table 28
Share of LED Fixtures Installed in Linear Applications in Year Prior to Survey

	California		Comparison Area	
Linear Technology	n=		n=	
T5	94	26%	63	10%
High Performance T8	90	18%	57	17%
Reduced-Watt T8	91	14%	57	25%
800 Series T8	92	19%	54	26%
700 Series T8	74	9%	54	9%
T12	91	2%	60	3%
LED Panel	94	5%	60	4%
LED Retrofit Kits	94	6%	60	2%
Unknown	94	2%	64	3%

Share of LED Products in Other Applications. Table 29 displays the project-weighted average share of LED products installed in various non-linear applications by sample contractors in 2012. These findings suggest that LED technologies had already begun to make significant inroads into sales of medium screw base lamps, outdoor fixtures, and interior high bay fixtures when we fielded the surveys in 2013. Moreover, the LED share for contractor installations of these kinds of equipment was higher in California than in the comparison area. These findings are consistent in the general direction and relative size of the differences between California and the comparison area that we find in the distributor interviews and in the customer survey reported on below.

Table 29
Share of LED Fixtures Installed in Non-Linear Applications
2012 (Commercial Lighting Contractor Telephone Survey)

Fixture Type	% of Projects with LED Technologies Installed	
	CA (n = 90)	Comparison Area (n = 64)
Medium Screw Base Lamps	15%	7%
Outdoor Fixtures	17%	12%
High Bay Fixtures	10%	4%
Other LED Technologies	3%	8%

Trends in LED Market Shares. Table 30 summarizes the project-weighted share of contractors in California and the comparison area who reported that the share of LED panels and retrofit kits as a percent of total linear fixture installations increased, decreased, or stayed about the same between 2011 and 2012. Generally, the pattern of response is consistent with increasing market shares for both product types in both study areas. Contractors representing 74 percent of installations in the California market reported that the market share for LED overhead panels had increased, versus 47 percent in the comparison area. For LED retrofit kits, the project-weighted portion of contractors who reported increased share was higher in the comparison area than in California, even though the current share of sales was higher in California. The results of the contractor surveys in regard to trends in LED fixture sales mirror those reported by distributors and manufacturers.

Table 30
Trends in LED Market Share for Linear Applications, 2013
(Commercial Lighting Contractor Telephone Survey)

Trend 2011 - 2012	Project-Weighted Percent of Contractors			
	Overhead LED Panels		LED Linear Retrofit Kits	
	CA (n = 90)	Comparison Area (n = 64)	CA (n = 90)	Comparison Area (n = 64)
Increased	74%	47%	66%	90%
Decreased	8%	1%	3%	3%
No Change	18%	49%	31%	7%
Don't Know	0%	3%	0%	0%

Contractor view of customer response to LED products. The contractor questionnaire contained a number of questions that probed respondents' perceptions of customer response to LED lighting products. First, we posed the same question regarding the frequency of customer-initiated requests for LED lighting that we used in the distributor and designer interviews. The responses summarized in Table 31 suggest that customer awareness and interest in LED lighting is particularly high in California. Contractors representing 17 percent of installations reported that their customers request information and proposals about LED lighting on *all* of their projects. Contractors representing 11 percent of installations reported their customers express interest in LEDs on most of their projects. In the comparison area, none of the contractors reported that customers expressed interest in LEDs on all projects and only 7 percent (project-weighted) reported receiving requests for LEDs in most cases. Contractors representing 44 percent of total projects in the comparison area reported that they never received customer-initiated requests for LEDs, versus 25 percent in California.

Table 31
Frequency of Customer-Initiated Requests for LED Lighting, 2013

How often do customers request LED lighting on their own, without your recommendation?	Project-Weighted Percent of Installations	
	California (n=85)	Comparison Area (n=64)
All cases [where LED application is appropriate]	17%	0%
Most cases	11%	7%
Some cases	34%	11%
Few cases	8%	36%
Very few cases	5%	2%
No cases	25%	44%

Sample contractors in both study areas reported that their customers who had installed LED lighting were generally very satisfied with the equipment. Contractors representing 57 percent of installations in California reported that their customers were very satisfied with their LED lighting installations; 41 percent in the comparison area (Table 32). Hardly any of the contractors in either area were aware of customers being dissatisfied with LED equipment. We note that contractors' perception of customer satisfaction with LED lighting products mirrors almost exactly the levels of satisfaction reported by respondents to the commercial customer surveys. This finding contrasts strongly with consumer reception of early versions of other lighting technologies, such as compact fluorescent lamps, which customers found unsatisfactory on the grounds of performance and aesthetic deficiencies versus competing technologies.

Table 32
Contractor Perception of Customer Satisfaction with LED Lighting Equipment Installed, 2013

Generally, how satisfied have your customers been with the LED technologies they have installed?	Project-Weighted Percent of Installations	
	California (n=80)	Comparison Area (n=54)
Very Satisfied	57%	41%
Somewhat Satisfied	28%	22%
Somewhat Dissatisfied	1%	0%
Very Dissatisfied	0%	1%
Don't Know	14%	36%

When queried about barriers to customer acceptance of LED technologies, contractors identified high first cost as the primary barrier in nearly all cases in both areas. By contrast, manufacturers and distributors mentioned cost among another of other issues, such as range of applications served, light color and quality, light output, and reliability.

Competitive importance of promoting LED lighting equipment. The contractor survey asked respondents how important they believed promotion of LED products will be to the competitive position of their firm over the next three years. High percentages of contractors believe that promotion of LEDs will be important (Table 33). The distribution of responses is roughly equal for the two study areas. This finding is particularly striking considering that competition in the electrical contracting industry is stiff and often driven by price, including many projects in which engineers tightly specify the equipment to be installed.[68]

Table 33
Importance of Promoting LEDs for Contractor Competitiveness, 2013

Importance of promoting LED to firm's competitive position over the next three years	Project-Weighted Percent of Installations	
	California (n=85)	Comparison Area (n=64)
Very Important	40%	52%
Somewhat Important	35%	30%
Not Very Important	14%	16%
Not at all Important	10%	3%
Don't Know	1%	0%

Program Awareness and Participation. Table 34 summarizes the results of items that queried contractor awareness of and participation in national and local programs that support LED lighting. A substantially higher percentage of contractors (project-weighted) in California were aware of the principal product testing programs compared to contractors in the comparison area. However, a much higher portion of contractors in the comparison area claimed to be aware of local utility programs that promote LED lighting. Moreover, three times as many contractors (project-weighted) in the comparison area claimed to have participated in versus those in California. Nearly all contractors surveyed in both study areas characterized these programs as "Very Important" or "Somewhat Important" in increasing the share of LED

[68] KEMA, Inc. 2010.

technologies sold to commercial and industrial customers. Clearly, this high level of program awareness and participation among contractors in the comparison area poses issues concerning the use of cross-sectional comparisons to assess the market effects of California programs. We discuss those issues at length in Section 4.

Table 34
Contractor Awareness of and Participation in Programs that Promote LED Lighting, 2013

Awareness/Participation	Project-Weighted Percent of Contractors	
	California (n=85)	Comparison Area (n=64)
Aware of US EPA ENERGY STAR Lighting	63%	38%
Aware of Design Lights Consortium	38%	16%
Aware of Local Utility Program	32%	58%
Participated in Utility Program	15%	45%

Conclusions. Key conclusions from the results of the contractor surveys include:

- The level of promotion for LEDs and the business motivation behind it appear to be nearly as strong at the bottom end of the supply chain as at the top.
- LED products have achieved significant market share for outdoor fixtures and interior high bay fixtures, and are beginning to sell into linear applications. These findings are consistent with those from distributors.
- Customer interest in and knowledge of LEDs is sufficiently strong that a significant fraction of contractors receive customer-initiated requests to install LEDs.

3.3 The Commercial Customer Market for LED Lighting

This section provides information on recent installations of LEDs in non-residential facilities as well as customer awareness and attitudes regarding LED equipment. The analysis team obtained these results from commercial customer telephone survey efforts conducted as part of CPUC EM&V WO29 and WO54.

Before presenting the customer survey results, it is necessary to discuss a number of circumstances regarding their execution which affect the comparability of the results of the commercial customer surveys in California and the comparison areas. The California estimates are based on the results of the California Commercial Market Share Tracking (CMST) telephone survey. This survey was conducted as one part of a suite of customer telephone, customer on-

site, and vendor surveys to characterize the saturation and current purchases of key categories of energy-using equipment, including lighting. Itron, Inc. implemented this project.

The CMST telephone survey included interviews with a sample of 7,890 commercial and industrial customers. The sample frame for the survey consisted primarily of records from the IOU's Customer Information Systems (CIS), which included monthly billing records. Itron staff stratified the sample by building type and size as measured by annual energy consumption, and computed results on both an energy- and site-weighted basis.

Data collection for the telephone survey began in early 2013. Itron staff developed the telephone survey questionnaire in 2012, prior to the completion of the study plan for the LED Market Effects study, and contained only a few items concerning customer purchase of LEDs in retrofit situations. The full set of LED questions whose results are summarized below was only added to the questionnaire after roughly half of the interviews had been completed.

The telephone survey of commercial customers in the comparison area used a subset of questions included in the California CMST, focusing only on collecting basic information about the sample site, recent purchases of linear and high intensity discharge (HID) lighting equipment, and saturation and experience with LEDs. Other significant differences from the CMST effort included the following:

- **Timing.** Data collection for the CMST telephone survey was largely completed in the first quarter of 2013. The commercial customer survey in the comparison area was completed during the third quarter of 2013. Given the rapid pace of change in the LED market this difference in timing of roughly six months may have affected the comparability of results between the study areas in regard to awareness and adoption of LED lighting.
- **Sample Frame.** Utility records for establishments in the comparison area were not available to the study team. We therefore used the InfoUSA establishment database as the sample frame, and used the data on number of employees at each establishment instead of energy consumption as a measure of size.
- **Absence of LED questions from early calls in California.** As mentioned earlier, the LED-specific questions were not included in the first months during which the California survey was in the field. Ultimately, most of the LED questions were included in only 42 percent of the completed interviews. It is possible that this pattern of deployment had a systematic effect on the results of questions related awareness and adoption of LEDs, although we can only speculate on what the effects might have been.
- **Expansion of Results.** For both surveys we had the option of expanding survey results using weights that reflected the number of establishments in the sample strata or weights that incorporated measures of size for each sample element (electric consumption in California and number of employees for the comparison area).

Theoretically, at least, this approach should produce estimates of market share that are comparable to those which were provided by contractors and distributors. We therefore used the consumption-weighted results for the California survey and the employment-weighted results for the comparison area survey. Results of the U. S. Energy Information Administration's Commercial Building Energy Consumption Survey suggest that facility electric consumption is related to the number of employees, although that relationship is not statistically precise.[69] This difference in weighting may affect the comparability of results between the California and comparison area commercial customer surveys.

In some cases, it is more useful to use establishment-weighted results, for example when describing patterns of program participation where tracking systems count firms rather than fractions of the market. We call out the instances in which we use establishment weighted results below.

- **Response Rate.** The response rate for the California survey was approximately 6 percent. The response rate for the comparison area survey was approximately 3 percent.

It is impossible to know exactly how the differences in the timing, sample construction, and response patterns affected the results of the non-residential customer survey in the two areas. Generally, however, we believe that these differences led to the inclusion of firms in the comparison area sample that were on average more predisposed to be aware of LED lighting technology and to purchase it than the firms in the California sample. The results must be treated as indicative of general levels of awareness, knowledge, and adoption of LED technology by customers in the two study areas. The use of a two-stage study design should mitigate some of the threats to validity of comparisons between the two areas by providing for measures of change over time in both.

3.3.1 Awareness of LED Lighting

The commercial end user surveys included questions about whether customers were aware of LEDs. The first (unprompted) awareness question asked, "Before this call today, had you ever heard of LEDs... Light Emitting Diodes?" If respondents did not answer yes to the unprompted awareness question, they were asked about their familiarity with LEDs once more with a detailed description of the technology. The majority of customers in California and the comparison area are aware of LEDs without an additional prompt. As shown in **Error! Reference source not found.**, 96 percent of customers in California and 94 percent of customers in the comparison area reported being aware of LEDs without a description of the

[69] Review of the table series "Electric Consumption and Conditional Energy Intensity by Census Division" shows that electricity use per square foot remains fairly constant among facilities grouped by number of workers for establishments with more than 10 employees, which corresponds to sample inclusion criteria for this study. However, the relative standard errors for these estimates are high. (EIA 2003)

technology. After being read a description, an additional 1 percent of California customers and 3 percent of respondents in the comparison area reported that they were aware of LEDs[70].

Table 35
Non-Residential Customer Awareness of LEDs, 2013
(Non-Residential Customer Telephone Surveys)

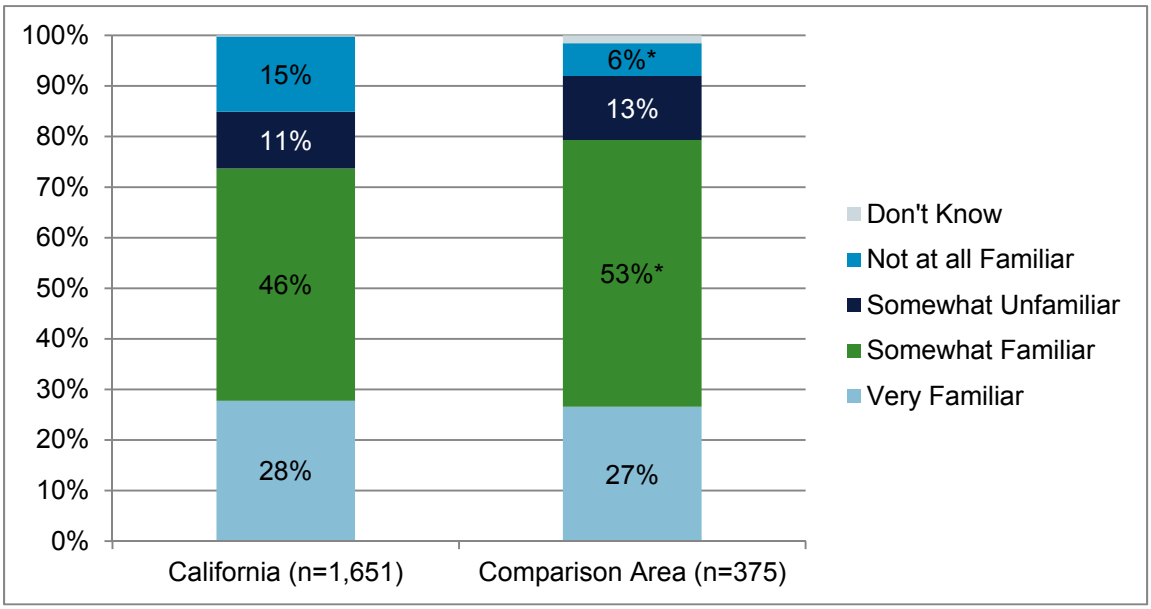
Awareness	California (n = 2,233)	Comparison Area (n = 332)
Aware of LEDs without prompting/description	96%	94%
Aware of LEDs with prompting/description	1%	3%
Unaware of LEDs	3%	3%
Total	**100%**	**100%**

Although the share of customers who reported being aware of LEDs was roughly the same in California and the comparison areas, California customers were somewhat less familiar with LEDs *for business applications* than customers in the comparison area. As **Error! Reference source not found.**shows, 74 percent of LED-aware customers in California reported that they were "very familiar" or "somewhat familiar" with LEDs for business use compared to 80 percent in the comparison area[71].

[70] Customers were prompted with the following question "Light emitting diodes, also known as LEDs are small light sources that become illuminated by the movement of electrons through a semiconductor material. LEDs can be integrated into all sorts of products including light bulbs, signs, and integrated light fixtures. Before today, were you familiar with LEDs?"

[71] We defined"familiar with LEDs for business use" as respondents who reported being very familiar, somewhat familiar, and somewhat unfamiliar with LED lighting products for business use.

Figure 25
Non-Residential Customer Familiarity with LEDs for Business Use, 2013
(Non-Residential Customer Telephone Surveys)



***Difference from California results is statistically significant at the 90% level of confidence.**

3.3.2 Purchase and Installation of LED Lighting Products

Over the past four years, LED lighting products have begun to penetrate the commercial market in both regions. Forty-six percent of non-residential end users in California reported that they had at least one kind of LED product installed at their facilities compared to 42 percent of customers in the comparison area.

Table 36
Non-Residential LED Installations and Rebates, 2013
(Non-Residential Customer Telephone Surveys)

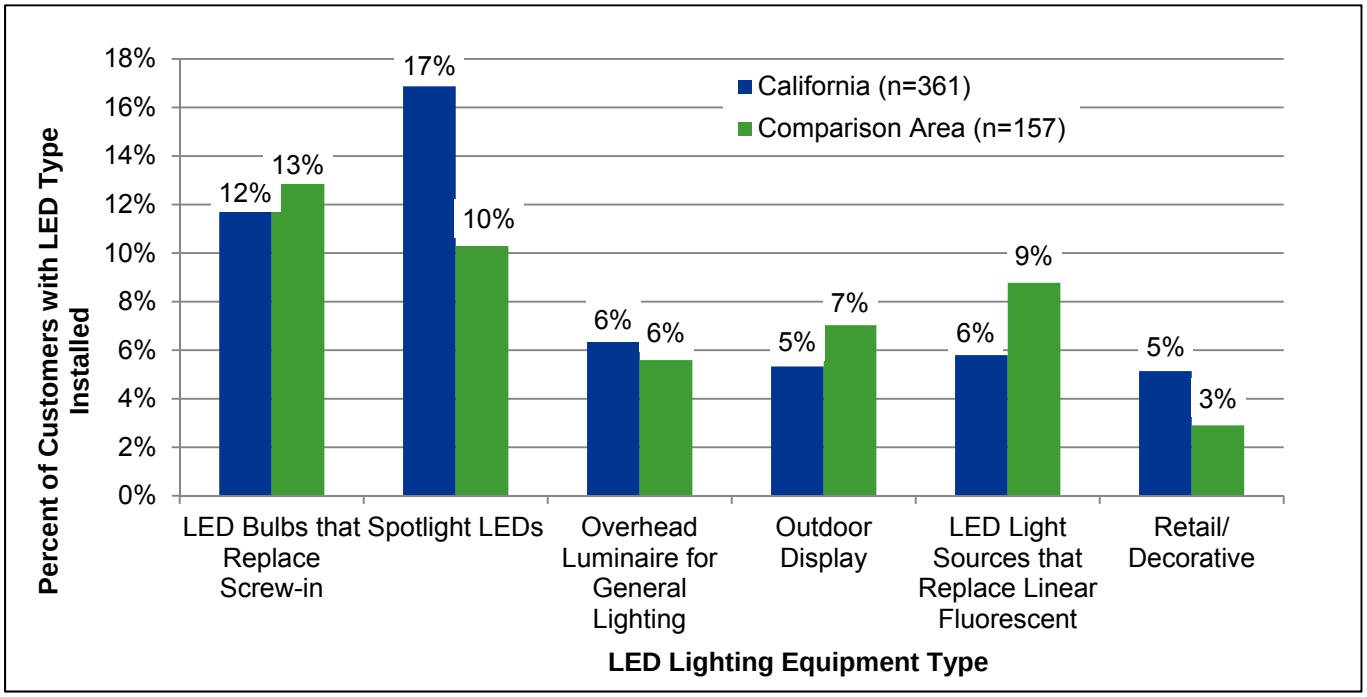
Installation/Rebates	California		Comparison Area	
	%	n	%	n
Businesses that have installed LEDs since 2009	46%	1,770	42%	384
Businesses who received a rebate for LEDs (site or establishment weighted)	2%	315	6%	157

Seven percent of California customers with LED purchases or 2 percent of the overall sample reported that they had received a rebate from their utility for that equipment. This level of

participation corresponds exactly to the ratio of customer sites with rebates to total customers discussed in Section 1. A far higher percentage of LED purchasers in the comparison area – 19 percent or 6 percent of the total sample – reported receiving rebates. This finding is consistent with our hypothesis that patterns of response led to a sample of comparison area customers who were generally more interested in energy efficiency and new lighting technologies than their California counterparts.

To better understand the adoption practices among customers in California and the comparison area, the survey asked respondents what types of LED equipment they installed at their facility since 2009.**Error! Reference source not found.** shows the prevalence of various types of LED technologies installed since 2009 in both regions.

Figure 26
Percent of Sample Customers Installing LED Products, by Type, 2013
(Non-Residential Customer Telephone Surveys)



The most commonly installed types of LEDs in both regions were screw-base lamps and downlights. There is no significant difference between study areas in the portion of customers who have installed the various types of LEDs reviewed.

For each type of LED mentioned by LED users, the survey also asked how many of each was installed at their facility at the time of the survey.[72] **Error! Reference source not found.** shows the distribution of establishments that reported installing LED fixtures and their more established technology counterparts by the number of fixtures installed. For linear fixtures, we note that 61 percent of purchasers installed 10 or fewer fixtures versus 15 percent for high performance T8 fixtures.[73] This suggests that customers who installed LED overhead panels did so as a trial before moving on to more extensive adoption. Similarly, 52 percent of the reported installations of LED linear retrofit kits involved 30 or fewer fixtures. For other types of interior fixtures, we compared the size distribution of installations of hard-wired compact fluorescent versus LED downlights. We note that a much higher portion of the sample facilities reported installing LED downlights than hardwired compact fluorescents. However, 75 percent of the reported installations of LED downlights involved 30 or fewer fixtures, versus 29 percent of the reported hardwired CFL fixture installations.

Table 37
Distribution of Establishments in California Sample by Number of Fixtures Installed in Replacement and Retrofit Projects: LED versus Alternative Technologies, 2013
(Commercial Customer Telephone Surveys)

# of Fixtures Installed	Linear Fixtures			Other Interior Fixtures	
	High Perf. T8	LED Panels	LED Linear Retro. Kits	Hardwired CFL	LED Downlight
n	188	43	48	36	127
0 to 10	15%	61%	26%	20%	40%
11 to 30	15%	19%	26%	9%	35%
31 to 50	11%	7%	3%	10%	8%
51 to 100	10%	2%	15%	13%	2%
101 to 500	35%	0%	22%	47%	12%
501 to 1000	7%	0%	5%	0%	1%
More than 1000	7%	12%	2%	0%	2%

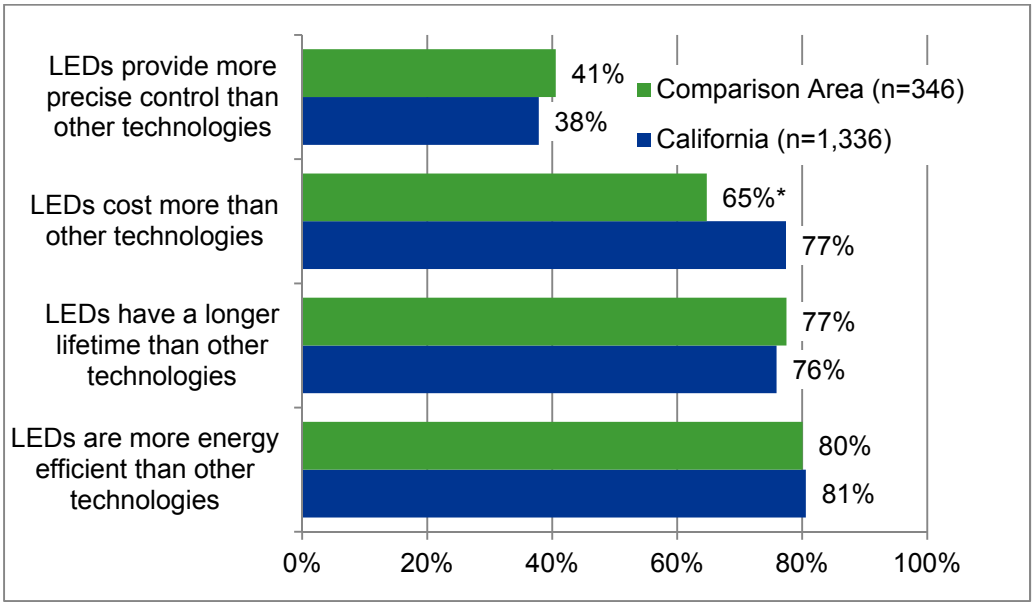
[72] To reduce respondent burden, the surveys only asked respondents the additional questions about the first three technologies mentioned. As such, the sample sizes for some technologies is small.

[73] Customers who could not recall how many fixtures they installed are not included in this table.

3.3.3 Knowledge and Experience of LED Products

The non-residential customer telephone surveys asked respondents who were familiar with LEDs for business a series of follow up questions about their perceptions of LED attributes compared to alternative lighting technologies. Overall, the majority of customers in both regions had accurate perceptions about the costs, efficiency, and produce life of LED lighting technologies in comparison to alternative technologies, though fewer customers were knowledgeable about the amount of control provided by LEDs. More customers in California think that LEDs cost more than alternative technologies than in the comparison area (77% versus 65%). This difference is statistically significant at a 90% confidence level. **Error! Reference source not found.** compares customers' perception of LED attributes.

Figure 27
Commercial Customer Knowledge of LED Attributes, 2013
(Commercial Customer Telephone Surveys)

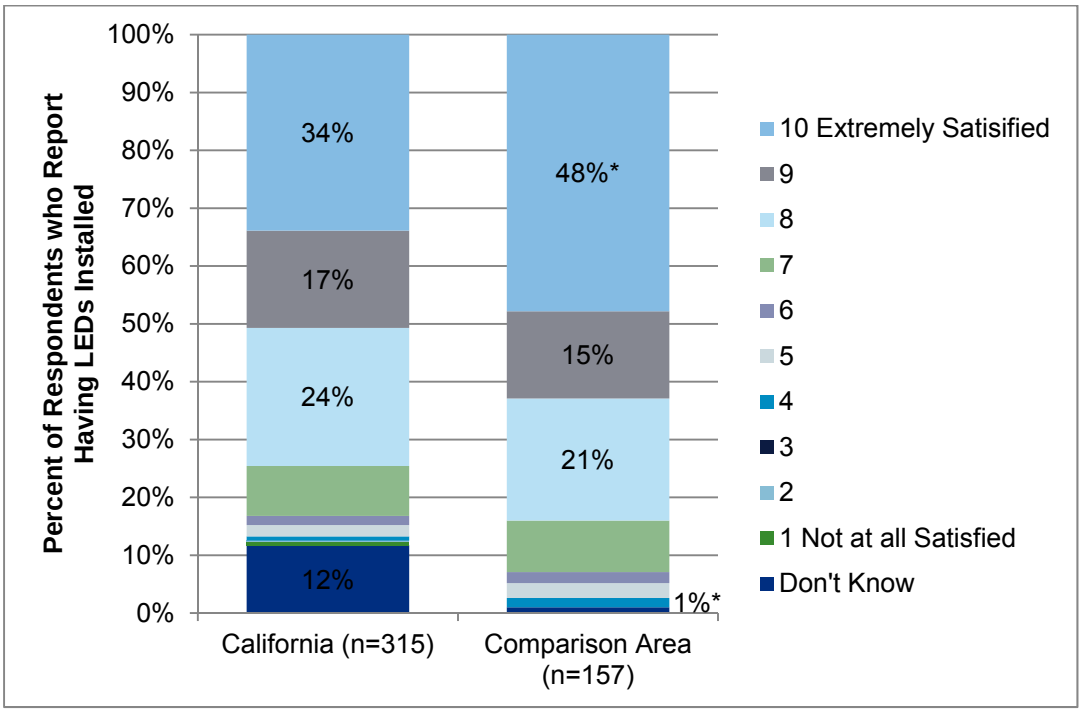


*Difference from California results is statistically significant at the 90% level of confidence.

Overall, customers in both regions are very satisfied with the performance of LED equipment installed in their facilities. However, more customers in the comparison area are very satisfied with their LED equipment: ninety-three percent of customers ranked their satisfaction as a 7 or greater, compared to 83 percent in California. This disparity could be due in part to the large

number of customers who responded to this question with a "don't know" in California. Figure 28 shows the responses provided by customers in California and the comparison area.

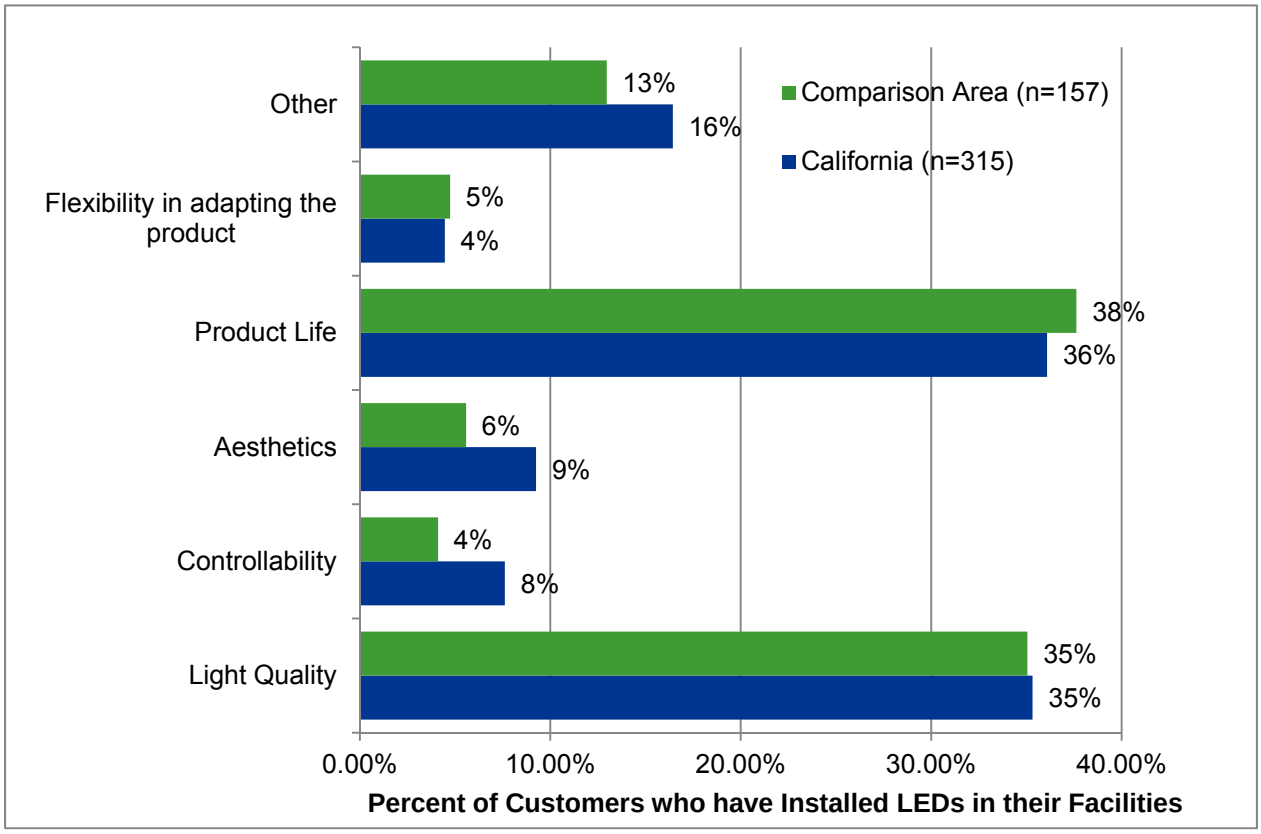
Figure 28
Non-Residential Customer Satisfaction with LED Performance among Respondents who Have Installed LEDs in their Facilities, 2013
(Commercial Customer Telephone Surveys)



*Difference from California results is statistically significant at the 90% level of confidence.

The survey also asked all LED users to describe the aspects of their LED equipment with which they were most satisfied. In both regions, customers reported that the light quality and product life were satisfactory. Customers also expressed satisfaction with the controllability provided by LEDs, though a larger portion in California found this aspect satisfactory. **Error! Reference source not found.** provides additional details.

Figure 29
Satisfactory Aspects of LEDs Among Non-Residential Customers who have Installed LEDs in their Facilities, 2013 (Non-Residential Customer Telephone Surveys)



3.3.4 Conclusions

Despite methodological issues that complicate direct comparison of the commercial customer survey findings from California and the comparison area, the results of both surveys support a number of important conclusions regarding development of the customer side of the commercial LED lighting market. These are as follows.

- **Awareness of LED products among commercial customers is high.** Awareness of LED products is nearly universal among commercial customers. Over 70 percent of customers in both study areas report being either "Very Familiar" or "Somewhat Familiar" with LED lighting products for business use during the 2013 telephone surveys.

- **Commercial customers are knowledgeable about key attributes of LED lighting.** The large majority of customers in both study areas correctly characterized LEDs as having longer useful lives and providing for greater control over light levels than alternative technologies. They also knew that LEDs cost more than alternative products.
- **Over 40 percent of the commercial market (weighted by kWh or employees) has purchased and installed at least one type of LED lighting product.** Data on the number of fixtures purchased and installed suggest that customers are still in a trial phase for most LED products.
- **Customers are satisfied with their LED installations.** Overall, customers are very much satisfied with the LED equipment they have installed. Over three-quarters of all LED purchasers rated their satisfaction with their installations from 8 to 10 on a 10 point scale. This finding contrasts sharply with the record of customer complaints concerning the performance and appearance of compact fluorescent lamps and early versions of electronic ballasts/T8 technology.

4. Integrated Analysis: Market Indicators and Their Implications

In this section we distill the findings from Sections 2 and 3 into a set of market indicators that we propose for use to track the development of the LED lighting market over time and to characterize the development of the markets in the study areas based on those indicators. We then trace the implication of those findings for program design and for the methods to be applied in the follow-up phase of the study.

4.1 Market Indicators and Summary of Market Development

Residential Sector Findings

Table 1 below summarizes the residential LED market development indicators proposed as part of this study. These include the retailer awareness rate; metrics for availability, lamp model diversity and pricing at retail; consumer awareness, purchase and installation rates; and consumer purchase quantities. The following paragraphs synthesize these and other findings from the report to provide a strategic view of the residential LED lighting market for reference by program sponsors and regulators.

The study found no significant differences between California and the comparison area with regard to key indicators of residential market development for LED lighting. As Table E1 shows, the values for key market indicators of consumer awareness and adoption of LED products on the one hand and retailer stocking and pricing of important product types were virtually the same in the California and the comparison area. This suggests that the residential market for LED lamps and fixtures has attained similar stages of development in both areas. Detailed findings in support of this conclusion are as follows.

- **Consumers have access to a growing variety of LED lamps and fixtures at the retail level.** On average, retailers stocked 7 models of LED lamps in late 2012, versus 30 models of CFLs and 40 models of incandescent lamps. Home improvement stores in California stocked 30 LED models on average, versus 36 LED models in the comparison area.
- **Pricing trends for LED lamps varied by product type and retail channel.** As April 2014, prices for 60 watt equivalents have fallen below $10 per unit online and are roughly equivalent in large home improvement stores. This compares to prices for all types of LED lamps in the $15 range recorded in the shelf surveys conducted for this study in 2013. Comparison of the results of shelf surveys undertaken in California in 2012 and 2013, however indicate that these price decreases are not universal across

product types (form factors) or channels. For example, the price of A-lamps sold in big box stores decreased by roughly two dollars between 2012 and 2013, while it increased by $1.50 at all other types of retailers. Similarly, the average price LED reflector lamps decreased by $6.50 per unit at big box stores while increasing by roughly one dollar at other retailers. Retailers continue to identify high first cost as the major barrier to LED sales to residential customers. On average, across major retail channels, prices for the various types of LED lamps were similar in the two study areas.

Table 38
Market Indicators for Residential LED Lighting

Market Indicator *(Source)*	2012 – 2013 Values	
	California	Comparison Area
RETAILER AWARENESS RATE (*Retail Store Manager Phone Survey*)		
Percent of retail store managers aware of LED lamps	96%	97%
AVAILABILITY (*Retail Store Shelf Survey*)		
Percent of retail stores stocking LED lamps	26%	32%
Percent of retail stores stocking LED fixtures	55%	44%
RETAILER PRODUCT DIVERSITY (*Retail Store Shelf Survey*)		
Average number of LED lamp models available per store	7.0	6.9
PRICE (*Retail Store Shelf Survey*)		
Average LED A-lamp price on Large Home Improvement store shelves	$18.26	$19.97
Average LED Reflector lamp price on Large Home Improvement store shelves	$32.26	$32.74
CONSUMER AWARENESS RATES (*Self-reports per Consumer Phone Survey*)		
Percent of consumers aware of LED lamps	83%	80%
CONSUMER PURCHASE RATES (*Self-reports per Consumer Phone Survey*)		
Percent of consumers who have purchased LED lamps since Jan 2010	19%	16%
Percent of LED-aware consumers who have purchased LED fixtures since Jan 2010	17%	19%
SATURATION		
Average number of LED lamps installed per household (*Self-reports per Consumer Phone Survey*)	1.62	1.49
Average number of LED lamps installed per household (*On-site Survey*)	0.5	n/a
CONSUMER PURCHASE QUANTITIES (*Self-reports per Consumer Phone Survey*)		
Average number of LED lamps purchased per household (population level) since Jan 2010	1.55	1.03
Average number of LED fixtures purchased per household (pop. level) since Jan 2010	0.51	0.56

- **Retailer support for LED lamps is strong.** The shelf surveys conducted for this study found that LED lamps are available from 26 percent of all retailers who carry lighting products of any kind in California and 32 percent of retailers in the comparison area. In both study areas, LED lamps are available in all wholesale clubs and hardware stores, 75 percent of home improvement stores, one-third of drug stores, and one quarter of grocery stores. Retailers reported strong business motivations for stocking LED lamps. In both study areas, retail store managers mentioned corporate policy and customer requests for LED lamps as the main motivations for stocking them.
- **Customer awareness of LED lighting products is high.** Eighty-three percent of sample customers in California reported that they were aware of LED lamps, as did 80 percent of sample customers in the comparison area. This was roughly equivalent to the level of recognition for compact fluorescent lamps, which have been in the market for thirty years.
- **Customer adoption of LED lamps has reached measureable levels and is increasing.** The strongest evidence for this finding comes from on-site lighting inventories conducted with large samples in California. The 2009 survey (n = 1.237) found fewer than 0.1 LED lamp installed per household; the 2012 survey (n = 1,987) found an average of 0.5 LED lamps installed. These findings are consistent with results of the consumer telephone survey (conducted in 2013), which found that 16 percent of customers reported purchasing at least one LED since January 2010. Self-reported purchase and saturation of LEDs was similar in the Comparison Area. Nineteen percent of CA customers reported that they had purchased at least one LED since 2010, as did 16 percent of customers in the comparison area sample.
- **Customers are satisfied with the performance of the LED lamps they have installed.** Eighty-six percent of California residential customers who purchased LED lamps rated them from 8 to 10 on a 10 point satisfaction scale (where 1 means “not at all satisfied” and 10 means “very satisfied”), as did 74 percent of customers in the comparison area.

Commercial Sector Findings

Table 39 displays the proposed commercial LED lighting market development indicators. Summarized at a high level, we find that:

1. **The broadest indicators of market development – primarily measures of awareness and adoption of LED lighting products developed from population-based surveys of customers and contractors – suggest that the commercial markets in California and the comparison area had reached comparable levels of development as of early 2013.**

2. **However, the results of the distributor and designer interviews, as well as some findings from the customer and contractor surveys, suggest that early adopter segments of the supply chain and customer population may be more advanced in their awareness and adoption of LED products in California than in the comparison areas.**

The following paragraphs provide details on the two major findings.

Similarity in Broad Indicators of Commercial LED Market Development

- **Awareness of LED products among commercial customers is high in both study areas.** Awareness of LED products is nearly universal among commercial customers. Twenty-eight percent of customers in both study areas report being "Very Familiar" with LED lighting products for business use.
- **Commercial customers in both study areas are knowledgeable about key attributes of LED lighting.** The large majority of customers in both study areas correctly characterized LED lamps as having longer useful lives, being more energy-efficient, and costing more than alternative technologies. Thirty-eight percent of sample customers in California and 41 percent in the comparison area also correctly characterized LEDs as providing for greater control over light levels than alternative technologies. They also knew that LEDs cost more than alternative products. The portions of customers with accurate knowledge of LED attributes were nearly identical in the two study areas.
- **Over 40 percent of the commercial market in both study areas (weighted by kWh or employees) has purchased and installed at least one type of LED lighting product.** The portion of sample customers who reported having at least one LED product installed at the time of the survey was 46 percent in California and 42 percent in the comparison area. Data on the number of fixtures purchased and installed suggest that customers are still in a trial phase with all products categories. Most reported installations of LED products of all types involved 30 or fewer units.
- **Contractors in California and the comparison area report installing roughly equal shares for LED linear fixtures and high bay lighting.** Contractors are directly involved in the full range of commercial lighting installation projects and are therefore in position to provide the most accurate view of technology shares in those projects. The fourth set of rows in Table E2 above summarizes the average share of installations accounted for by LED products for key applications reported by contractors in California and the comparison area. The LED share for linear fixtures, retrofit kits, and high bay lighting are quite low in both study areas, but somewhat higher in California.

Table 39
Market Indicators for Commercial LED Lighting

Market Indicator *(Source)*	2012 - 2013 Values	
	California	Comparison Area
LED AVAILABILITY (*Distributor Survey – Self Reports)*		
Average number of linear fixture models carried by sample distributors	10	9
Average number of high bay fixture models carried by sample distributors	8	11
Average number of downlight fixtures carried by sample distributors	23	17
PRICING (*Distributor Survey – Self Reports)*		
Median "price premium" for linear LED fixture (Troffer)	140%	100%
LED MARKET SHARE – DISTRIBUTOR-SUPPLIED PROJECTS *(Distributor Survey)*		
Interior Linear Fixtures	18%	7%
Downlights	39%	31%
High Bay Lighting	21%	3%
Outdoor Lighting	36%	39%
LED MARKET SHARE – GENERAL (*Contractor Survey – Self Reports))*		
Interior Linear Fixtures (as % of interior linear fixtures installed)	5%	4%
Linear Fixture Retrofit Kits (as % of interior linear fixtures installed)	6%	2%
High Bay Lighting	10%	4%
Outdoor Fixtures	17%	12%
Medium Screw-Based Lamp Fixtures (Downlights)	15%	7%
CUSTOMER AWARENESS & INTEREST		
% of contractors (installation weighted) reporting customers always or mostly ask about LEDs for relevant installations. (*Contractor Survey –Self Reports, Project-weighted)*	28%	7%
Percent of customers aware of LEDs without prompting (*Customer Survey – Self-Reports, size weighted)*	96%	94%
Percent of customers reporting they are "very familiar" with LEDs for business use (*Customer Survey – Self-Reports, size weighted)*	28%	27%
CUSTOMER KNOWLEDGE OF LED PRODUCT ATTRIBUTES V. ALTERNATIVES (*Customer Survey – Self-Reports, size weighted)*		
Percent of customers who report that LEDs offer more precise control	44%	38%
Percent of customers who report that LEDs last longer	76%	72%
Percent of customers who report that LEDs are more energy efficient		
CUSTOMER ADOPTION OF LED TECHNOLOGIES(*Customer Survey – Self-Reports, size weighted)*		
Percent of customers who report having at least one type of LED lighting product installed in their facility	46%	42%
Percent of customers who report having LED linear fixtures installed	6%	6%
Percent of customers who report having LED linear replacement kits	6%	9%
Percent of customers who report having LED downlights installed	17%	10%
Percent of customers who report having screw-based LED bulbs installed	12%	13%

Customers are satisfied with their LED installations. Overall, customers are very much satisfied with the LED equipment they have installed. Over three-quarters of all LED purchasers in both study areas rated their satisfaction with their installations from 8 to 10 on a 10 point scale (where 1 means "not at all satisfied" and 10 means "very satisfied"). This finding contrasts sharply with early records of customer complaints concerning the performance and appearance of compact fluorescent lamps and early versions of electronic ballasts/T8 technology.

- **The number of available models for all major applications is increasing at all levels of the supply chain.** Generally, products introduced by manufacturers are finding their way quickly into the stream of equipment stocked, specified, and installed. Distributors reported stocking or having access to 20 to 30 models of product types that have been in the market for a number of years, such as downlights and outdoor fixtures. They reported stocking or having access to 10 to 15 models of more recently introduced product types, such as LED overhead panels and high bay lighting. Web sites for large warehouse distributors currently display similarly extensive lines of fixtures and lamps. Very few designers or contractors mentioned availability of appropriate products as a barrier to increased adoption of LED lighting.
- **Prices are decreasing for products in all categories, but cost remains the major barrier to adoption.** Virtually all respondents among distributors, contractors, and designers reported that prices were decreasing for major LED product categories. However, analysis of national data show that prices for commercial fixtures is decreasing more slowly than prices for LED lamps, largely because the solid state components of the fixtures are falling in price more rapidly than the other components such as sheet metal and other electronics. All groups of supply side actors as well as customers identified high prices as the major barrier to further adoption of LEDs.

Differences in Selected Indicators of Market Development

- **Contractors in California report that customers request LEDs in advance of their recommendations much more frequently than contractors in the comparison area.** Contractors representing 28 percent in the market in California reported that customers initiate requests for use of LEDs in all or most of their relevant installation projects, versus only 7 percent in the comparison area.
- **Contractors in California report installing higher shares of LEDs for downlights and outdoor lighting than contractors in the comparison areas.** In California, the reported LED market share for products that have been available in large numbers for a number of years, namely outdoor fixtures (17 percent) and downlights (15 percent) are beginning to suggest transition from the early adopter to early majority phases of market acceptance. Uptake for these products in the comparison

area has not progressed as rapidly. Market share of other LED products is considerably lower in both study areas. The differences in LED share between the two study areas are not statistically significant, due primarily to the relatively low sample size for the contractor study and the variability in the responses.

- **Distributors and manufacturer representatives in California report selling larger shares of selected LED products than their counterparts in the comparison area.** The distributors and manufacturer representative firms interviewed for this study generally focus on supplying new construction and large remodeling projects. Roughly 60 percent of projects completed by the interviewed firms in California and 50 percent of those in the comparison area were in new construction and remodeling. Typically new construction and remodeling lighting projects constitute a small portion of the total market (less than 20 percent of total installations). Given the relatively high representation of larger projects in the distributors' portfolios, they can be understood as a leading indicator for the development of broader market. As the third set of rows in Table E2 shows, there was little difference between the study areas in the LED share of downlights and outdoor fixtures. However, the reported LED share of linear overhead and high bay lighting was much higher among California distributors than among those in the comparison area. These findings may indicate greater willingness among CA distributors to promote products that have only recently been introduced to the market, as well as greater interest among the distributors' direct customers.
- **The reported price premium for LED linear fixtures was higher in California than in the comparison area.** Distributors in California reported a median price premium for LED versus fluorescent linear fixtures of 140 percent, versus 100 percent in the comparison area. This finding could reflect a higher level of demand for LED linear fixtures, although caution should be used in generalizing from a relatively small sample.
- **Differences in applicable building codes.** The most recent revisions of California's Title 24 building energy codes favor the use of LEDs to a greater extent than the International Energy Conservation Code, 2009, which many states including those in the comparison area have adopted as the model for their state building codes. These provisions include more stringent lighting power alliances, requirements for continuous and/or multilevel dimming, and extension of code coverage to a large share of remodeling and retrofit projects.
- **Influence of codes and standards.** While nearly all designers in both study areas reported that they used LEDs to meet energy codes, 16 of 17 California interviewees identified this as an important strategy for meeting code requirements versus only 10 of 15 comparison area respondents. Fifteen of 20 distributors in CA believe that code compliance is an important motivation for specifying LEDs, versus 6 of 18 in the comparison area.

Conclusions and Implications for Market Effects Assessment

From the findings summarized above, we conclude that development of the commercial market for LED lighting is well under way in both California and the comparison area. California's level of development as of the beginning of 2013 was slightly more advanced, particularly in regard to larger projects served by specifying distributors and manufacturers. The advancement of the California market was also evidenced by contractor reports of higher LED shares for downlights and outdoor fixtures, as well as the frequency with which they reported customer initiation of requests for LEDs.

We do not believe that the differences observed between the two study areas in the development of commercial LED lighting market stem primarily from IOU programs to support LEDs. During the 2010 -2012 cycle, participation in LED incentive programs was relatively low. Less than two percent of commercial customers received incentives for LEDs versus the 46 percent who reported having LED products installed in their facilities. Some of the observed difference could be attributable to conditioning of the market through decades of programs to promote efficient commercial lighting in general.

We believe that at least some part of the observed difference in selected market development indicators can be attributed to differences between the California and comparison area markets for which we simply were not able to account in the development of the comparison area. At this point in time, it is impossible to identify a region that features the robust lighting supply chain found in California as well as the huge market to support it *and* that is not served by long-standing energy efficiency programs. The sheer size and complexity of the California market means, among other things, that the high end of the market is sufficiently large to drive a diffusion process. This hypothesis is consistent with the large differences in LED market reported by distributors and manufacturers representatives and by the differences in contractor-reported LED shares for product types that have been in the market the longest.

Some of the observed differences in uptake of LEDs in the commercial sector may also be due to recent changes in Title 24. These apply lighting power allowances and control requirements which are generally higher than corresponding sections of the International Energy Conservation Code 2009 version, which many states use as the model for their building energy codes. Moreover, the 2013 Title 24 revisions extend the range of remodeling and retrofit projects to which code requirements apply. Prior to this revision, code requirements were invoked for all new construction plus all remodeling and retrofit projects in which 50 percent of luminaires in the affected areas are replaced. These limits have been reduced to 10 percent of luminaires or 40 total luminaires. The majority of designers and distributors in both study areas report using LEDs as part of their strategies to meet code requirements. However, in California, these requirements appear to be somewhat more stringent and apply to a wider range of projects than in the comparison area.

One of the main reasons the consultant team and its CPUC advisors selected the two-stage study approach was to provide a method for generating cross-sectional comparisons of the pace of market development in the event that the baseline study found that one or more elements in the development of the California LED market had already advanced beyond the comparison area. We recommend that the next phase will develop measures of the pace of change in market indicators for California and the comparison area, and use those measures to assess met program effects.

Cross-Sector Findings

The market for lamps and fixtures of all types is international, and manufacturers hold the most powerful position among all market actors in terms of decisions regarding product design and pricing. This study compiled extensive evidence of the intensity of competitive efforts by manufacturers to create a market for LED lighting products and to capture their share of that market. Examples include:

- **The number and variety of quality LED lamps for residential use has increased rapidly in the past two years.** Between September 2012 and July 2013, the number of ENERGY STAR qualifying lamp models increased from 1,273 to 2,288. Reflector lamps for use in primarily in recessed and outdoor fixtures accounted for 71 percent of these models. However, the fastest-growing product type was omnidirectional screw-in A-lamps. Moreover manufacturers introduced multiple models with light output in the range of 60 to 100-watt incandescents.
- **The number of quality commercial grade fixtures available in the market has increased rapidly in the past two years**. Between January 2012 and January 2013, the number of commercial grade fixtures included in the DesignLights Consortium Qualified Products List more than doubled from 8,452 to 19,520, then increased by 71 percent to 33,329 by November 2013, before qualifying standards were changed.
- **Large numbers of companies have entered the market for LED lamps and fixtures**. In July 2013, over 170 companies had LED lamps approved for ENERGY STAR labeling. As in the incandescent and CFL markets, concentration in the LED lamp market is high, but there are a sufficient number of capable competitors to stimulate competition on price and product design. As of December 2013, 537 firms had products listed in the DLC Qualified Products List, versus 228 companies in December 2012. Also, more manufacturers have introduced significant model ranges of products in the past year.
- **Manufacturers have focused research and development and product development efforts on LED technology.** We interviewed ten commercial lamp and fixture manufacturers in support of this study. Four reported spending all of their R&D funds on LED products; 3 more reported that they spent 90 to 95 percent of their R&D

budgets on LED products. None reported spending less than 50 percent of their R&D budgets on LEDs.

- **Manufacturers have focused their marketing efforts on supporting LED products**. All manufacturers interviewed for this study reported spending at least 75 percent of their marketing budgets to support LED offerings. Four reported spending 100 percent to support LED products.
- **Manufactures are cooperating with government testing and product certification programs**. Many identified the need to mitigate the risk that poor product performance will dissuade customers from trying, retaining, and recommending LED products.

Despite the level of product research and development discussed above, LED technology is forecasted to be nearly three times as expensive per unit of light output as linear fluorescents in 2025. Thus, over the next decade or so, LEDs will need to continue to compete on non-energy benefits such as longer useful life, reduced maintenance costs, improved control, fixture aesthetics, and greater control over light color.

4.2 Implications for Programs that Support LED Lighting

The characterization of the LED lighting markets summarized in Section 4.1 suggests the following guidelines for state-level programs that support LED lighting.

Continue to support the development of product standards and management of product testing programs. Given the rapid influx of manufacturers and new products into the LED market, it will be important to ensure that new products meet basic performance standards in order to avoid negative customer reaction, similar to that which greeted the introduction of CFLs. The U. S. Environmental Protection Agency (EPA) has assumed this role for lamps through its ENERGY STAR program, and the DesignLights Consortium has taken up this function for commercial grade fixtures. In addition, the CEC has developed lamp standards for application in the California. While there will always be some conflict of interest between manufacturers and standards/testing program sponsors, most of the contractors interviewed for this study acknowledged the need for and value of these programs. The California IOUs currently support the EPA and DesignLights program, and have been deeply involved in related codes and standards proceedings before the CEC. It will be important to continue this work and to stay abreast of changes in product price and performance so that standards can be revised to reflect the best elements in currently available technology.

Maintain incentives for LED fixtures and lamps. While early market response to LED lighting products has been strong, the level of acceptance for most product types and customer groups is still in the “early adopter” category. Moreover, first cost is the barrier to acceptance mentioned most often by customers and market actors in the supply chain. Incentives will not

only assist customers in the "Early Majority" category to overcome cost barriers, they will also call customer attention to other benefits offered by LED products, including extended life, low maintenance costs, low heat output, and enhanced controllability.

Increase energy savings in the short term by linking LED fixture incentives to improvements in controls. According to a recent national study of the non-residential lighting market, only 25 percent of total fixtures, accounting for 32 percent of total commercial sector lighting energy are under any kind of automated control.[74] A meta-analysis of 88 assessments of controls installations found a range of energy savings ranging from 24 to 38 percent of baseline consumption, depending on the control strategy employed.[75] Given the high level of control that LED light sources can support, structuring incentives to favor inclusion of controls in the installation could help increase the overall cost effectiveness of LED incentives during the next few years, when the difference in efficacy between LEDs and fluorescent technology is forecasted to remain small.

4.3 Guidance for Follow-up Research

This study encompassed a large number of primary research initiatives. While all of these efforts provided information that was useful in characterizing the LED lighting markets, we acknowledge that some worked better than others. In this section we identify specific methodological issues that will need to be addressed in the follow-up study and suggest approaches for addressing them.

Comparison Area Construction. Over the past several years, most of states with significant metropolitan areas have initiated or expanded energy efficiency programs funded by public goods charges. At this point, it is not possible to identify a set of states or metropolitan areas not served by public goods programs that resemble California in terms of the scale of its lighting markets and the density and sophistication of the supply chain establishments in those markets. Moreover, most state-level energy efficiency programs have added LEDs to the list of measures they support, or are in the process of doing so. Thus, we will not be able to use comparison areas in other states to represent the development of California's LED lighting market in the absence of LED incentive programs. More precisely, we will not be able to use changes in the values of indicators of awareness, knowledge, and adoption registered in the comparison area as the baseline for observed changes in those indicators for California, at least not as the term "baseline" is commonly defined.

Notwithstanding these issues, we believe that it will be useful and informative to maintain the cross-sectional structure for the follow-up study for a number of reasons. First, without some

[74] Navigant Consulting, 2012b

[75] Williams et al., 2012.

point of comparison, it will be difficult to assess observed changes in California market indicators. To our knowledge, there are no readily available metrics (such as manufacturer shipment data or retailer sales data) from which to develop trends at the national or state level. Second, we are aware of other states (including Massachusetts and New York) which have or are likely to undertake market-based studies of LED adoption. These studies will provide additional points of comparison for progress in California from states with long-standing energy efficiency programs. Combined with observations developed for this study from less active states, this information will likely provide insights into the effects of programs of varying intensity and time in the field on the development of the LED market.

To take best advantage of the analytic opportunities offered by the "difference of differences" approach at the heart of the current study design, we believe it will be best to monitor the following on an ongoing basis as part of the development of the Market Studies Roadmap:

- Spending, program design, incentive levels, and participation in programs that support LED lamps and fixtures in the states which are currently in the comparison area. This information will be difficult to obtain retrospectively at the time of the follow-on study and will be useful for putting differences in market indicators into perspective.
- Market-oriented studies of LED products and program evaluations carried out in all states.
- Availability and terms of acquisition for sales data sources such as NPD and Nielson for consumer products.

Coordination of surveys with other CPUC efforts. Differences in sampling approach and timing between the Commercial Market Share Tracking survey in California and the commercial customer telephone survey undertaken for this project complicate direct comparisons of their results. There were also differences between the retailer telephone surveys deployed in California and the comparison area that precluded comparison of some potentially useful indicators of promotional efforts. In the future, greater effort is needed to ensure that survey methods and content are as uniform as possible so that results can be more meaningfully compared across studies.

Continued focus on differences between study areas in relevant building and energy code provisions. This study found that differences between Title 24 and model codes used by most states may be affecting the pace of adoption for LEDs. Any successive phase of the study will need to summarize the development of codes in the study areas, including provisions related to the types of projects to which they are applied and probe the effects of codes on lighting specification decisions in interviews with designers and distributors, as well as contractor surveys.

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B. Selection of Comparison Areas

This memo presents DNV KEMA's analysis of comparison states for the CPUC work order (WO054) designed to characterize and quantify baseline conditions for LED lighting products in California (CA) and a non-program comparison area.[76]

As discussed in the March 14, 2012 work plan, the objective of this study is to "develop a comprehensive baseline characterization of the market for LED lighting products in California and in areas that have not experienced intensive promotion of efficient lighting products." Development of the baseline level of activity will greatly improve the our ability to estimate market effects associated with California LED programs. Identifying the appropriate comparison area is essential to accurately determining the relative level of LED awareness, promotional practices in California for the pre-program period, as well as the extent of market effects in the future period.

The remaining sections present our analysis of comparison areas for the LED baseline study. We first present criteria for the selection of comparison areas, with reference to recent studies that have used cross-sectional methods at the state of regional level to characterize market effects or cumulative net savings. This is followed by a comparison of candidate states that are candidates for the comparison area along the dimensions indicated by the selection criteria. Finally, we identify the recommended comparison areas for the LED market effects study. An appendix contains more detailed information on program characterizations of the candidate comparison area states.

B.1 Methodological Considerations

Before going into the criteria for comparison area selection, it is useful to review briefly the kinds of state and regional level cross-sectional methods that have been used to characterize and quantify market effects and the conceptually-related phenomenon of net savings inclusive of non-participant spillover. Essentially, all of these studies attempt to quantify differences among geographic areas on indicators of measure adoption that are associated with differences in levels, types, or longevity of promotional programs, while controlling in some way for the effect of differences among the areas on customer and market characteristics that affect measure adoption. Recent studies have used the following three cross-sectional approaches.

[76] Prepared Work Plan for Market Effects Study: LED Lighting. for: California Public Utilities Commission Energy Division. DNV KEMA Energy & Sustainability March 14, 2012

- **Comparison of state-level market effects indicators between the program state and one or a few comparison area states.** KEMA has used this approach in studies of the market effects of energy efficiency programs for high bay lighting in California and Massachusetts, as well as for efficient fluorescent lighting and variable speed drives in Wisconsin.[77] The studies attempted to the extent feasible to identify comparison areas that resembled in some way the program area in terms of factors that might affect the naturally occurring level of customer acceptance for the measures in question. Since these studies focused on products intended for the commercial and industrial market, matching efforts focused on assessment the populations of commercial enterprises between the program and comparison areas. This is the general approach that will be used in the LED market effects study.
- **Modeling of state-level market effects indicators using data from all fifty states.** In these studies, analysts obtain data on market effects indicators, such as the market share of efficient models, for all or a large portion of the fifty states. They then use some type of regression analysis to estimate the effect of differences in promotional programs on state-level market effects indicators while controlling for differences between states in demographic or economic indicators that may affect levels of energy efficiency measure adoption. For consumer products, these typically include indicators of income, education, and the presence of large national retailers who actively promote ENERGY STAR products. KEMA and NMR have used this approach to analyze the effect of energy efficiency programs on the state-level market share of ENERGY STAR appliances.[78] Application of this approach requires uniform measurement of the market effects indicators for a large number of states or regions, and is thus limited to a small number of technologies for which market share or sales data are available at the state level.

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[77] KEMA, Inc. 2011. *Massachusetts Energy Efficiency Programs' Large Commercial & Industrial Evaluation. HBL Market Effects Study Project 1A New Construction Market Characterization. Final Report*. Massachusetts Energy Efficiency Advisory Council. June 7, 2011; KEMA, Inc. 2010. *High Bay Lighting Market Effects Study. Final Report*. California Public Utilities Commission Energy Division. June 18, 2010; KEMA Inc, *Focus on Energy Evaluation. Business Programs: Channel Studies - Fiscal Year 2008*. Final Report, Public Service Commission of Wisconsin. January 17, 2009

[78] Rosenberg, Mitchell. "The Impact of Regional Incentive and Promotion Programs on the Market Share of ENERGY STAR® Appliances." Paper presented at the International Energy Program Evaluation Conference, Seattle, Washington, August 20-22, 2003; Wilson-Wright, Lisa, Shel Feldman, Lynn Hoefgen, and Angela Li, 2005. "Front-Loading Marketing: Assessing Cumulative Effects of ENERGY STAR Appliance Promotions on State-by-State Penetration Levels." In *Proceedings of the 2005 International Energy Program Evaluation Conference. B*rooklyn, New York: August 2005. KEMA, Inc. 2007. *Efficiency Vermont Residential Program Evaluations*. Vermont Department of Public Service.

- **Modeling of individual customer purchase decisions in states characterized by different levels of program support.** Two recent evaluations of the net savings attributable to CFL promotion have used residential customer survey data to support the development of logistic regression models of the likelihood of purchasing CFLs and of the number currently installed. Among the variables tested in the model were a wide range of demographic, housing, and attitudinal characteristics of the individual respondents, regional economic variables such as the price of electricity, and variables that characterized the intensity and time in the field of promotional programs.[79]

In preparing this memorandum, we reviewed the studies mentioned above and identified the following findings which provide guidance in identifying and constructing the comparison areas for the LED study.

1. **Effect of past program efforts.** NMR's cross-sectional studies of ENERGY STAR appliance market share and CFL market penetration and holdings both identified the length of time that promotional programs had been active in the state as a strong influence on net measure adoption, and estimated significant levels of contribution from historical programs to currently observed market effects indicators. KEMA obtained similar results in its 2007 evaluation of Efficiency Vermont's appliance program. Other studies have made similar findings without explicitly modeling the effect of historical programs. These findings suggest that our approach to selecting comparison areas take into account the cumulative effect of support for efficient lighting in the various states as well as the effect of new efforts to promote LEDs.
2. **Effect of program breadth.** Several of the regression-based studies have identified the range of program activities as a significant influence on net savings. For example, the appliance evaluations found significant coefficients for variables that represented offerings of retailer and publicity support, in addition to financial incentives.
3. **Residential customer attributes that affect efficient product adoption.** Efficient consumer product adoption has been found to be associated with indicators of higher socioeconomic status. Specific indicators or attributes that have been found to yield significant measures of association include:
    - Household income, and composite education/income scores.

[79] NMR Group, Inc. 2011. *Massachusetts ENERGY STAR Lighting Program: 2010 Annual Report.* Massachusetts; Appendix C. June 13, 2011. The Cadmus Group, Inc. 2010. *CFL Market Effects Study.* California Public Utilities Commission. February, 2010.

- Educational attainment (college degree of higher).
- Homeownership.
- Size of home as measured by number of bedrooms or respondents' estimate of square footage.
- Age of head of household (between 45 and 59).
- Respondent's self-report of race.
- Level of urbanization (generally interpreted as a proxy for proximity to large national retail chains that actively promoted CFLs and ENERGY STAR products).

4. **Commercial customer attributes that affect efficient product adoption.** Given the difficulties of obtaining data on sales or purchases of efficient commercial equipment and of obtaining information on purchase decision-making from commercial customers in general, the association between customer attributes and measure adoption in the commercial sector has not been studied in the same way as in the residential sector. There are, however, many market studies that explore segmentation of the markets for efficient products and related services in the commercial and industrial markets. These studies usually find the following.
   - Adoption of efficient products is associated with establishment size, with larger establishments having higher rates of adoption.
   - Very often, the relationship between establishment size and measure adoption is associated with the availability of energy management staff either on site or in a corporate location.
   - Establishments that are owned by national chains generally have higher rates of efficient measure adoption than the population as a whole. This tendency is associated with the presence of corporate energy management staff and policies.
   - Owner occupied facilities are more likely to adopt efficient measures since they directly benefit from energy savings.

B.2 Areas Characterized by Program Activity

In moving towards implementation of the study plan, the KEMA project team realized that appropriate characterization of the impacts of the California LED projects will involve assessment of two conceptually different sets of effects. The first is the effect of the newly added initiatives to encourage broader adoption of LEDs. The second is the cumulative effect of decades of program activity to promote efficient lighting generally, both directly to end users and through mobilization of various elements of the supply chain. Based on findings from previous studies discussed above, it is at least reasonable to hypothesize that the past programs will have some effect on the pace of adoption of LEDs, for example by helping customers become

familiar with potential savings from lighting upgrades and by providing vendors with the experience creating business opportunities around lighting upgrades.

In light of these considerations, we believe it will be most useful to select and collect data from two non-program areas: one with an established history of lighting promotion programs (Comparison Area – High Activity), but no current programs to promote LEDs, and one with little prior energy efficiency program activity (Comparison Area – Low Activity). So long as states in the first group do not launch programs to promote LEDs, comparison of results between them and California can be interpreted to reflect the effects of LED-specific efforts in California. We suspect that many of these states will initiate LED programs over the next three years, but it will at least be worthwhile to compare current baselines in these states to California's. Comparison of the level of market indicators between the High Activity and Low Activity states should provide a characterization of the effects of past programs on current adoption and promotion of LED products.

Surveying program activity in the individual states, we find that they can be classified into the following three groups.

1. **Established Program States** – States such as California, Massachusetts, Wisconsin, and New York that have had programs in place continuously for 20 years or more, in some cases with shifts in the organizations responsible for program administration.
2. **Newer Program States** – States such as Pennsylvania, Arizona, Maryland and Illinois which have had programs in place fewer than 10 years, or which have had prolonged gaps in offerings due to changes in regulatory policy.
3. **Laggards** – States which have experienced little to no energy efficiency program activity at any time.

Table A-1 in the Appendix to this memorandum displays LED program offerings in 9 established program , 6 newer program, and 6 laggard states. The first thing that is apparent from the table is that nearly all of the established program states already have programs that cover LED lighting products. Florida is the only state in this group without existing LED programs. Further, 3 of the 6 newer program states also have programs that cover LEDs. Consequently, the possible range of states with more advanced energy efficiency programs is limited to Florida, Arizona, and Nevada. None of the laggard states currently have energy efficiency programs that cover LEDs.

To develop further information to characterize program offerings, we arrayed the information on LED offerings with ACEEE's energy efficiency scorecard rating for the states under consideration. The rating ranks the 50 states plus the District of Columbia according to their

energy efficiency policies and programs, and the scores are reviewed by over 200 experts in the industry. Of the states considered as possible comparison areas, Arizona is the state with the closest ACEEE ranking at 17. Nevada is the next closest state with an ACEEE ranking of 22, while Florida's ranking places is roughly in the middle of the US rakings at 27. Of the laggard states, only Georgia received a ranking less 40.

Table 1. Program Activity Characterization for Candidate Comparison Area States

State	Overall Program Characterization	Presence of LED Programs	ACEEE Ranking
CA	Established	Yes	2
FL	Established	No	27
AZ	Newer	No	17
NV	Newer	No	22
GA	Laggard	No	36
AL	Laggard	No	43
MI	Laggard	No	49
SC	Laggard	No	46
KS	Laggard	No	48
NE	Laggard	No	40

Source : http://www.aceee.org/energy-efficiency-sector/state-policy/aceee-state-scorecard-ranking

B.3 Residential Market Characteristics

Demographic Characteristics

Table 2 displays indicators of residential market size and demographic composition for the candidate states. The first point to note is California's size: it is larger than any two of the candidate comparison sites put together, in terms of number of households. Clearly, California ranks highest among all the states displayed in terms of income, education, and level of urbanization. Among the potential High Activity states, Nevada has the highest income indicators, but a lower percentage of college graduates than either Arizona or Florida. The education and income indicators for Arizona and Florida are nearly equal. All three states show relatively high levels of urbanization. Among the Low Activity states only Georgia, Kansas, and Nebraska have income and education levels that are in any way comparable to California's, although the level of urbanization in these three states is significantly than for California and the other High Activity States.

Table 2. Demographic Characteristics of Candidate States*

	Occupied Housing Units 2010	% Population over 25 w/ Bachelor's Degree, 2011	Median Income, 2011	% Households with income > $100,000, 2010	Percent of population in urban areas
CA	13,682,976	30.1%	$57,708	26.4%	94.4%
AZ	2,846,738	25.9%	$46,789	17.3%	88.2%
NV	1,175,070	21.7%	$51,001	18.5%	91.5%
FL	8,994,091	25.8%	$44,409	15.8%	89.3%
GA	4,091,482	27.3%	$46,430	17.7%	71.6%
AL	2,174,428	21.9%	$40,474	14.1%	55.4%
MS	1,276,441	19.5%	$36,851	11.0%	48.8%
SC	2,140,377	24.5%	$42,018	13.5%	60.5%
KS	1,234,037	29.8%	$48,257	16.6%	71.4%
NE	797,677	28.6%	$48,408	15.7%	69.8%

*States with High Program Activity are shaded. Sources: American Community Survey, Bureau of Labor Statistics, Bureau of Economic Analysis.

Housing Characteristics

Table 3 displays indicators of residential market size and demographic composition for the candidate states. The median occupant-reported home value for owner-occupied units in California in 2010 was more than twice the level in any of the candidate comparison states. On the other hand, the percentage of owner-occupied units in California was lower in 2010 than in any of the candidate comparison states. Other than Nevada, the proportion of owner-occupied units was more than 10 percent higher in the candidate states than in California. Given the relationship between tenure on the one hand and level of urbanization, home prices, and the composition of the workforce, home ownership may not prove to be a useful indicator for guiding selection of the comparison areas. Finally, home size, as characterized by the percent of homes with four or more bedrooms, is distributed similarly to the demographic variables. Among the High Activity states, Arizona and Nevada are closer to California than is Florida, which has a large portion of owner-occupied units in multifamily buildings. Among the Low Activity states, Georgia, Kansas, and Nebraska most closely resemble California.

Table 3. Housing Characteristics of Candidate States*

	Occupied Housing Units 2010	% of Occupied Housing Units Owner-Occupied	% with 4 or More Bedrooms	Median Value (per occupant report) 2010
CA	13,682,976	55.60%	20.6%	$370.9
AZ	2,846,738	65.20%	20.8%	$168.8
NV	1,175,070	57.20%	21.1%	$174.8
FL	8,994,091	68.10%	15.2%	$164.2
GA	4,091,482	66.20%	23.9%	$156.2
AL	2,174,428	70.10%	17.8%	$123.9
MS	1,276,441	69.80%	16.7%	$100.1
SC	2,140,377	68.70%	17.7%	$138.1
KS	1,234,037	68.10%	23.8%	$127.3
NE	797,677	67.40%	23.1%	$127.6

*States with High Program Activity are shaded. Sources: American Community Survey, Bureau of Labor Statistics, Bureau of Economic Analysis.

B.4 Composition of Economic Activity

As discussed earlier, prior studies have identified associations between the type and size of establishments on the one hand and adoption of energy efficiency measures on the other. To assess similarities and differences between California and the candidate comparison areas we analyzed both the distribution of establishments and employment by major industrial category and the distribution of establishments by size, as measured by number of employees.

General Economic Characteristics. Before going into findings on the distribution of firms by type and size, it is worthwhile to consider more general indicators of similarities and differences between California and the candidate comparison states. Table 4 displays statistics on output and employment for those states for the year 2010. Again, the first fact that stands out is the size of the California economy. It's gross domestic product is more than 2.5 times as large as the largest state economy among the candidate comparison options – Florida. It's labor force is twice as large as Florida's. California's productivity per worker – a proxy for the level of capital investment and worker training and education engaged in the state – is second in the group only to Kansas, and is significantly higher than any of the other states excepting Nebraska and Nevada. The high level of productivity in Kansas is likely due to the importance of agriculture in the state and the presence of large farms.

Table 4. Indicators of Economic Activity by State

State	Economic Indicators									
		High Activity States			Low Activity States					
	California	Arizona	Nevada	Florida	Georgia	Alabama	Mississippi	South Carolilna	Kansas	Nebraska
Gross Domestic Product in Millions of Dollars(2010)	$1,901,088	$253,609	$125,650	$747,735	$403,070	$172,567	$97,461	$127,170	$164,445	$89,786
Labor Force in thousands (2010)	18,316	3,100	1,386	9,132	4,695	2,179	1,317	2,151	1,505	989
Average Productivity per Worker (2010)	$103,794	$81,809	$90,657	$81,881	$85,851	$79,196	$74,002	$59,121	$109,266	$90,785

Distribution of establishments by industry. Generally speaking, the distributions of business establishments (the closest Census analog to a utility customer) by industry and size does not reveal the kind of pronounced differences among states shown by the more aggregated indicators in Table 4. As shown in Table 5, the distribution of establishments by the major industrial groupings used in the North American Industrial Classification System (NAICS) is fairly uniform across states.[80] The one pronounced difference is the higher representation of

[80] We did not include data for segments that will not be included in the sample, such as construction, utilities, and agriculture.

Professional, Scientific, and Technical Service establishments in California and selected candidate comparison states: Nevada, Arizona, Florida, and Georgia. This difference appears to be made up by a higher representation of Retail Trade establishments in the other states.

Table 5. Distribution of Business Establishments by NAICS Grouping and State

Distribution of establishments by industry and size. Table 6 displays the portion of establishments with 100 or more employees by NAICS grouping for California and the candidate comparison states. As was the case for distribution of all establishments, there are relatively few differences between the states in terms of the prevalence of large establishments – either at the NAIC or state level. The one exception, oddly enough, is in the information industry, where the representation of large firms is higher in all other states than in California. On the other hand, nearly 7,000 information industry establishments with 100 or more employees were located in California in 2010.

Generally speaking our analysis of states according to the distribution of business establishments by industry and size did not provide much guidance in characterizing states for selection as comparison areas.

Table 6. Percent of Total Establishments with 100 or more Employees by NAICS Grouping and State

NAICS Industrial Grouping	CA	NV	AR	FL	GA	AL	MS	SC	KS	NE
Accommodation and food services	7%	10%	10%	8%	9%	10%	9%	8%	9%	7%
Administrative and support and waste mgt services	5%	5%	5%	4%	6%	6%	6%	5%	5%	5%
Arts, entertainment, and recreation	2%	5%	5%	3%	3%	2%	1%	3%	2%	2%
Educational services	4%	4%	5%	4%	4%	3%	8%	3%	4%	4%
Finance and insurance	14%	14%	17%	14%	16%	18%	15%	18%	11%	11%
Health care and social assistance	4%	4%	6%	4%	5%	6%	6%	6%	8%	6%
Information	10%	13%	17%	14%	19%	21%	24%	21%	21%	17%
Management of companies and enterprises	29%	19%	33%	30%	32%	30%	30%	32%	28%	26%
Manufacturing	3%	4%	5%	4%	7%	7%	9%	8%	7%	6%
Other services (except public administration)	2%	3%	3%	2%	2%	2%	1%	1%	1%	2%
Professional, scientific, and technical services	2%	3%	2%	2%	2%	3%	3%	3%	3%	3%
Real estate and rental and leasing	5%	6%	6%	5%	8%	7%	6%	7%	6%	5%
Retail trade	10%	14%	14%	11%	11%	11%	10%	12%	9%	9%
Transportation and warehousing	7%	10%	8%	5%	9%	7%	7%	9%	7%	4%
Wholesale trade	4%	8%	7%	4%	7%	8%	8%	8%	9%	9%
All	5%	7%	7%	5%	7%	7%	7%	7%	6%	6%

Distribution of employment by industry. We also assessed the distribution of employment by industry to determine whether such an approach would yield useful distinctions between the states. To make the analysis more tractable, first consolidated the NAICS categories into 9 groups which share construction elements or patterns of occupancy. We then took a closer look at 5 of these groups that account for nearly two-thirds of total employment in California: Manufacturing, Retail Trade; Professional; Scientific, and Management, and related firms; Education and Health Services; and a group of facility-based retail services, including food service, arts and entertainment, and lodging.

Table 6 shows the distribution of employment in California and the candidate comparison states by the nine NAICS-related groupings.

Table 6. Distribution of Employment by NAICS Groupings

State	Manufacturing	Wholesale trade	Retail trade	Transportation and warehousing, and utilities	Information	Finance and insurance, and real estate and rental and leasing	Professional, scientific, and management, and administrative and waste management services	Educational services, and health care and social assistance	Arts, entertainment, and recreation, and accommodation and food services
CA	10.0%	3.3%	11.2%	4.6%	2.8%	6.4%	12.5%	21.0%	9.6%
Established Program States									
FL	5.5%	2.9%	13.5%	5.1%	2.0%	7.7%	12.1%	21.4%	11.5%
Newer Program States									
AZ	7.3%	2.4%	12.7%	4.9%	1.9%	7.5%	11.4%	22.6%	10.8%
NV	4.1%	2.3%	11.6%	4.7%	1.6%	6.1%	10.5%	15.5%	25.9%
Laggards									
GA	10.5%	3.2%	12.1%	5.9%	2.6%	6.2%	11.0%	21.3%	8.8%
AL	13.7%	2.8%	12.3%	5.0%	1.7%	5.7%	9.1%	21.4%	8.4%
MS	12.9%	2.8%	11.7%	5.6%	1.7%	4.5%	5.9%	24.6%	9.7%
SC	13.1%	2.8%	12.4%	4.6%	1.7%	5.9%	9.3%	22.4%	9.9%
KS	12.3%	2.7%	11.5%	4.5%	2.3%	6.0%	8.3%	24.9%	8.1%
NE	10.0%	2.9%	11.6%	5.9%	2.0%	7.7%	8.4%	24.4%	7.9%

Source: 2010 American Community Survey 1-Year Estimates. Table S2405

Table 7 shows the ratio of the share of total employment for the industry grouping in question to the corresponding share of employment in California. We highlight the cells in which that ratio is within the range of 90% to 110%. Among the High Activity States, Florida and Arizona have two broad industrial groupings in this category. Among the Low Activity States, Georgia has three industrial groupings in this category; Alabama and South Carolina have two.

Table 7. Representation of Industries by Employment, Relative to CA

State	Manufacturing	Retail trade	Professional, scientific, and management, and administrative and waste management services	Educational services, and health care and social assistance	Arts, entertainment, and recreation, and accommodation and food services
Established Program States					
FL	54.7%	120.9%	**97.2%**	**101.8%**	120.1%
Newer Program States					
AZ	72.9%	113.1%	**91.5%**	**107.9%**	112.2%
NV	41.0%	**103.2%**	84.5%	73.9%	269.6%
Laggards					
GA	**105.1%**	**108.2%**	88.1%	**101.5%**	**91.3%**
AL	136.7%	**109.7%**	73.2%	**102.0%**	87.1%
MS	128.9%	**104.6%**	47.7%	117.4%	**100.8%**
SC	131.3%	110.6%	74.6%	**106.6%**	**103.0%**
KS	123.3%	**103.0%**	66.5%	118.6%	84.5%
NE	**100.3%**	**103.4%**	67.4%	116.4%	82.1%

Table 8 displays the value of the demographic, housing, and economic variables we considered to be useful in characterizing the candidate comparison states. Table 9 shows the rank of the states by least difference from the value for California, by program group. So, to interpret the first column of Table 9, Arizona is the closest to California among the High Activity States in terms of the portion of the population over age 25 with a bachelor's degree. Among the Low Activity States, Kansas is the closest.

B.5 Summary and Recommendations

Table 8. Summary of State Demographic, Housing & Economic Indicators

State	Occupied Housing Units 2010	% Population over 25 w/ Bachelor's Degree, 2011	Median Income, 2011	% Households with income > $100,000, 2010	Percent of population in urban areas	% with 4 or More Bedrooms	Median Value (per occupant report) 2010	Productivity per Employee ($000s)	Large NAIC Groupings with Similar Shares
CA	13,682,976	30.10%	$57,708	26.40%	94.40%	20.60%	$370.90	$103.7	
AZ	2,846,738	25.90%	$46,789	17.30%	88.20%	20.80%	$168.80	$81.8	2
NV	1,175,070	21.70%	$51,001	18.50%	91.50%	21.10%	$174.80	$90.7	1
FL	8,994,091	25.80%	$44,409	15.80%	89.30%	15.20%	$164.20	$81.9	2
GA	4,091,482	27.30%	$46,430	17.70%	71.60%	23.90%	$156.20	$85.9	3
AL	2,174,428	21.90%	$40,474	14.10%	55.40%	17.80%	$123.90	$79.2	2
MS	1,276,441	19.50%	$36,851	11.00%	48.80%	16.70%	$100.10	$74.0	2
SC	2,140,377	24.50%	$42,018	13.50%	60.50%	17.70%	$138.10	$59.1	2
KS	1,234,037	29.80%	$48,257	16.60%	71.40%	23.80%	$127.30	$109.3	1
NE	797,677	28.60%	$48,408	15.70%	69.80%	23.10%	$127.60	$90.8	2

Table 9. Rank of States – Least Difference in Indicator Value from California within Program Area Categories: High Activity Shaded

State	% Population over 25 w/ Bachelor's Degree, 2011	Median Income, 2011	% Households with income > $100,000, 2010	Percent of population in urban areas	% with 4 or More Bedrooms	Median Value (per occupant report) 2010	Productivity per Employee ($000s)	Large NAIC Groupings with Similar Shares
CA	30.10%	$57,708	26.40%	94.40%	20.60%	$370.90	$103.7	
AZ	1	2	2	3	2	2	3	2
NV	3	1	1	1	1	1	1	1
FL	2	3	3	2	3	3	2	2
GA	3	3	1	1	1	1	3	3
AL	5	5	4	5	4	5	4	2
MS	6	6	6	6	6	6	5	2
SC	4	4	5	4	5	2	6	2
KS	1	2	2	2	2	4	1	1
NE	2	1	3	3	3	3	2	2

Based on review of Tables 8 and 9 we recommend the following selection of states for use as comparison areas:

- **High Activity States.** Arizona, Nevada, and Florida
- **Low Activity States:** Georgia, Kansas, and Nebraska

Our rationale for this recommendation consists of the following points.

- **Size and diversity of the California market.** Given the approach we have taken to defining the program characteristics of states, we are limited to selecting the comparison areas from a set of three High Activity States and six Low Activity States. Within that

limitation, we believe that it is important to construct the comparison group to best reflect the size and diversity of the California market. We therefore selected all three High Activity States for inclusion in the comparison group. Together, they have nearly the same number of resident households as California: 13.1 million v. 13.8 million. 2.4 million business establishments are located in the three High Activity States v. 3.1 million in California.

To some extent, the states balance out differences in individual characteristics. Arizona and Florida show somewhat higher levels of educational attainment than Nevada, and their population of establishments is more similar. Nevada's income, home size, and home value characteristics are closer to California's than the other two states.

Among the Low Activity States, Georgia, Kansas, and Nebraska rank 1, 2, and 3 on nearly all variables in terms of least difference from California. The one exception is that Kansas ranks fourth on home value. The remaining three Low Activity states -- Alabama, Mississippi, and South Carolina -- differ markedly from their peers on indicators of household income, educational attainment, urbanization level, house size, and worker productivity. Unfortunately, these three states contain only 6.1 million households compared to California's 13.8 million and 1.2 million business establishments compared to California's 3.1 million.

- **Mitgate risk to study design due to changes in program portfolios.** As mentioned earlier, it is quite possible that one or more of the states in the High and Low Activity groups will launch programs to promote LED lighting over the next 3 – 5 years. Choosing more than one state in each program category mitigates the risk of losing a program category entirely at the point that the research is repeated to assess changes over time.

Provide adequate sample frame for commercial customer and contractor surveys. We have encountered difficulty in the past fulfilling stratified sample designs of commercial customers and vendors in individual states that use number of employees as the measure of size. Very often, a handful of establishments account for the entire "Large" stratum. Including a number of the states in the population should help mitigate this problem.

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